Vision, Mission and Strategy

R&D in European Micro-and Nanoelectronics

Aeneas

CATRENE
Cluster for Application and Technology Research in Europe on NanoElectronics

INTRODUCTION

This document gives the mission, vision and strategy of the major industrial and research organisations involved in the future of micro- and nanoelectronics in Europe. The time horizon of this document covers the remainder of this decade. Its scope is limited to the co-operative part of the research and development (R&D) within public-private partnerships. It is intended as strategic document for the two Europe-wide funding instruments in this field: CATRENE under the EUREKA framework and the ENIAC Joint Undertaking (JU).

The mission, vision and strategy are provided for both funding instruments. The document also spells out the differences between them. However the strategy presented, their delineation and their potential to achieve the goals as formulated under "Mission" are all based upon fundamental assumptions. These include the appropriate use and support of the funding instruments by all parties involved in a consistent way. Consistency implies that R&D actors will not be excluded from either of the funding instruments.

Appropriate use and support of the funding tools is only possible when the resources required are available. The estimate of the R&D actors is that the two funding instruments together will need to be resourced with about 7,000 person-years (PY) a year to make a substantial contribution to the goals of the mission. This is in line with expectations created during the start-up phase of the funding instruments; the strategy presented in this document builds upon these expectations. The number of 7,000 corresponds to 10-15% of the total R&D effort in the nanoelectronics value chain in Europe.

The R&D actors herewith reconfirm to contribute their part to the needed resources of the funding tools. A large part of the vision, mission and strategy is common to both tools. Yet the tools are clearly separate with their own specificities. The combination of parts A, B, C and annexes 1 and 3 of this document forms the CATRENE White Book. The combination of parts A, B, C and annexes 2 and 3 forms the ENIAC Multi-Annual Strategic Plan (MASP), as proposed by AENEAS.

In early September 2010, the public authorities of five countries with major nanoelectronics activities issued policy guidelines entitled: “Enhancing the competitive advantage of Europe in nanoelectronics” (see annex 3). This document has been formally approved by consensus in the ENIAC Public Authorities Board on October 6th, 2010. Industry and R&D organisations welcome this document and subscribe to its analysis and conclusions. This VMS paper is in full accordance with this public- authority document but gives more details in many aspects and provides priorities, focus and implementation aspects in line with the proposed R&D and industrial policy.

Industry and R&D organisations feel supported by the public authorities and look forward to achieving, in a joint effort with them, the goal of strengthening European skills in the field of nanoelectronics using a smart innovation policy with the aim of facilitating "the development and manufacturing of innovative products and services while at the same time the position of European industry on the global playing field is improved".

VMS summary

Public-private R&D partnerships crucial for European competitiveness in micro- and Nanoelectronics

Micro- and nanoelectronics are a key enabling technology for the European economy – as well recognised in the Europe 2020 strategy. Many of our everyday products – from computers, telecommunications and consumer electronics to industrial-production, energy-management and transport systems depend on semiconductors, which are the core of the now-ubiquitous information society.

Strong public-private partnerships for research and development (R&D) uniting political will and private entrepreneurship at European and Member-State level are crucial to maintain European competitiveness in this major area and to address the great challenges such as an ageing population and climate change that face our society in the coming years.

MEDEA and MEDEA+ in the past and the ENIAC Joint Undertaking (JU) and the EUREKA CATRENE Cluster have together proved their importance in guiding these efforts to the benefit of European industry and its citizens. Increased support is now essential to capitalise on recent advances and ensure that Europe maintains its competitive edge.

Key global market

The global semiconductor market reached $226 billion in 2009, directly stimulating a larger electronics industry valued at over a $1,100 billion. Altogether, the electronics sector and related service providers represented a market of $6,3 trillion in 2009, equivalent to 10% of global GDP and involving the largest and fastest-growing manufacturing industries worldwide. With a 5% average annual increase in the past decade, the growth rate of the electronics industry today is higher than that of global GDP.

However, while Europe consumes some 13% of worldwide semiconductor output, it has only close to 10% of the global wafer-processing capacity. Unfavourable cost structures for manufacture in Japan, the USA and especially Europe have led to semiconductor production moving increasingly to Asia. Rich incentive packages offered by Asian governments drive a more advantageous financial return for companies ready to build up manufacturing capacities in those countries.

R&D intensive industry

At the same time, the evolving value chain, the changed landscape related to semiconductor fabrication, increasing functionality of products and growing complexity of designs and embedded software in semiconductors have turned the electronics market into an R&D intensive industry. R&D spend in European semiconductor companies has risen from 14% in 2001 to 20% currently to meet this need.

Semiconductors are now one of the most R&D-intensive industry sectors and a driver for innovation in Europe. This move is supported by the widespread presence of R&D locations and a network of knowledge-based clusters in which these activities are embedded. These installations are a significant part of Europe's strength. It is essential to maintain this knowledge by ensuring continuing access to manufacturing and design facilities here while also making sure that engineers and scientists are receiving adequate training and funding.

Strong OEMs in Europe

Europe is characterized by the strong presence of key original equipment manufacturers. These OEMs establish the importance of Europe as a manufacturing base for electronics applications – and hence as a market for semiconductors.

Moreover, new opportunities with dynamic growth patterns are emerging, addressing societal needs. In these domains, Europe can build on its strength in multi-market applications, leadership in radio-frequency (RF), analogue/mixed signal, smart power and More-than-Moore and More Moore technologies, which increase circuit functionality, its excellent R&D capabilities in industry, institutes and universities and close interdisciplinary co-operation in its well-known clusters.

European electronics companies have a strong position in specific applications areas such as communications, digital lifestyle, automotive and industrial production. Europe also supports world-class suppliers of the equipment required for the manufacture of semiconductors with dominance in areas such as lithography.

Role of SME's

Both ENIAC and CATRENE have proven to generate innovative projects with a good balance between large companies, SME's, research institutes and academia. In the last years SME's share and contribution have shown a continuous growth. SME's form the bedrock of innovation and employment in Europe. However, the global "hi-tech" industry is notoriously difficult to access

due to high development & penetration costs. The ability for SME's to participate in European Funding programmes not only provides essential investment but also introduces them to a network of companies, large and small, that can help them in both product and business development.
As the number of applications dramatically increase, especially in the "more than Moore" arena, SME's (& academia) have much to contribute in terms of innovation. A strong Public/Private Innovation partnership involving the best ideas available provides the environment to bring together advanced research & development from organisations of all sizes and help ensure these ideas can be brought together into developments that have the potential to give Europe worldwide leadership in key electronics segments. Successful exploitation of these innovations has the potential to support the development and growth of SME's into industry leaders in their own right as well as supporting European industry as a whole.

Developing innovative solutions

The co-operative R&D programs in Europe aimed at developing innovative solutions for the technological domains needed in today's and tomorrow's applications contributed to this leading position. The ENIAC JU and the CATRENE are the pillars for the support of advanced R&D in the European electronics industry and represent between 10 and 15% of the total R&D effort in the nanoelectronics value chain in Europe.
These two programmes and their predecessors in EUREKA – JESSI and the MEDEA and MEDEA+ Clusters – have helped revitalise this sector and maintain consistent European presence in key sectors such as mobile phones, automotive electronics, industrial control systems and multimedia.
The fastest growth is now expected in segments more related to the new societal needs where Europe is particularly strong – such as medical, security and environmental-related industries. Leveraging on this capability will be an important driver for global competitiveness of the European industry. The VMS document spells out the priorities, focus and implementation aspects of the complementary efforts proposed by the ENIAC JU and CATRENE in line with the R&D and industrial policy proposed by the Member States and the European public authorities.

Part A: Vision, Mission and Strategy

1. Vision

The electronics industry in Europe shares a common vision to reinforce the global competitive position of the European electronics value chain by leveraging and aligning its individual core competences and strengths in design as well as in its local industrial infrastructures while remaining viable and profitable.

The European micro- and nanoelectronics industry value chain will guarantee the controlled access to information and communications technology (ICT), applications and products for a smart, sustainable and inclusive European 2020 society[1][2].

2. Mission

The mission of the European micro- and nanoelectronics industry value chain encompasses a series of elements which have also been identified by public authorities in the policy guidelines of annex 3. Therefore a broad agreement on these can be assumed. These are to:

- Provide innovative and sustainable solutions to societal challenges in areas such as energy, mobility, health, communications and safety;
- Strengthen those sections of the value chain where Europe can achieve global competitiveness and gain new market shares through differentiation;
- Enable an adequate level of advanced CMOS manufacturing capability in Europe;
- Foster the advancement of European More-than-Moore production sites and European foundries in the most advanced market areas;

[1] Chapter 4 of part B details the consequences of this vision for the R&D actors.

[2] In line with the proposed Europe 2020 strategy, micro- and nanoelectronics are key enablers and contributors to the three mutually reinforcing priorities:

1. **Smart growth**: developing an economy based on knowledge and innovation
   Micro- and nanoelectronics represent 20% of electronics systems content but close to 100% of their performances – including software contribution – and a large majority of industrial and service innovation comes from electronic innovation
2. **Sustainable growth**: promoting a more efficient, greener and more competitive economy
   Micro- and nanoelectronics contribute to 10% of global GDP thanks to their enabling roles for both industry and services. In addition they are key for energy generation, management and efficiency.
3. **Inclusive growth**: fostering a high-employment economy delivering social and territorial cohesion.
   Micro- and nanoelectronics are a very high-tech, high added value industry that produces and induces high educational level employment and are a key enabler to address new societal needs.

- Set up and support mechanisms to integrate the strengths and capabilities of small and medium-sized enterprises (SMEs) and research institutes; and
- Endorse the creation of R&D platforms for design, equipment, materials, manufacturing and silicon processes.

To accomplish the above, the mission of the European micro- and nanoelectronics industry value chain is to progress and remain at the forefront of state-of-the-art innovation in the further miniaturisation and integration of devices, while dramatically increasing their functionalities and thus enabling solutions for societal needs.

The main building blocks of the mission, assembled thanks to dedicated R&D and innovation are:

- Design technologies;
- Semiconductor process and integration; and
- Equipment, materials and manufacturing.

The driving forces for such progresses are the development of high-tech applications in the areas of automotive and transport, communications, energy efficiency, health and ageing society, and safety and security.

While some of these developments are mainly cost and business driven, others are impelled by important emerging societal needs and related grand challenges. They will materialise in Europe, ahead of other regions of the world and, as such, will provide Europe with the opportunity to build up the new competences and skills required for global leadership in selected domains.

The ever-increasing complexity of integrated circuits with expanded interface capabilities has resulted in the ability to offer increased functionality at the circuit and component level[3]. The semiconductor industry, therefore, has to deal with more complex higher level systems functions and combinations of different technologies. As value shifts to the higher levels, the semiconductor industry will have to move up and address new competences to capture the added value of the new systems. **European R&D will pursue leadership in market use by providing controlled access to high-tech, high-quality systems solutions in a timely manner.**

[3] For example: smart phones have increased complexity with more memory, more processing power, more pixels etc. They also have increased interface capabilities – touch screens, connectivity, GSM, Internet, camera, multimedia etc. In terms of functionality convergence, new smart phones incorporate traditional phone, internet browsing, navigation, gaming, TV watching, payment, identification, social networking, etc.

3. Strategy

Europe has demonstrated its capability to create innovation over the past 15 years with major success stories such as GSM mobile phones, automotive electronics, smart cards, lithography equipment and silicon on insulator (SOI) just to name a few. **The first pillar of the strategy for the European micro- and nanoelectronics industry is therefore to build on its leading position in specific technology and application domains.**

The second pillar of this strategy is 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. Today's emerging markets include energy efficiency and health and ageing society, as well as some specific areas within safety and security, communications and automotive.

The synergy of these two pillars will enable the European semiconductor industry to expand its leadership position in More-Moore as well as in More-than-Moore technologies, providing optimised systems solutions adapted to the demand of European original equipment manufacturer (OEM) leaders in the new emerging markets. The intimate co-operation with world-class R&D laboratories from academia and from large institutes such as IMEC, LETI and Fraunhofer – whose activities correspond to industry needs and mega trends, as well as the involvement of highly specialised and flexible SMEs – are the key elements for developing leading edge technologies and solutions.

While More-than-Moore technologies offer the European semiconductor food chain new opportunities for development through complex heterogeneous integration, current More-Moore technologies will continue to be the base for future More-than-Moore development and production. Therefore, Europe has to maintain a sufficient level of manufacturing in the most advanced CMOS technologies to secure its future competitiveness on advanced integrated products and platforms.

A viable and reasonable return on the investments made in Europe is a condition for a successful implementation of this strategy. Such a condition is mentioned here, because of its importance, but it will not be developed because it is outside the scope of the current document which is limited to co-operative R&D.

Part B. Changing Landscape and Boundary Conditions, Implementation of the Strategy

CHAPTER 1: LANDSCAPE

1.1 The rapidly changing global landscape (value chain)

Since the 2001 ICT recession, the semiconductor global landscape has changed dramatically, leading the industry to adopt new business models. The focus of the semiconductor market has shifted from developed to developing countries, particularly Asia Pacific. This region increased its market share from 25% in 2001 to around 50% in 2009 with a forecast by WSTS (World Trade Semiconductor Trade Statistics) to increase further, whereas Europe's market share declined from 20 to 13%, and America and Japan have dropped even more dramatically.

The stability of Europe linked to the decline in Japan and the USA may be explained by the strong presence of key OEMs here that have maintained the importance of Europe as a manufacturing base for electronics applications – and hence as a market for semiconductors.

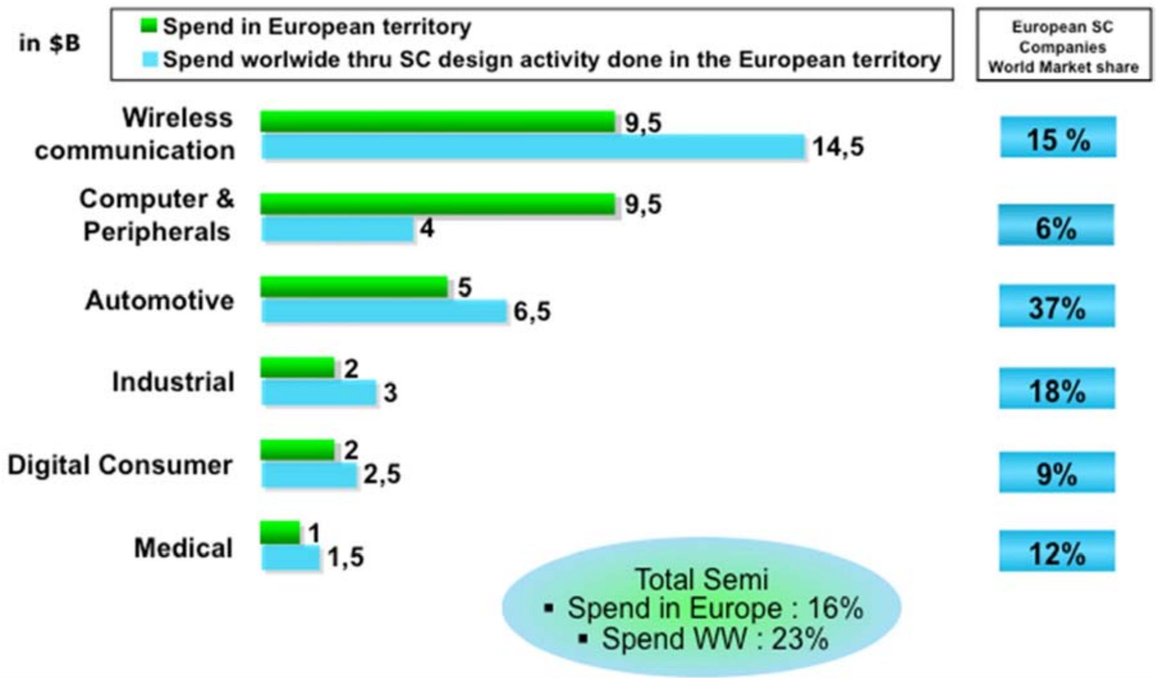
Meanwhile, the gradual market saturation by large killer applications and growing competition led to enormous price pressure resulting in a lasting market slow down. The semiconductor annual market growth rate has more than halved since 2001, differing from the trend in previous decades. However, new market opportunities with dynamic growth patterns are emerging in developed regions, including Europe, addressing societal needs. In these domains, Europe has the assets to support the market pull thanks to its strength in multi-market applications, leadership in radio-frequency (RF), analogue/mixed signal and More-than-Moore technologies, its excellent R&D capabilities in industry, institutes and universities and close interdisciplinary co-operation in its well-known clusters.

The leading position of Europe is the result of the existence of R&D cooperative organisations aimed at developing innovative solutions for the technical and technological domains needed in the today applications.

CATRENE and ENIAC are the pillars for the support of the European electronic industry R&D. They are complemented by ITEA and ARTEMIS and by other EUREKA ICT clusters such as EURIPIDES and CELTIC.

ITEA is addressing mostly application software technologies and system software solutions. ARTEMIS is focusing on middleware and embedded software solutions. EURIPIDES generates innovation for new products, processes and services using or enabling the use of integrated smart systems based on microtechnology. CELTIC is addressing the end-to-end telecommunications solutions, in four main working areas which are broadband infrastructure, broadband services, optical networks, security and mobile services.

European strength is demonstrated by the fact that from one to three European semiconductor companies are in the top five of each of the major application segments, particularly in automotive and industrial applications – including medical and power – and to a significant extent in wired and wireless communications. The following figure illustrates the European world market shares per domain. It clearly demonstrates the strength of R&D activities located in Europe for designs in almost every domain.



Source iSuppli 2007 est, DECISION est

Although Europe accounts for approximately 13% of worldwide semiconductor consumption, it has only around 9% of the global wafer-processing capacity. This implies that Europe is a net importer of semiconductors. The centre of gravity for semiconductor production has moved from Japan, the USA and, more gradually, Europe to Asia Pacific, which now has more than 50% of the worldwide capacity. The main reasons for this are the move of the semiconductor market to this region and particularly the unfavourable cost structures of manufacturing facilities in Japan, the USA and especially Europe. The various and rich incentive packages – including reduced taxation – which Asian governments offer to companies building up manufacturing capacities in their countries drive a more advantageous financial return compared with Europe.

New business models such as fab-less or fab-light complement the traditional integrated device manufacturer (IDM) business models, where the whole value chain is within one company. In fab-less companies, manufacturing is outsourced to foundries and the added value comes mainly from the middle part of the value chain: chip design, systems design and systems integration.

In 2000, only Japan and Europe had 300-mm fabs in production but, by the end of 2007, Taiwan and South Korea had become the leaders in 300-mm production capacity. Moreover, in Europe, for more than three years, no new 300-mm wafer fab has been planned, foreshadowing a further decrease in Europe's share of semiconductor production[4].

The required economies of scale and increasing process complexities cause a more than proportional increase in investments needed for next-generation fabs. As a result, more and more IDM players are driven towards the so-called fab-light model, with which a major part of the wafer manufacturing – particularly in advanced standard CMOS processes – is outsourced to foundries. The IDMs simply can no longer afford the capital expenditures needed and they do not have the demand for fabs with a competitive economy of scale. As a result, investments in new production equipment in Europe continue to decline. In 2000, Europe had 14% of the worldwide semiconductor market share for manufacturing equipment; this dropped to around 5% in 2009.

With the commoditisation of mainstream manufacturing, the increasing functionality of products together with the exploding complexity of designs and the embedded software in semiconductor, solutions become increasingly the differentiating factor between semiconductor providers. The move goes from capital expenditure for manufacturing capability to an R&D-intensive industry. R&D spend went up from 14% in 2001 to a current 20% in European semiconductor companies. Semiconductors are now one of the most R&D-intensive industry sectors and a driver for innovation in Europe. This move is supported by the widespread presence of R&D locations and the network of knowledge-based clusters in which these activities are embedded. These installations are a significant part of Europe's strength.

[4] Except extension of capacity by STMicroelectronics and Global Foundries.

1.2 SWOT analysis for the European semiconductor industry

Strengths	Weaknesses
• Excellent R&D capabilities/capacities in industry, institutes and academia • Global leadership in More-than-Moore technologies and applications • Leading position in several semiconductor market segments and applications – e.g. automotive, industry, security and communications • Leading competence in analogue and mixed signal technologies and intellectual property • Market leaders in equipment and material, such as lithography, SOI and deposition technologies • Big semiconductor home market in key domains • Strong industrial base • Highly skilled employees with outstanding professional experience	• Insufficient alignment of member states on a European semiconductor strategy • Lack of European industry policy; inadequate economic framework conditions • Very limited strategic approach for deployment of semiconductor solutions for societal challenges • Inadequate venture spirit for commercialisation of inventions and R&D results; lack of venture capital • Insufficient focus on high-tech products within the European manufacturing industry • No broad coverage of equipment and material suppliers • Only few ICT-dedicated faculties; technology-hostile European public; shortage of well-educated new talents • 40 % less patent applications than USA or Japan • Limited role in desk/lap-top related applications
Opportunities	**Threats**
• New societal challenges, which create new markets • Creation and steering of lead markets by setting standards and regulations – e.g. GSM and photovoltaic feed-in tariffs • Need for proprietary leading solutions in European industry – e.g. in automotive, industry, security and healthcare • Increased public procurement for stimulation of new markets • Leverage the More-than-Moore world-class leading position • Industrial exploitation of new materials and corresponding equipment • Increase R&D employment to address emerging societal needs	• Deterioration of the already unfair level playing field • Persistence of the unfavourable European framework conditions • Further loss of competitiveness with respect to production cost – labour, energy, • Loss of major parts of technology and production expertise and as a consequence, risk of degradation in leading-edge R&D • Loss of major parts of proprietary intellectual property • Brain drain to other regions • Dependence on non-European foundries • Increasing currency variations • Fragmented regulatory framework preventing economy-of-scale exploitation

1.3 Position of Europe and the European industry in the world

Micro- and nanoelectronics represent a global market worth $226 billion in 2009 directly stimulating a larger electronics industry valued at $1,340 billion. The electronics sector and related service providers are the largest and fastest-growing manufacturing industries with 5% average growth per year in the past decade, representing a market of $6.3 trillion in 2009 – equivalent to 10% of global GDP. Moreover, the growth rate of the electronics industry is higher than that of global GDP and this will continue, at least, for the next decade. The fastest-growing regions are China, Asia Pacific and India with roughly 50% of the world electronics production.

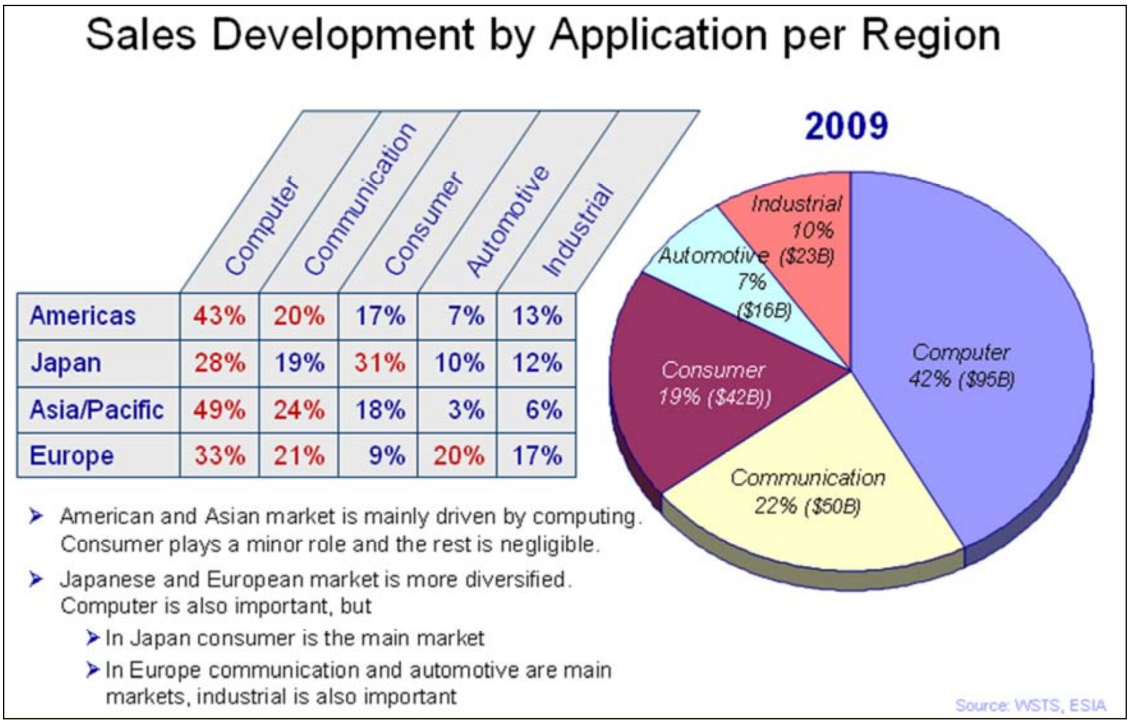
The semiconductor industry, which is its enabler, is driven by the replacement of existing equipment with innovative solutions, by new lead markets, by the grand socio-economic challenges such as an ageing society, energy shortages and global warming and by the fast penetration of electronic equipment in emerging regions.

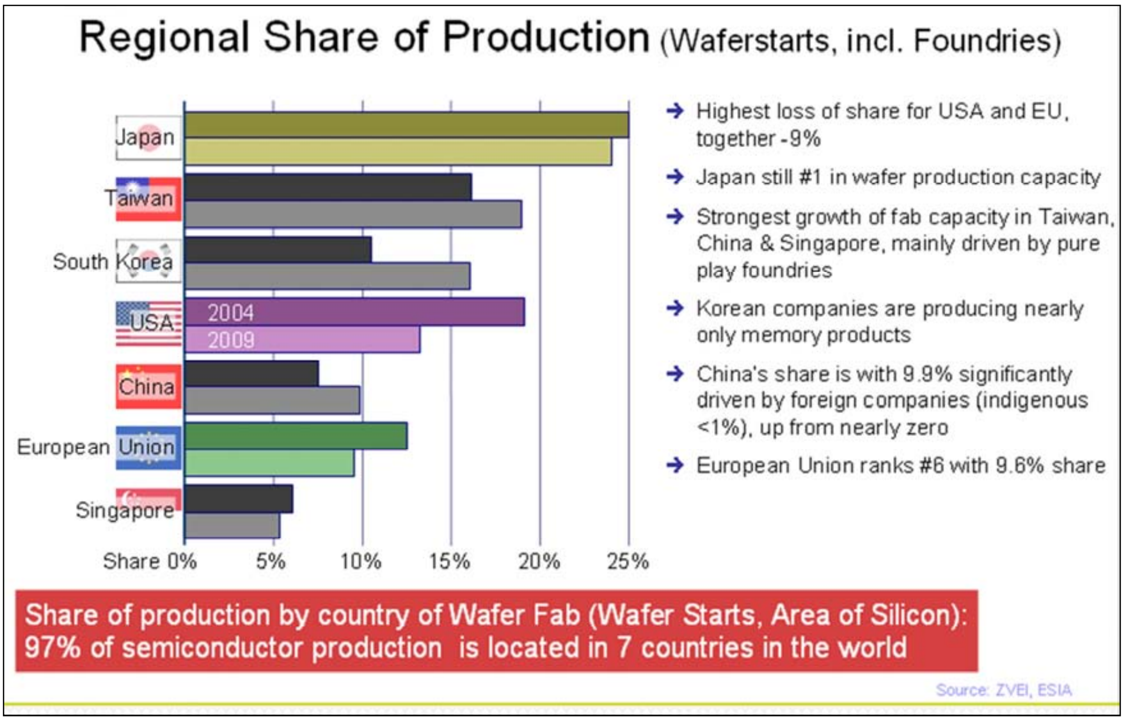
However, Europe has a strong position with a 25% share of the world electronics design and a leadership position in industrial, automotive, communications and medical applications. Although Europe has almost completely lost electronics segments such as computer and analogue consumer, the ability of European OEMs to innovate in existing and new market segments has enabled Europe to face increasing competition. Differentiation between products is increasingly based upon innovative functionalities and not only upon price.

New solutions in electronics applications are mainly driven by innovation in micro- and nanoelectronics. New societal needs require dedicated semiconductor solutions where a variety of technologies are integrated on a single chip or in one package. Access to these technologies is crucial to developing and providing the required innovative solutions and to securing the technological independence and competitiveness of European industry as a whole. The economic importance of the semiconductor industry is not only represented by its enabling nature but also by its direct economic contribution. In the next wave of applications that will address societal needs, the semiconductor content in electronic equipment could rise to 25 or 30% of its value.

The technological base supporting these new applications has a broader scope than in the past. Derivative technologies, such as power, analogue/mixed signal, RF and sensors, which are among the domains of excellence of European semiconductor companies, will be a crucial technological asset in addressing these new lead markets. As the development of these technologies and applications is very R&D intensive, the degree of expertise in Europe will need to be clearly uplifted, generating a lot of high-qualification jobs.

Despite the fact that innovative industrial products and socio-economic needs require an ever-increasing content in semiconductor products, the share of Europe in the global semiconductor market declined from 20% in 2000 to 13% in 2009. Its share in the global semiconductor production – diffusion – market dropped even more dramatically in the same period from 14.3 to 9.6%. These figures clearly demonstrate that Europe is losing market share in manufacturing, both in components and in end-products. The following figures detail the 2009 sales percentage per region and per domain and the wafer-starts' level per region between 2004 and 2009.





Differentiation in electronics OEMs is increasingly reliant on product functionality and, as a consequence, on semiconductor technology. For an electronics OEM, access to advanced semiconductor technology optimises product performance, keeps development costs under control and protects intellectual property (IP). This interdependence between semiconductor suppliers and electronics OEMs has been demonstrated in many applications sectors of the electronics industry, such as the Japanese consumer industry in the 1980s and 1990s and the German automotive industry in the past two decades.

Product performance and functionality is growing. Advances in miniaturisation allow ICT to be embedded everywhere, providing enhanced functionality, greater intelligence and more personalised products and services. These added-value operations are key elements for product diversification and strong European competence. They form the basis for a European strategic research agenda aimed at key European lead markets that hold a huge economic potential in the knowledge-based society.

These emerging lead markets which are driven by the grand socio-economic challenges represent an historical chance for the European electronics industry and service businesses to become world leaders. Important factors that underpin this unique set of opportunities are the open-mindedness of the European public vis-à-vis socio-economic topics, innovation capability of the industry, excellence of R&D in academia, institutes and industry and, last but not least, leadership of the European semiconductor industry in More-than-Moore technologies and solutions.

Business models are changing. Micro- and nanoelectronics are a global activity. Europe cannot afford to miss this future and so become dependent on other regions of the world for its social progress and well-being. Currently, the semiconductor industry reinvests about 20% of its turnover in R&D. The percentage of reinvestment continues to grow as industry faces the challenge of combining shortened product life cycles with the increased complexity of those products. It is only with significant additional investment in advanced R&D that a region can keep up with the pace of innovation in this sector.

However, Europe is not gaining market share and is a net importer of micro- and nanoelectronics: 10% of the worldwide semiconductor production capacity is located in Europe, while 13% of worldwide semiconductor products are consumed in Europe. Without adequate capital investment, this gap will widen. The global competition is fierce, especially from countries such as Taiwan, South Korea, China and the USA.

Integrated design and manufacturing companies are increasingly relying on foundries – third-party fabs – and go fab-light for their added-value operations or even fab-less, co-operating in ecosystems of knowledge for their R&D and in strategic alliances for their access to the most advanced technologies.

This is the result of the growing capital investments – a mega fab costs €5.5 billion typically – required to research and manufacture the new generations of components. This goes above what individual companies can afford – apart from Intel – in terms of return on investment. Consequently, generic micro- and nanoelectronics technology research is executed by a few major alliances, while manufacturing of advanced commodity products is done in a few mega fabs. Europe must ensure that its companies can play a strategic role in these global alliances and keep added-value operations including advanced manufacturing in Europe, accessible to European partners – including SMEs active in equipment, support, systems integration and design.

Europe is standing at a crossroads. It can either seize the opportunities given by the grand challenges and take up the leadership by solving the problems that society faces – and thereby build a prosperous economy – or, as was the case in the past decade, it can choose to sit back and lose the last bastion of production capability and, eventually, its development and innovation competences. Without a radical uplift in joint efforts, and the acknowledgement of the urgency of the situation by industry and public-private partnerships, opportunities as defined by the grand challenges will be lost.

1.4 Globalisation and need for a level playing field

The semiconductor industry landscape evolves rapidly. Over the past few years, the industry has experienced significant global shifts that have redistributed the roles of the respective economic regions in the world semiconductor market and industry that continue to remain very dynamic, hyper competitive and highly innovative. The semiconductor industry and its entire supply chain are now truly global.

Semiconductor companies are forced to reassess their global strategy continuously to deal with a highly competitive environment, to leverage their strength and limit or resolve their weaknesses, to capitalise on new opportunities and to guarantee the best return on investments for their shareholders. In doing so, companies are obliged to look at the attractiveness of each region to localise their activities and their new investments in R&D and manufacturing.

Delocalisation of micro- and nanoelectronics manufacturing holds a real risk in the migration also of added-value activities to other parts of the world. Some countries have developed special incentives to attract and retain foreign semiconductor investment, whereas the EU lacks a dedicated sectorial approach to support this key industry. Europe must react with comparable measures.

Currently however, the right mix of measures does not exist in Europe to guarantee a global level playing field. To be in a position to retain and attract new investment in the entire semiconductor value chain, appropriate governmental action in Europe should guarantee an equal level playing field with other global regions.

CHAPTER 2: DATA ON THE CURRENT STATUS OF THE INDUSTRY

2.1 Introduction

The nature of the nanoelectronics industry is such that everyone reading these words has probably benefited from the service of a broad range of semiconductor-based devices within the last hour. Whether using a laptop or tablet computer at home or in the office, making a mobile phone call, taking a digital photo, watching TV, making a financial transaction, using any form of transport, having been treated in hospital or having engaged in just about any other modern societal activity, one can be sure that semiconductors have been involved.

The ubiquitous nature of nanoelectronics products implies also that new products and services are only affordable, manageable and feasible with a healthy nanoelectronics industry. Adding it all up, these small but very complex and powerful nanoelectronics components are underpinning some 10% of our GDP.

Zalewski and Skawinska[5], OECD and others demonstrated in their studies the correlation between the rate of technological innovation and the economic or GDP growth in nations. The nanoelectronics industry is one of the most innovative industries, employing highly skilled workforces, facilitating innovation in almost every other type of industry and impacting our ways of living.

This chapter illustrates the relevance of nanoelectronics, the R&D perspective, the position of the nanoelectronics industry in Europe compared with competing regions and the measures taken by the various regions to facilitate this strategically important industry.

Semiconductors are for the Information Society what grain was for the agrarian, and iron& steel for the industrial society…

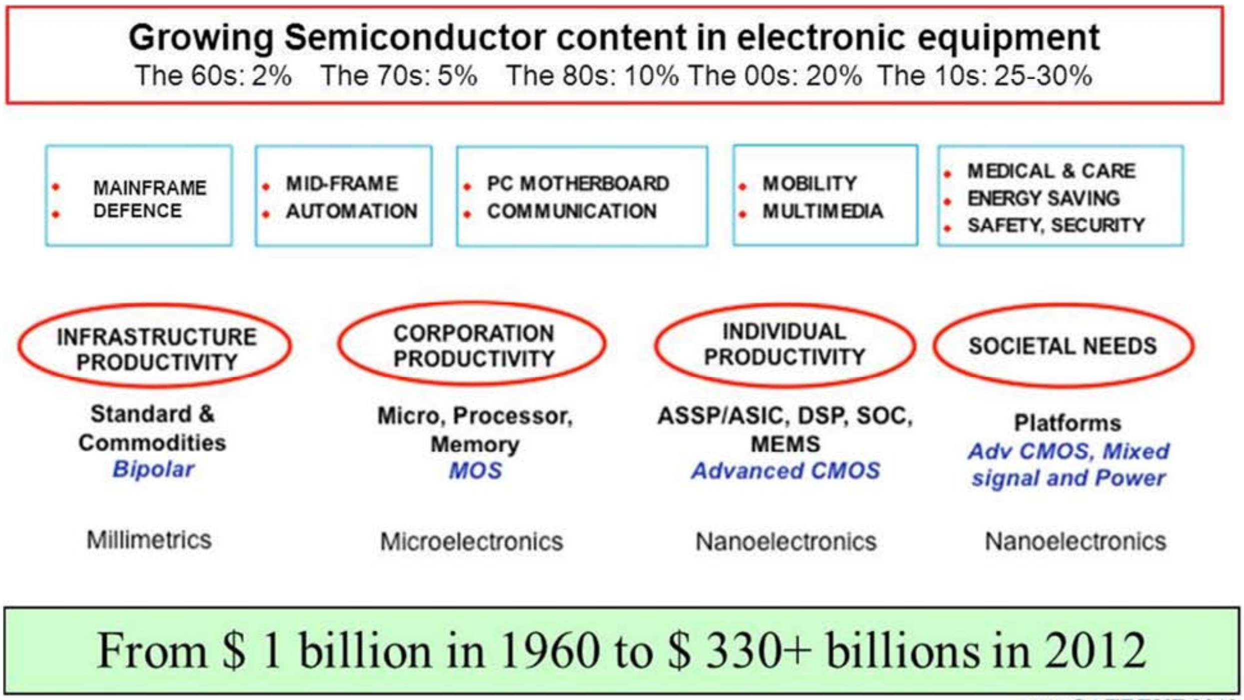
Src: Shanghai Museum of Urban Development 2004.

---

[5] Journal on Systemics, Cybernetics and Informatics (JSCI) (http://www.iiisci.org/journal/CV$/sci/pdfs/GF914HA.pdf)
Impact of technological innovations on economic growth of nations
Romuald I. ZALEWSKI, Faculty of Commodity Science, Poznan University of Economics, Poznan, Poland and Eulalia SKAWINSKA, Department of Economics, Poznan University of Technology, Poznan, Poland

2.2 The relevance of the nanoelectronics industry

The main driver for the development of electronics has changed regularly over time. In the 1960s, defence and the space race were the main drivers, by and large based upon government procurement. The share of the semiconductor in the bill of material (BoM) of the full system was pretty low, in the range of 2%. At that time, the products involved were both standard and commodity with millimetre line width as the characteristic measure. The next driver came in the 1970s and was aimed at improving corporate productivity. Mainframe computing and automation were the killer applications. The microelectronics share of these systems increased to 5%. Microprocessors and memories based upon N- and PMOS technology were the main products for the microelectronics industry.

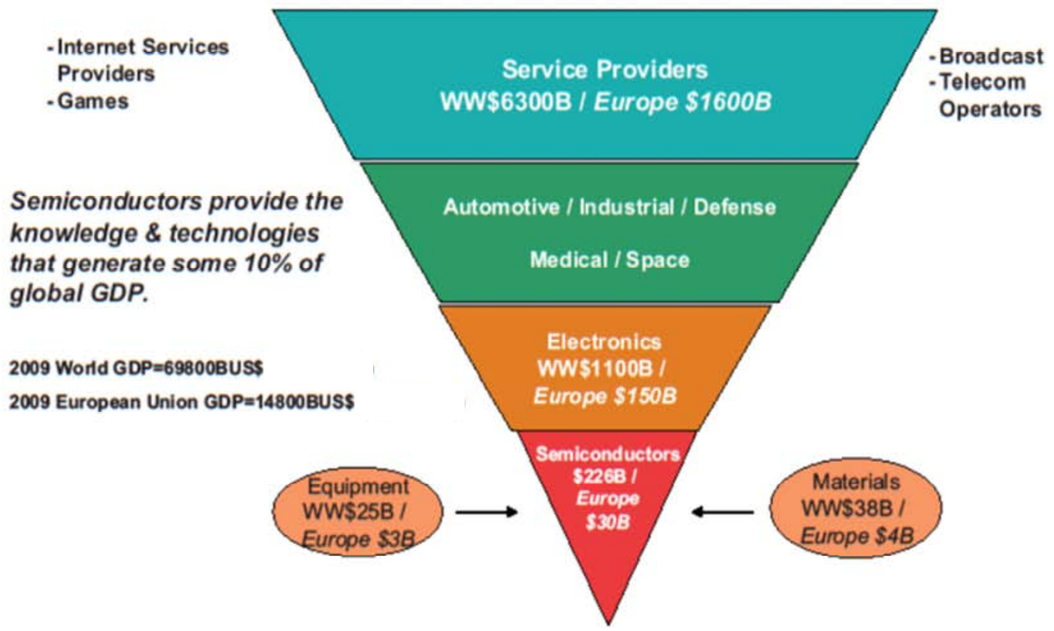


Moving ahead between the 1980s and the end of the century, consumer productivity and way-of-living improvements have been the main driver with related mass volumes in the range of hundreds of millions up to one billion plus. The share of semiconductors in the BoM moved up progressively from 10% to 20%. Notebooks and mobile phones were the killer applications and the products involved were mostly application specific, digital signal processors and system-on-chip (SoC) devices in advanced CMOS technologies at nanometric scales. Looking ahead, we believe that consumer and societal needs may become the main driver, focusing on energy efficiency, health and aging society, and safety and security[6,7]. The share of micro- and nanoelectronics in the BoM is forecast to increase to 25 or 30%. Main products will involve both More Moore and More than Moore processes.

[6] See VMS part A chapter 3, where these drivers have been identified as focal points for the VMS strategy.
[7] See VMS part C chapters 3, 4 and 5 for a technical description in terms of goals, values, challenges and success conditions on these drivers.

The micro- and nanoelectronics segment is today a globally profitable business with a higher value than for example the aerospace industry. Its relative importance is even higher than its specific value: this sector enables almost all innovation in all electronic segments – which are five times bigger; in turn this is key for the electronic services driven by information and communication technology, which in turn is again more than five times bigger than the electronics segment.

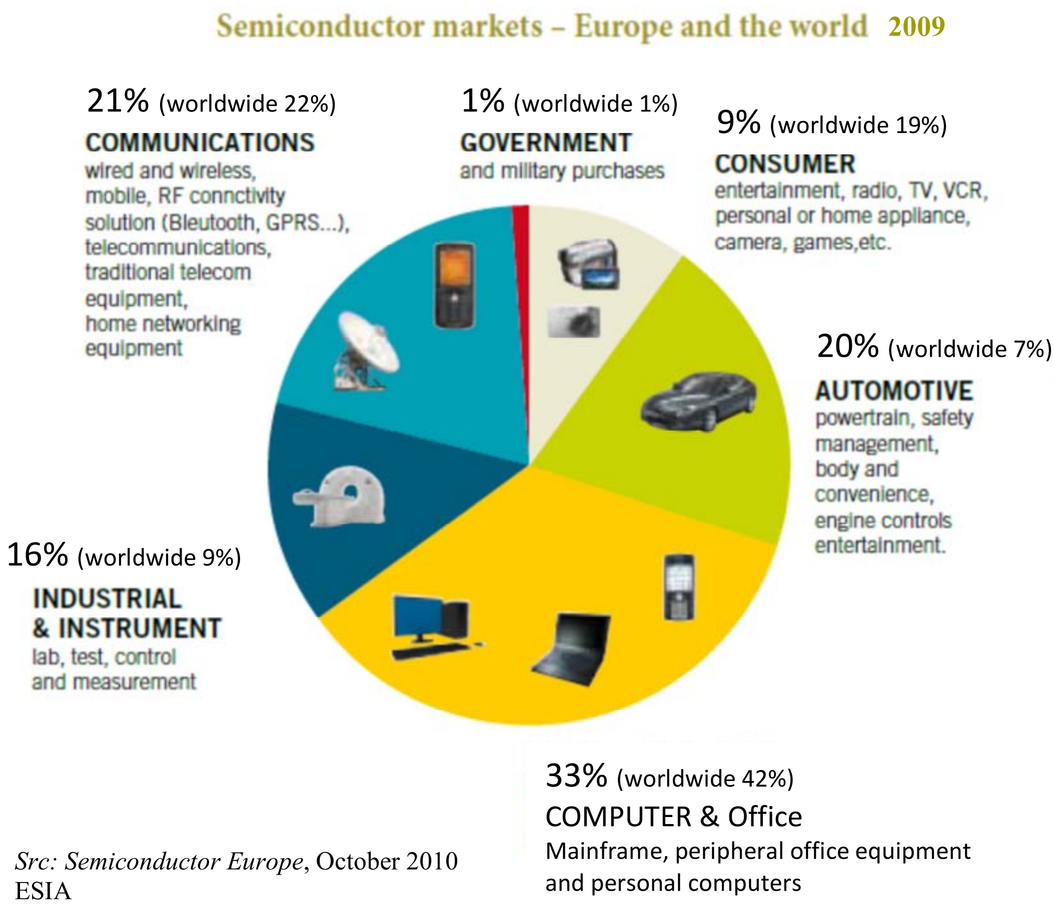
All in all, micro- and nanoelectronics is the enabler for many application and service jobs. In Europe and at world level this contributes more than 10% of GDP. The enabling role of this industry is recognised in many countries, both developed and developing, including many in Asia – see the quote in the introduction of the chapter, coming from the Shanghai Museum – and by the European Commission through its communication on key enabling technologies (KETs). [8]



src.: ESIA 2010

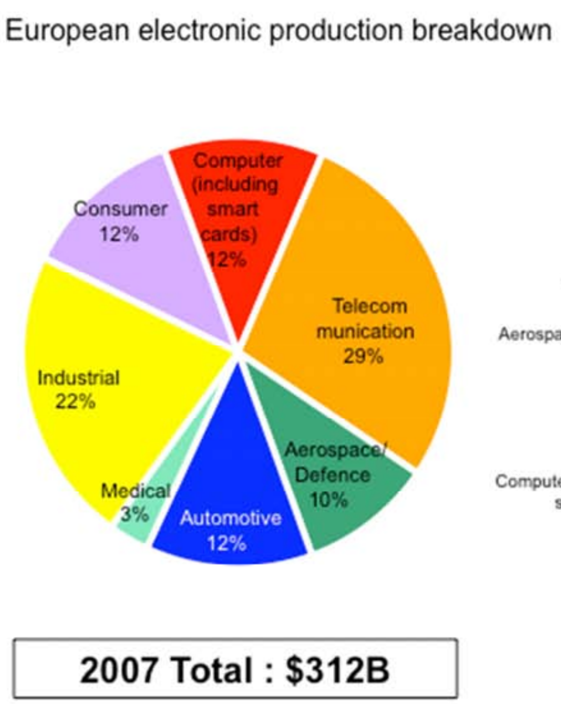
[8] Src.: Key Enabling Technologies (KETs) Open Day on Micro/Nanoelectronics 18.10.10 Brussels. http://ec.europa.eu/enterprise/sectors/ict/key_technologies/kets_high_level_group_en.htm

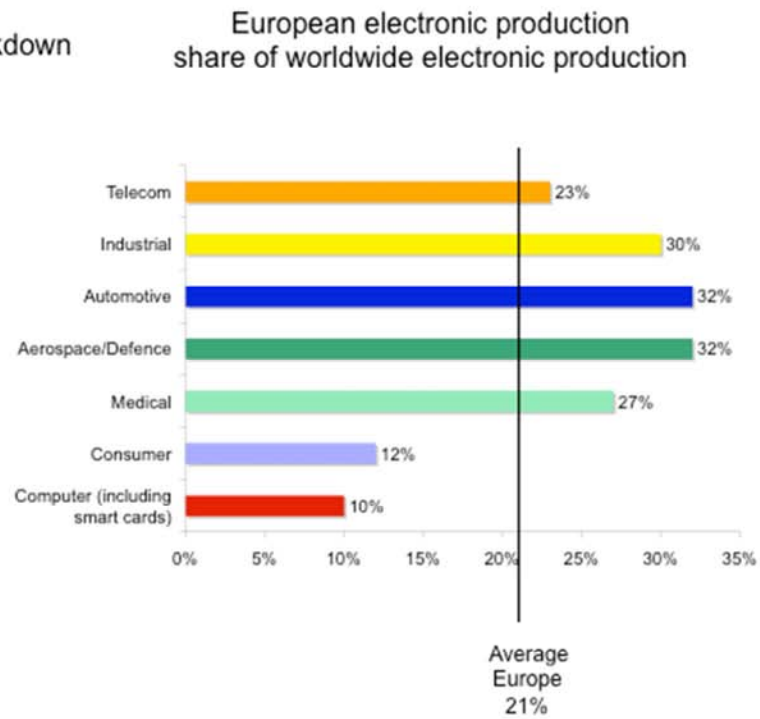
The micro- and nanoelectronics industry can be segmented into: 'Government'; 'Consumer'; 'Automotive'; 'Computer & Office'; 'Industrial & Instrument' – including Medical; and 'Communications'. The European micro- and nanoelectronics industries have strengths in the 'Automotive' and 'Industrial & Instrument' segments and a good position in 'Communications'. European systems industries benefit from these strengths. Interaction between systems and supply industries is the engine for innovation.



Src: Semiconductor Europe, October 2010
ESIA

Europe's electronic systems production is on average more than 21% of worldwide electronics production. Some segments – telecommunications, industrial, automotive and aerospace/defence – are particularly strong and exceed the average value. In computer and in consumer, most of the production centres are outside Europe, in the USA and Asia respectively. Europe's strengths in job-intensive industry segments such as industrial and automotive build upon equivalent strengths in the micro- and nanoelectronics supply industries for these segments. The segments where Europe is strong are those which are expected to have the fastest growth and are more related to new societal needs. This holds in particular for medical-, security-, energy- and environment-related industries. Know-how is strong in Europe in these segments. Leveraging on this trend and supporting and organising early market pull in Europe could be an important driver for global competitiveness of the European industry[9].

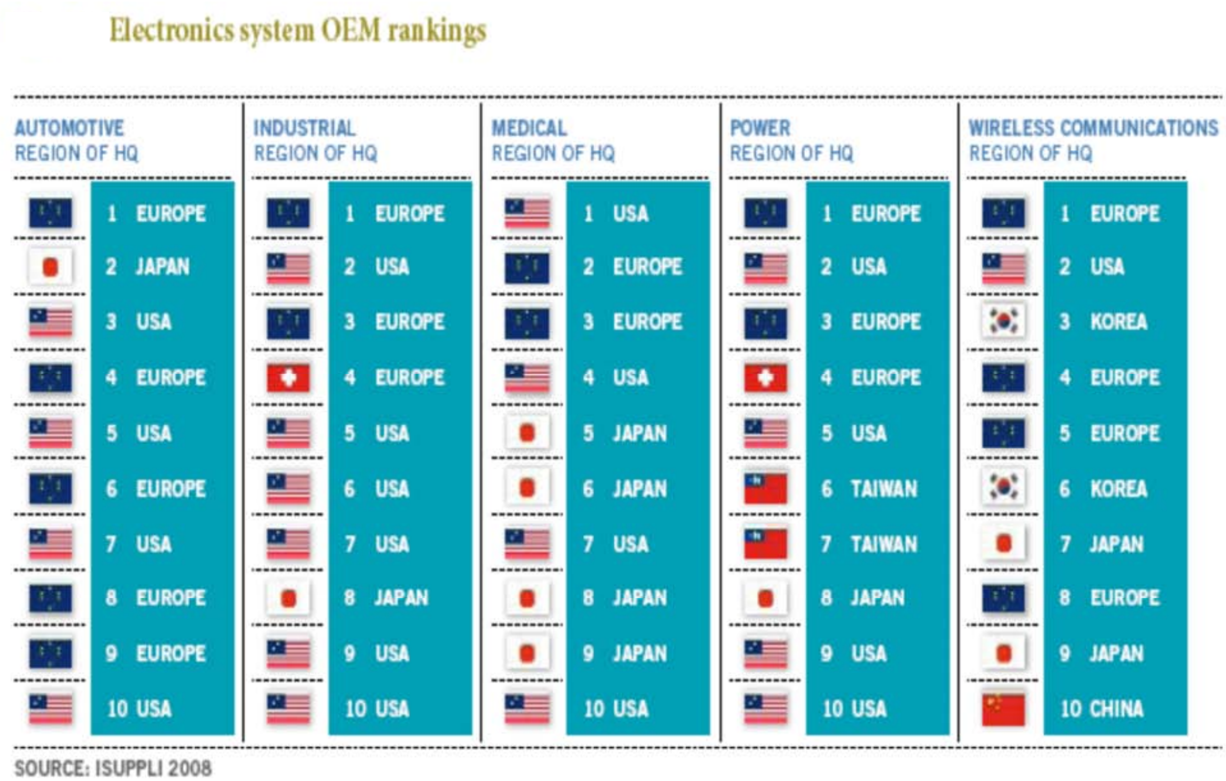




Src: Decision

[9] 2007 figures have been taken to eliminate the effects of the 2008/9 crisis that would otherwise distort the overall conclusion.

As can be seen from the chart below, there is a strong correlation between the strengths of the semiconductor industry in Europe and those of its customers in the various application areas:



Europe has global market leadership in lithography. In addition, Europe is amongst the strongest in metrology and selected materials. Europe's strengths and leadership in systems markets are in specific sectors such as automotive with Bosch and Conti, medical with Siemens and Philips), smart cards with Gemalto, G&D and Oberthur, wired communications with Ericsson, Alcatel/Lucent and Nokia/Siemens, and wireless with Nokia.

The 2009 global top 20 semiconductor companies included 3 EU companies. In some specific domains Europe is leading – such as in automotive (4 in top 6), industrial (2 in top 10), medical (2 in top 5) and smart cards (3 in top 5). Five European companies are in the global top ten in the segment of application-specific integrated circuit and system on chip (ASIC & SoC) devices.

In Europe only a limited number of countries host large R&D and diffusion fab activities. These include Austria, Belgium, France, Germany, Ireland, Italy, the Netherlands and the United Kingdom, In some locations, dedicated industrial policies have created clusters and ecosystems with a very positive impact on the large industries, SMEs, academia and public laboratories involved.

"The proximity of research, design centres and manufacturing facilities benefits technology transfer because it minimises delays. Where research and manufacturing meet, effective networks between companies and research institutes emerge, attracting engineers, researchers and academics to share knowledge and experience, thus stimulating and accelerating the innovation process in a particular geographic area. Examples of such clusters can be found in the Grenoble area, the ETNA Valley (Catania), the Nijmegen-Eindhoven-Leuven axis and in Dresden. Similar structures can be observed in the Dublin area."[10] Other important locations of knowledge exist in Europe.

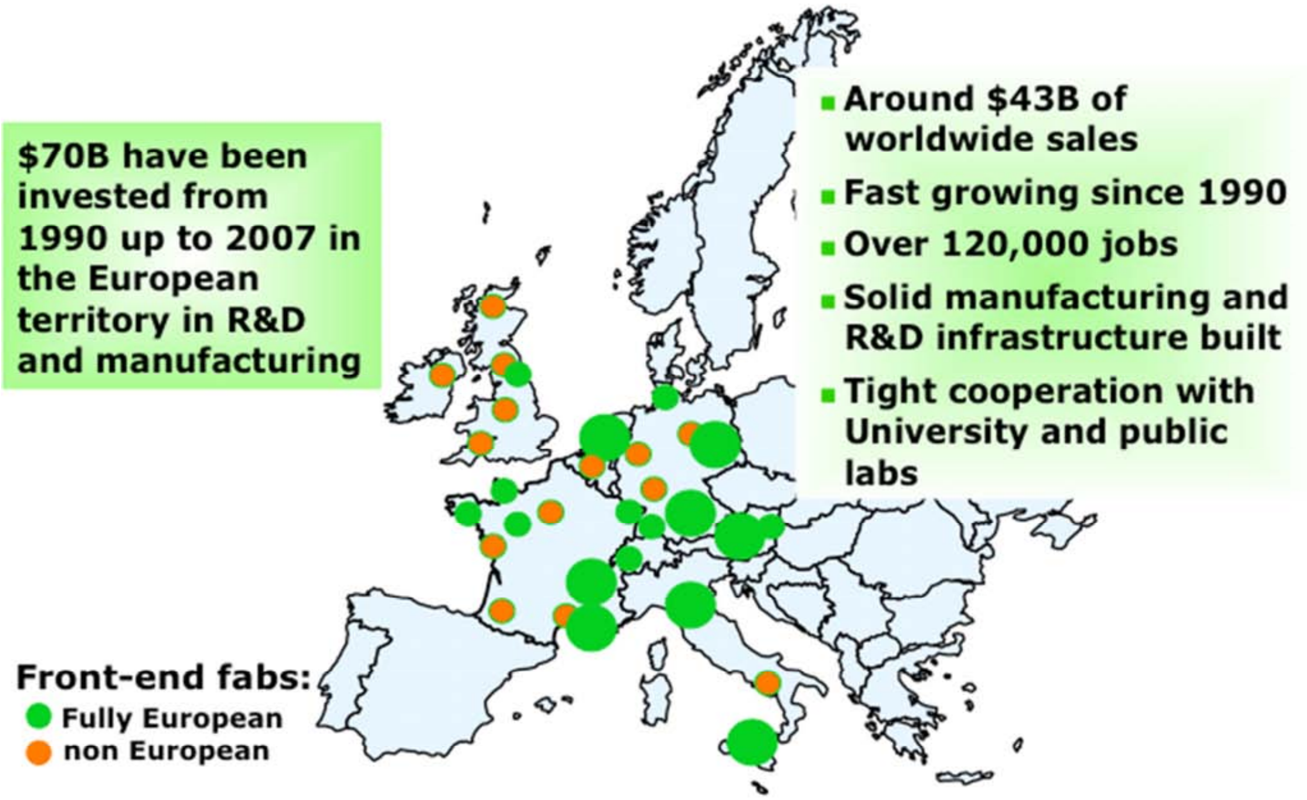
Main technology in Europe

src.: ESIA 2008 Competitiveness Report – *Mastering Innovation, Shaping the Future*; p. 33

These ecosystems have attracted foreign development investment (FDI) and have allowed some companies to become world leaders. According to studies in the Grenoble and Dresden clusters, the leveraging effect on the employment of these ecosystems can be quantified on the ratio of 1 to 6, comparing direct jobs to induced jobs in the local communities and at national level. A necessity for the optimal functioning of the ecosystem is access locally to advanced production facilities on top of the R&D ones.

More recently a new opportunity has been arising in Europe with the presence of foundry production sites, originated through foreign investment – Global Foundries – or management buy-out, such as Altis. X-fab, L-Fab and Telefunken. It is very important that R&D activity should be close to these foundries to achieve leadership in selected segments, allowing growth and global competitiveness. Such foundries have entered Europe only recently. This opportunity did not exist here just a few years ago. Foundries are available today in Europe in both the More-Moore and the More-than-Moore domains and, like everywhere else, their success is linked to industrial-policy decisions. However, many of these locations are not yet producing at the current industry standard level of 300 mm for More-Moore and 200 mm for More-than-Moore applications. Upgrading in Europe is necessary to keep this opportunity competitive.

[10] Quoted text and figure come from the ESIA 2008 Competitiveness Report – *Mastering Innovation, Shaping the Future*; p. 33



Semiconductor Industrial Landscape in Europe.
Src: adapted & updated from ESIA 2008 Competitiveness Report – Mastering Innovation, Shaping the Future; p. 32

Amongst the 1,300 fabless companies worldwide, only 12% are in Europe – 4% are in Israel, 46% in the USA and 38% in Asia. Within this subset, the top 10 fabless companies represent 57% of the total fabless revenues – 2007 figures.

The industries' employment levels are relatively stable in Europe with over 200,000 employees directly employed between IC producers and equipment and material suppliers. The induced employment – i.e. direct employment by IC producers PLUS indirect employment in the supply chain PLUS related employment – is estimated at 1,000,000 in Europe. Generally, the semiconductor industry is a medium-sized sector for employment and is characterised by a highly skilled workforce mainly from an engineering background. There is a high knock-on effect in terms of induced employment and a strong emphasis on the science, technology, engineering and maths (STEM) skills background of employees.

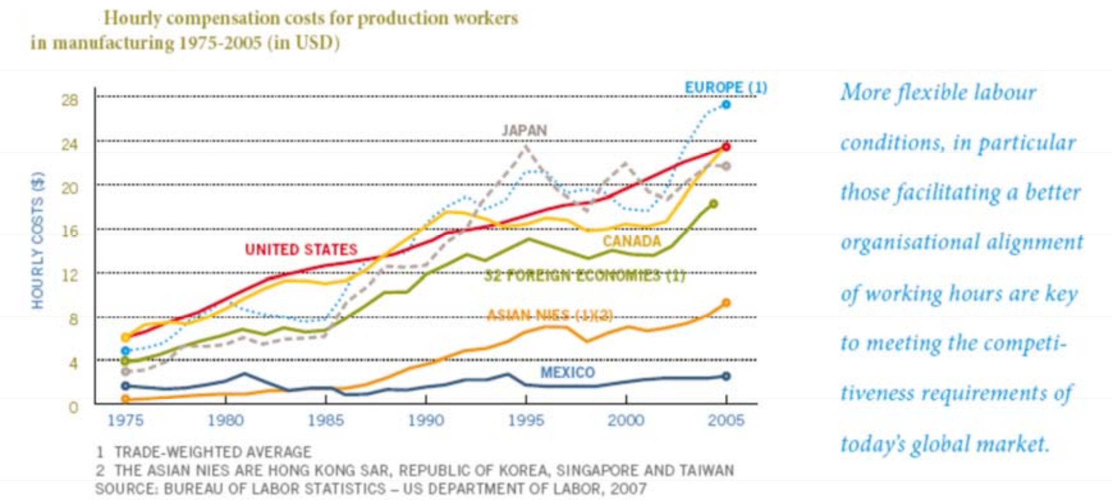
A study of the Grenoble-Crolles ecosystem from 1993 to 2006 [11] showed that for one job created in the Crolles' microelectronics operation site, three additional jobs were created in the Rhône-Alpes region, while two more jobs were created at the national level: the microelectronics multiplication factor in terms of job creation is thus six times. Moreover, while jobs in microelectronics operations are highly qualified, induced jobs cover the full spectrum of qualifications.

[11] CROLLES, UN SITE ET SA DYNAMIQUE, http://reverdy.associes.pagespro-orange.fr/Projet_Crolles.pdf

In the same study on the Grenoble-Crolles ecosystem from 2001 to 2006, public R&D support translated into a higher return in taxes generated by the production resulting from the R&D programmes with a significant return for the local authorities, while a six-times wealth creation – additional GDP – was estimated at the national level with most of the impact at the regional level.
A similar study on the Dresden ecosystem[12] showed that for one job created in industrial Dresden’s microelectronic operation sites, 0.7 additional jobs were created in the Dresden region, while 0.7 more jobs were created at the national level: the microelectronic multiplication factor in terms of job creation is thus 2.4 times.[13] Compared with a former study (2002), there was a total job increase in the Dresden semiconductor industry of about 50%. These numbers relate only to the industrial part of the Dresden semiconductor ecosystem. Triggered by its strong semiconductor ecosystem, Dresden counts another 4,500 jobs in research and about 4,500 students in IT.

In the 2008 study, the analysis of the fiscal effects of public support for the semiconductor industry in Dresden showed a nearly perfect balance. The cumulated fiscal return on investment was about 6% higher than the public support. The situation was different in the earlier period between 1999 and 2003, when the cumulated effect was about 1.8:1 – a remarkably stronger effect. For both periods, the income for social security was not taken into account.

Europe is at the top when comparing hourly labour costs. However, decisions on localisation of front-end manufacturing sites are mainly taken from a perspective of overall return of investment. Here industrial policies by public authorities play a major role.



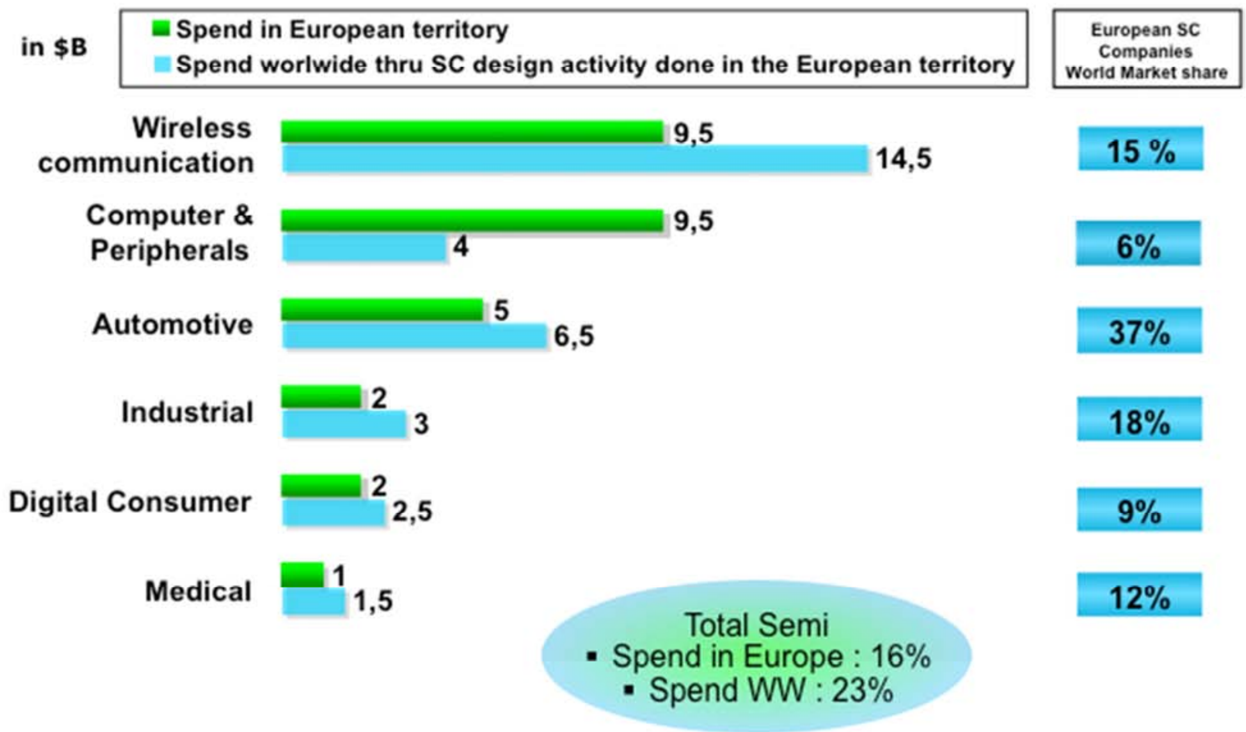
Several sources. See in: ESIA 2008 Competitiveness Report – *Mastering Innovation, Shaping the Future*; p. 21.

12 Der Halbleiterstandort Dresden, Studie zur gegenwärtigen Bedeutung und zu Perspektiven einer führenden deutschen Hochtechnologieregion, Berlin, Mai 2008, PROGNOS AG.

13 This does not contradict the Crolles data, because of the different approach in the Dresden study. Whereas the Dresden study limited itself to the semiconductor segment only, the Crolles study took the leverage on society as a whole.

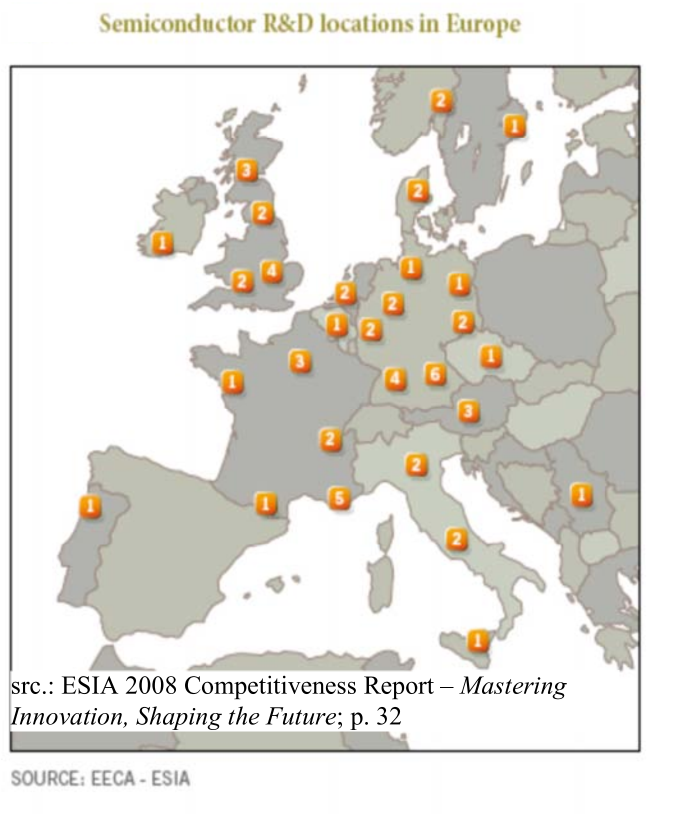
2.3 R&D

Europe has always been recognised by the electronics industry as key for innovation and design. The importance of Europe in R&D is much bigger than in local consumption or production. On top of development, debugging and start-up of volume production is typically located in Europe. Owing to unfavourable economic conditions, mass production in some segments has been moved and is still moving out of Europe. On a volume basis, Europe has a share of 23%, whereas local consumption equals only 16%. One domain where Europe is particular strong is automotive with a worldwide market share of 37%. This places Europe in an ideal position for important innovations in electric/hybrid cars and for contributions to solving the global-warming issue. The figure below reflects the good R&D climate in Europe when comparing local consumption with total consumption generated by local design.



Source iSuppli 2007 est, DECISION est

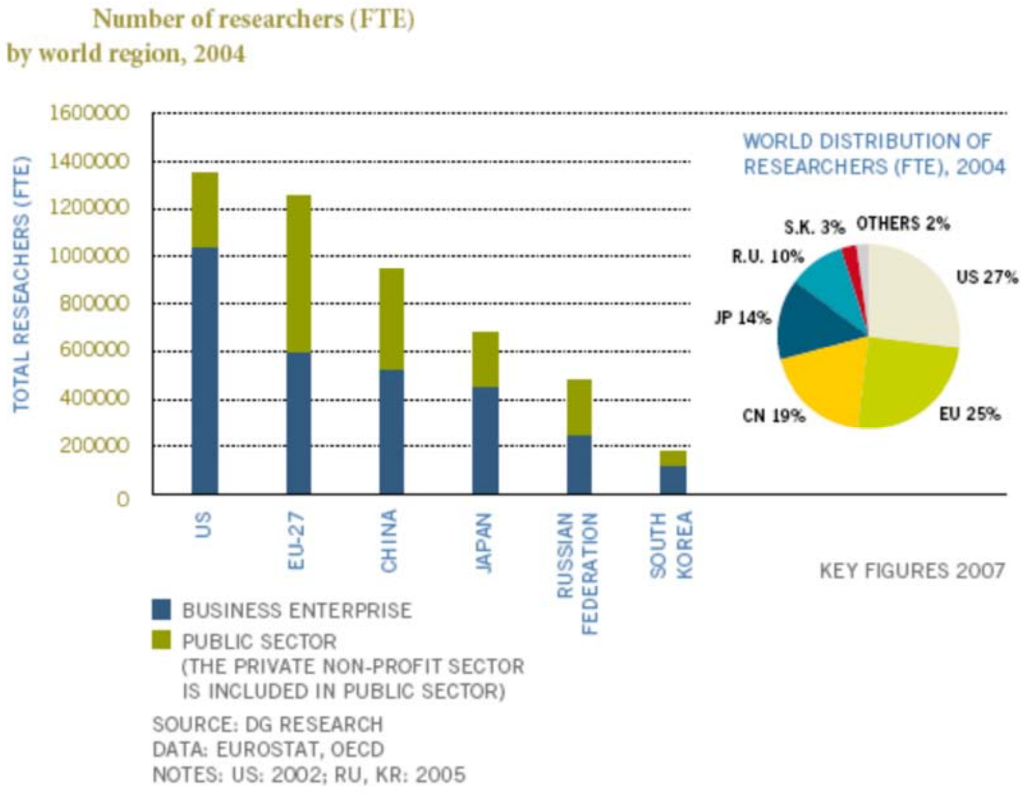
This European strength is backed up by excellent R&D centres, spread over many countries in order to attract the scarce talent needed for these activities. Europe is an attractive area for R&D.



src.: ESIA 2008 Competitiveness Report – *Mastering Innovation, Shaping the Future*; p. 32

The engineering cost of Europe is competitive compared with other regions, even to the Asian ones – excluding the impact of currency fluctuations as described in section 2.4. The next graph shows the total number of researchers per region for all domains. In this comparison, Europe comes second just after the USA.

The ratio between public and private R&D is very different per region. By implication, good co-operation between the public and private sector is not only very beneficial for Europe but is a must to compensate for a serious backlog in privately-driven research.



Micro- and nanoelectronics is the most innovative industry in terms of R&D intensity. Europe is –as a percentage – spending above average. The ever-increasing product-renewal rate makes R&D one of the most important business processes with a continuous upwards pressure to the percentage of revenues spent on it.

Semiconductors driving R&D in Europe

Ranking of high R&D intensity EU industries in the 2009 Scoreboard*

Rank	Sub-sector (4-digit ICB)[2]	R&D investment 2008 (€m)	Net sales in 2008 (€m)	R&D intensity (%)
1	Biotechnology	770.7	4075.9	18.9
2	**Semiconductors**	**3942.9**	**21818.2**	**18.1**
3	Pharmaceuticals	19485.3	122097.6	16.0
4	Software	3188.8	22976.8	13.9
5	Telecommunications equipment	11848.8	89651.6	13.2
6	Leisure goods	1856.1	30057.6	6.2
7	Aerospace & defense	7376.3	122563.2	6.0
8	Automobiles & parts	30116.7	567862.8	5.3

* High R&D intensity = Ratio of R&D investment over net sales higher than 55%.
Source: The 2009 EU Industrial R&D Investment Scoreboard European Commission, JRC/DG RTD.

November 22, 2010

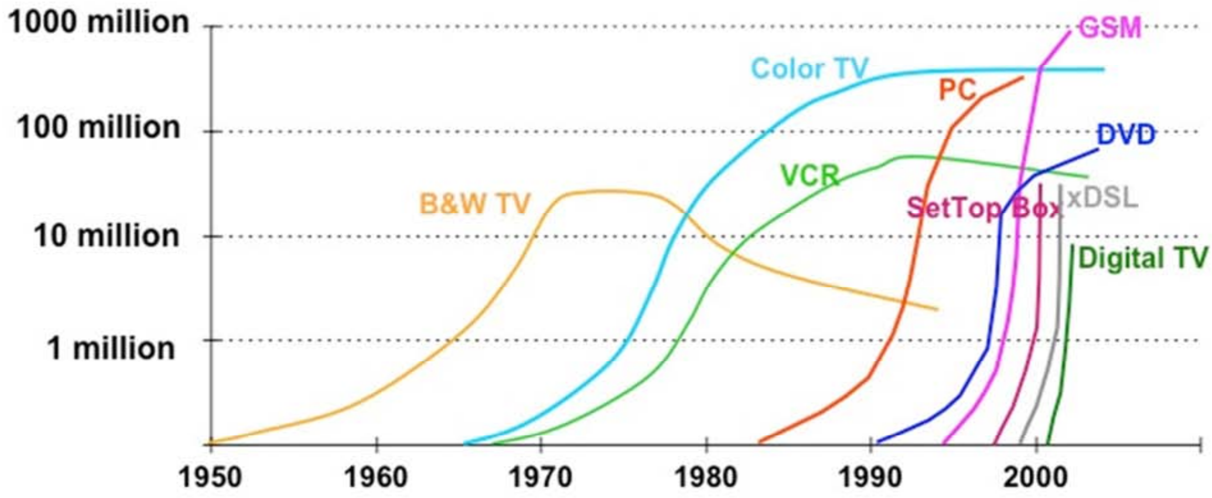
See also ESIA press release 3.2.10

src.: ESIA 2008 Competitiveness Report – *Mastering Innovation, Shaping the Future*; p. 32

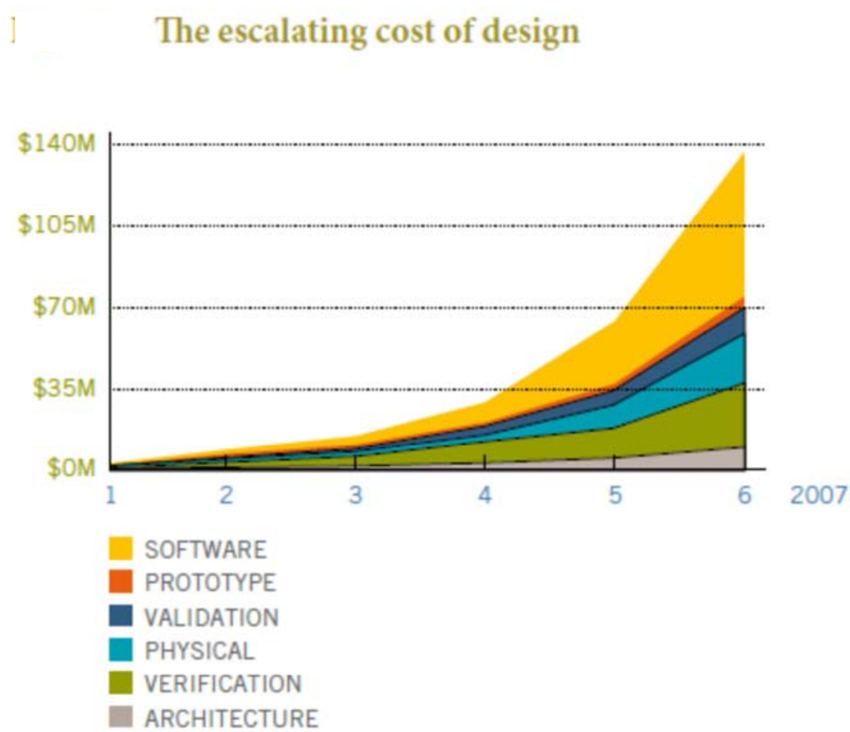
It is worth noting that the two highest scoring segments also have the largest leverage on the general economy through systems and related services – see the inverted pyramid in section 2.2.

In the past, it took a long time to move from product introduction to mass production. Today, time to market is extremely important.

An approval process for pre-competitive research of one year did not do a lot of harm in the past. Today, it would lead to unacceptable cost increases and due to the short time to volume may guarantee or not the return of investment on the research.



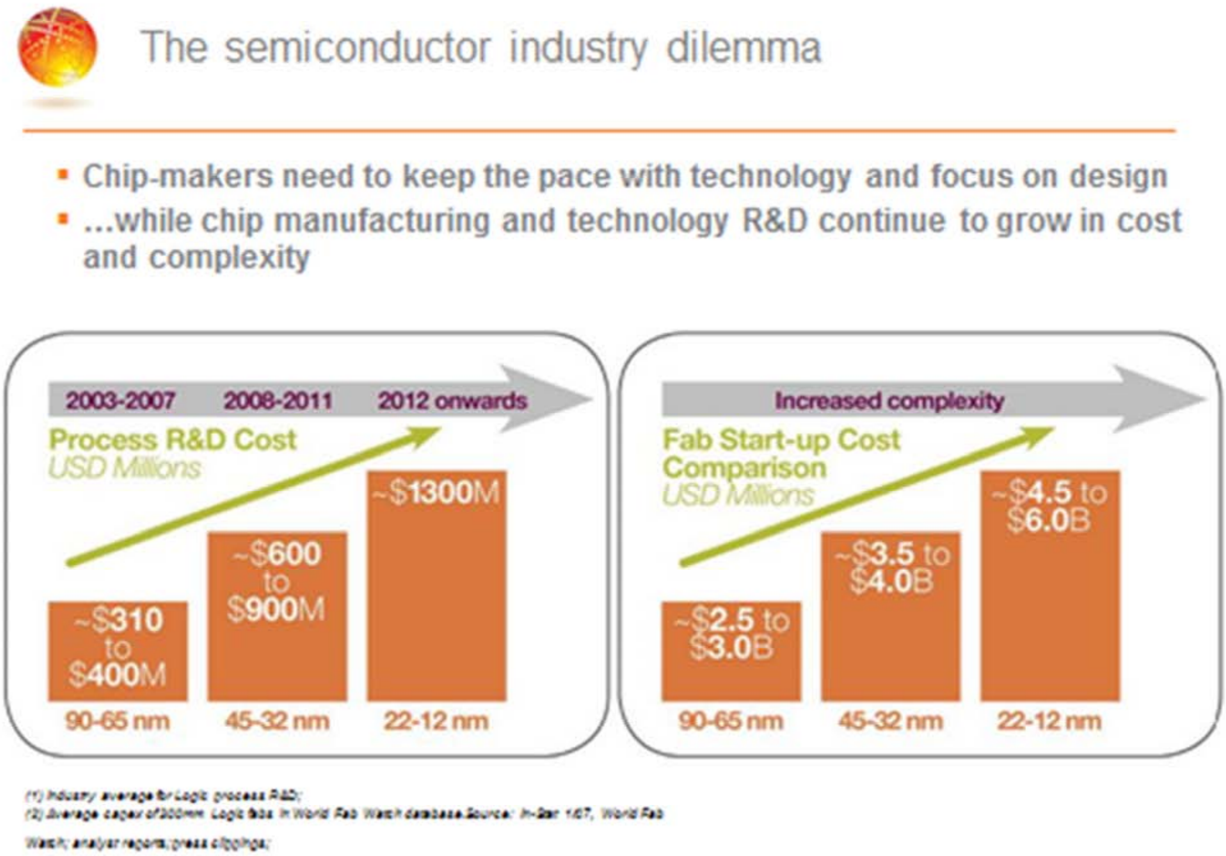
Very fast product renewals and the increase in complexity have caused R&D costs to explode. The complexity increase is driven by system and embedded software integration in the semiconductor solution. This holds specifically for the more recent trend to integrate complete systems on a single chip. The associated costs of software development take an ever increasing proportion of the total development costs.



src.: ESIA 2008 Competitiveness Report –
Mastering Innovation, Shaping the Future; p. 32

The labour-intensive system software development, together with the capital-intensive process development, is an issue for the semiconductor industry in general. Both elements are essential for the functioning of the final product, but do not show up often in the customer specification. As a result, so-called pre-competitive R&D has become increasingly important in this sector.

Over and above the extra costs for designs, the additional costs to start new processes and to start up a factory must be added to the equation. The figure below provides some staggering numbers about this.



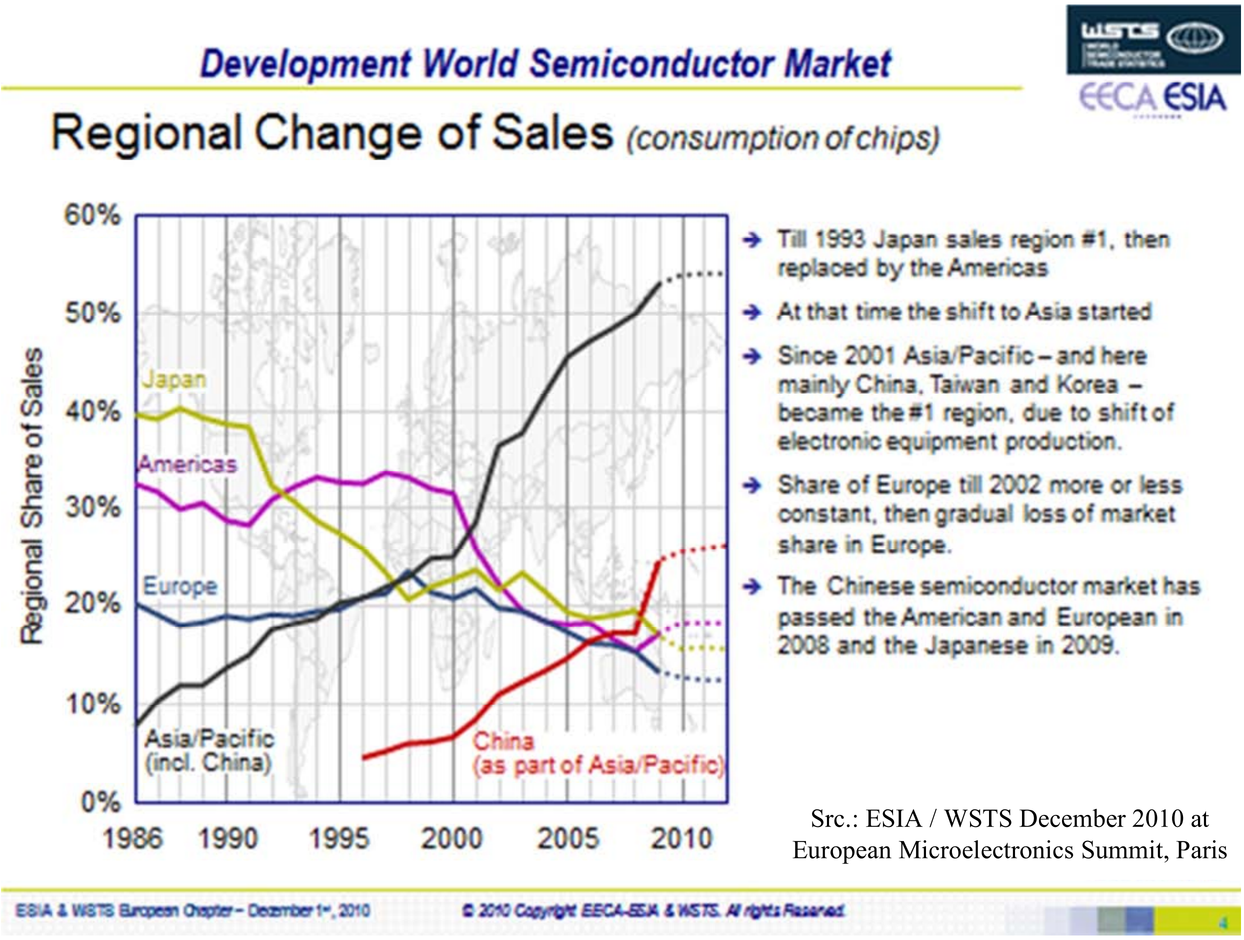
Src: Key Enabling Technologies (KETs) Open Day on Micro/Nanoelectronics 18.10.10 Brussels. Olivier Vatel, Vice President Technology Development division, Global Foundries.

2.4 Regional perspectives

The last decades were characterised by a very dynamic development of the world semiconductor market and by more or less dramatic changes in the share of the different regions of the world in this market. From 2000 onwards, China increased strongly in local semiconductor consumption, mostly due to local moves by original equipment manufacturers (OEMs), outsourcing policies executed by western OEMs in consumer, computer and telecommunications together with the development of the local industry. As a result, China semiconductor consumption now exceeds largely that of the USA, Japan or Europe. In other Asian countries, similar trends have occurred and, today, more than 50% of world consumption is in Asia.

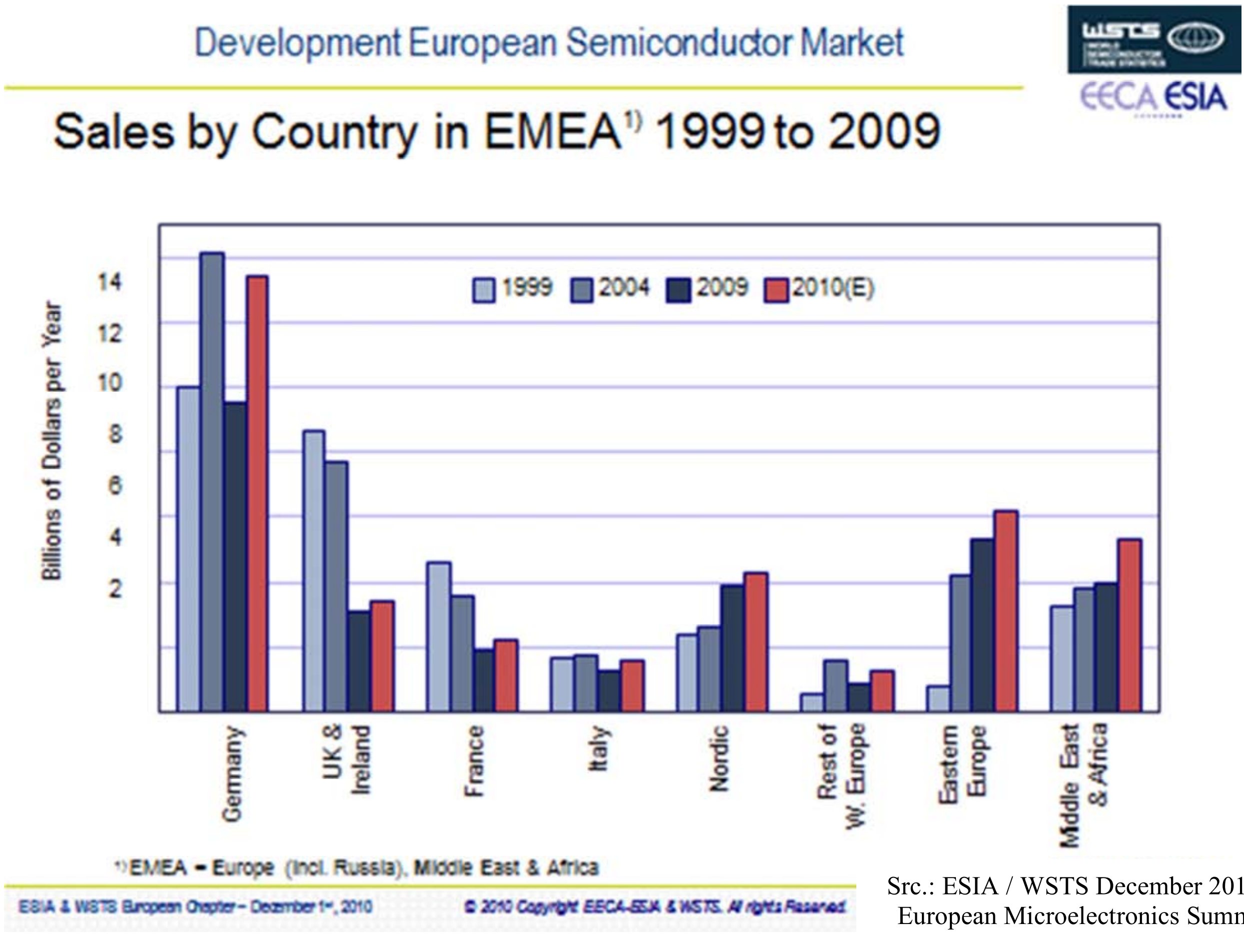
This rapid increase in the importance of the Asia Pacific region as a market for semiconductors took place initially at the cost of the Americas and Japan but, increasingly, also at the expense of Europe. By the beginning of 2008, the share of Europe had only slowly declined to 16% of the worldwide semiconductor market, whereas Asia Pacific, where the market is growing the fastest, had increased to almost 50% – and this trend apparently continues. In 2009, the European share had dropped to 13%.

The relative stability of Europe compared with the decline of Japan and the USA may be explained by the strong presence of key OEMs in Europe. This has so far ensured the continued importance of Europe as a manufacturing base for electronic applications and hence as a market for semiconductors.

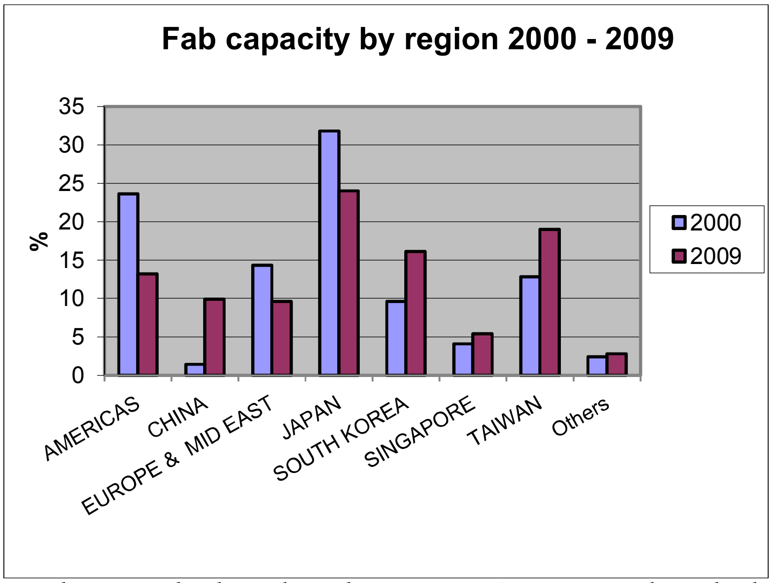


Src.: ESIA / WSTS December 2010 at European Microelectronics Summit, Paris

Looking more specifically to European semiconductor consumption, this has been more resilient compared with Japan and the USA but there is no doubt that the trend is downward. Looking at European consumption by country from 1999 to 2009, the 2009 crisis has negatively impacted sales in the main countries, reducing local consumption in absolute terms; this was due both to some transfer to the East Europe and some delocalisation to Asian countries. The expected recovery in 2010 is not equally distributed between the various countries – as can be seen from the figure below.



Src.: ESIA / WSTS December 2010 at European Microelectronics Summit,



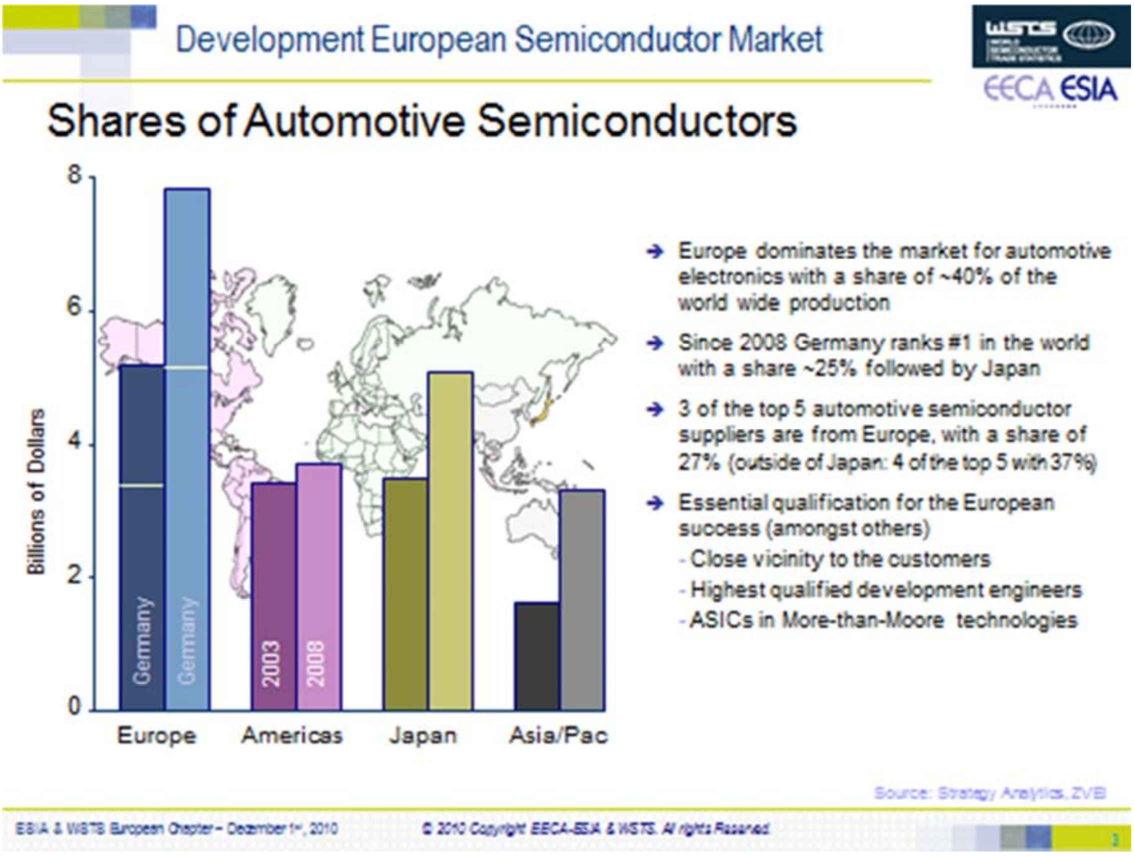
Current analysis of worldwide production capacity shows Europe fluctuating close to 10% of global fab capacity, down from 14% some years ago and losing ground on deployment of 300-mm and future technologies. In terms of capital investment, there has been a 5% decline in the past few years. Capital investment in European semiconductor manufacturing is at risk as framework conditions are not as attractive as other competing regions.

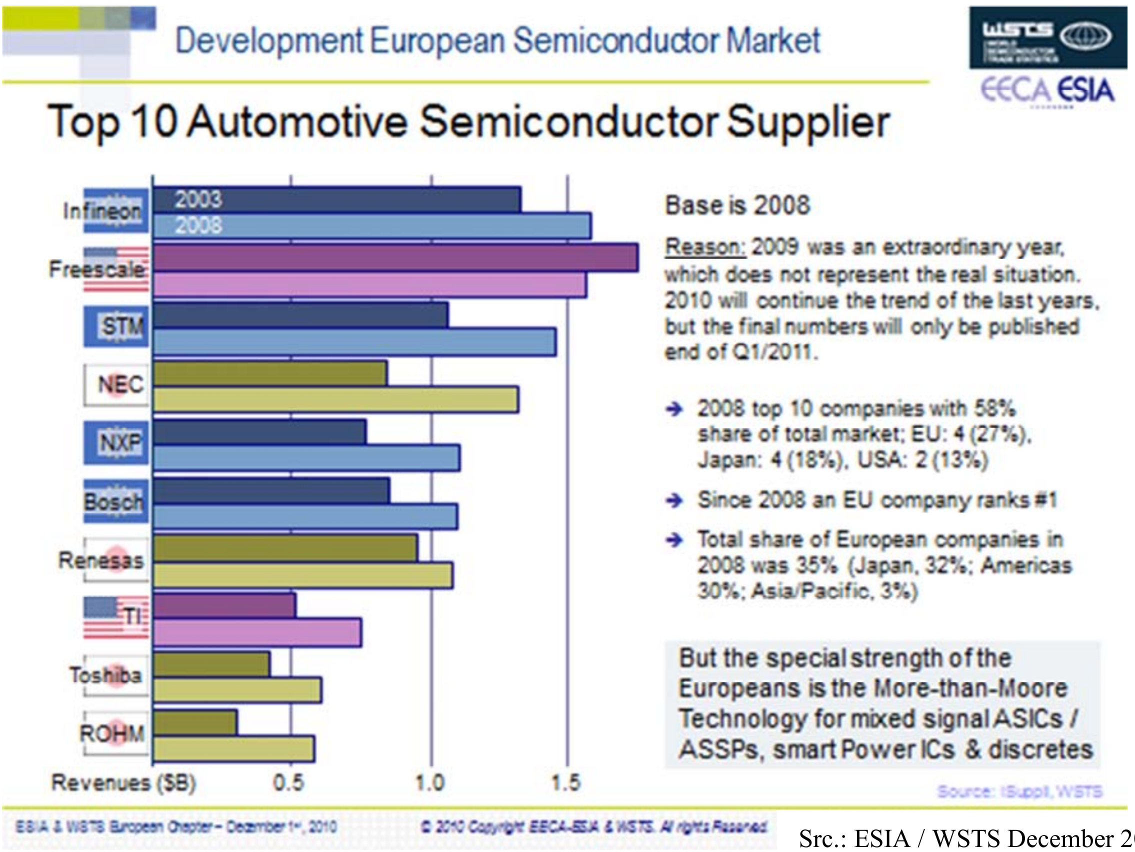
Looking to the top sales company ranking in the last decades, Europe's position has declined over the last few years. With a peak in 2002, when three European companies were in the top ten, currently STMicroelectronics is the only European company left, due to focusing and associated mergers and acquisitions.

	1980		1990		2000		2009
1	TI	1	NEC	1	Intel	1	Intel
2	Motorola	2	Toshiba	2	Toshiba	2	Samsung
3	Philips	3	Motorola	3	NEC	3	Toshiba
4	NEC	4	Hitachi	4	Samsung	4	TI
5	National	5	Intel	5	TI	5	ST
6	Toshiba	6	Fujitsu	6	ST	6	Qualcomm
7	Hitachi	7	TI	7	Motorola	7	Hynix
8	Intel	8	Mitsubishi	8	Hitachi	8	Renesas
9	Fairchild	9	Philips	9	Infineon	9	AMD
10	Siemens	10	Matsushita	10	Micron	10	Sony

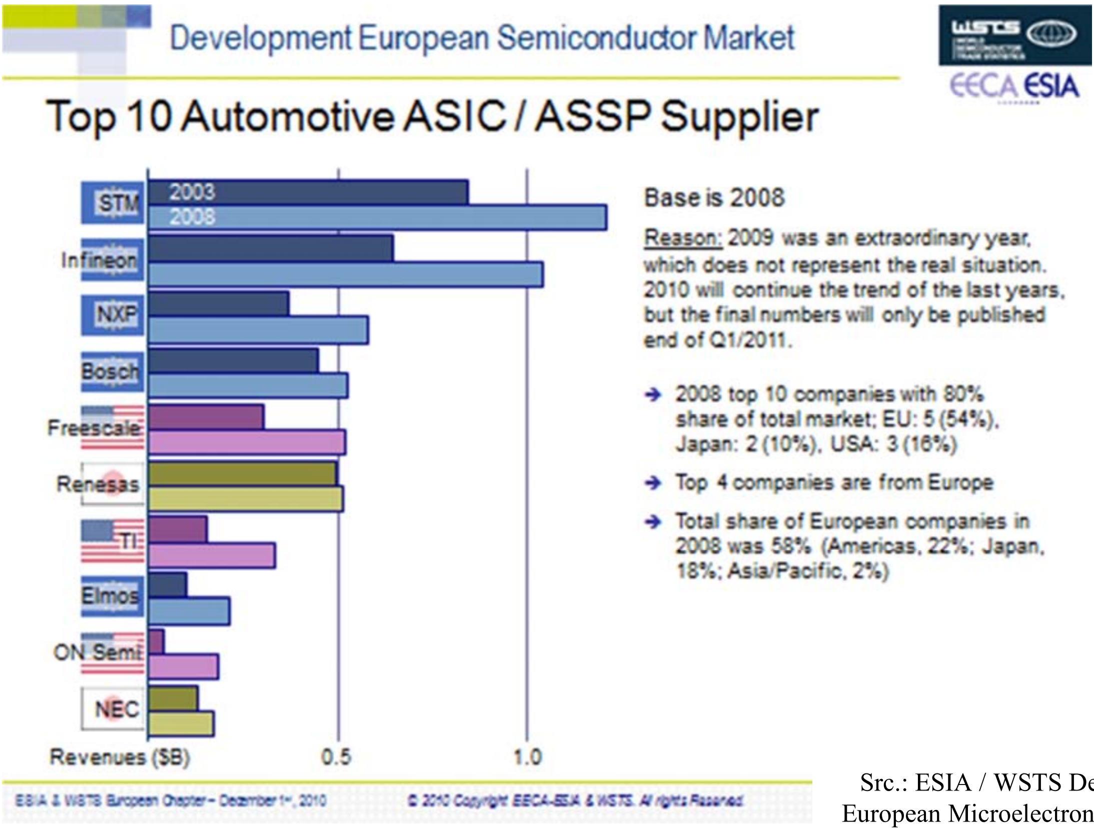
Sources : Future Horizons, Gartner, iSuppli

Important areas with European dominance remain. The following three figures describe just as an example the automotive segment. Other examples exist – see section 2.2.





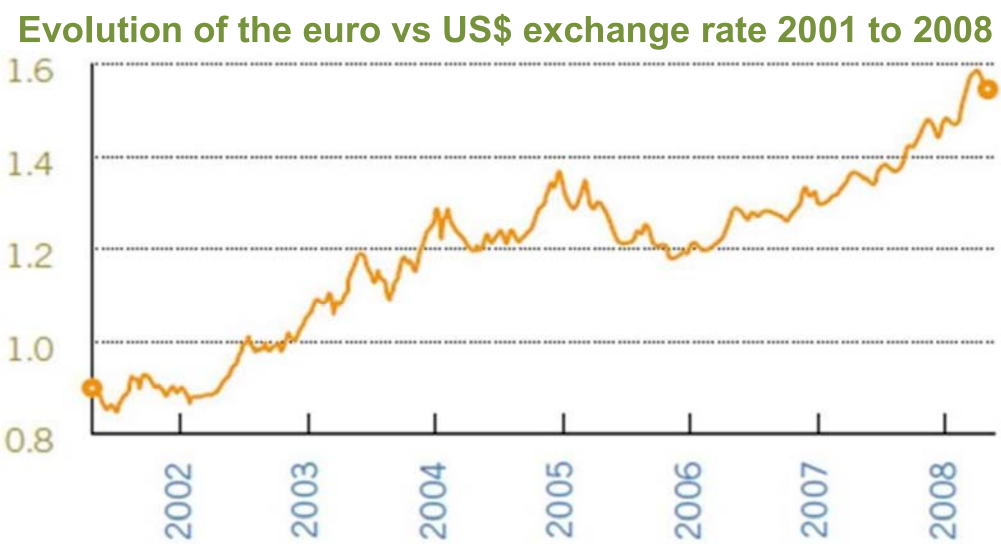
Src.: ESIA / WSTS December 2010 at European Microelectronics Summit, Paris



Src.: ESIA / WSTS December 2010 at European Microelectronics Summit, Paris

But – why is Europe losing ground while having such a good R&D infrastructure, such solid R&D spending and such good positions in selected segments?

One additional European dimension to the issue of exploding R&D costs – as described in section 2.3 – is the fact that revenues for semiconductors are collected in dollars while the researchers and developers are remunerated in euro. The figure below sketches the 50% additional penalty for European investments in R&D or otherwise, compared with its global competition.



src.: ESIA 2008 Competitiveness Report – *Mastering Innovation, Shaping the Future*; p.

Other factors are in the hands of national and regional public authorities. In many regions of the world, there is a dedicated and focused governmental industrial policy which creates attractive conditions for high-tech industries and related R&D institutions; in short, they offer state aid.

The table below compares some state-aid mechanisms in the various regions:

Country	Primary Incentive Type	Potential comparative value of incentive programs for Semiconductor
China	-Tax abatements	**Low/High**- Significant government assistance will general require companies share intellectual property…or being local
Malaysia	-Tax abatements -Cash grants	**Strong** – The Malaysian government can be very aggressive and creative in efforts to win projects deemed of significant value. Long-term tax abatements and potential cash and training grants can be valuable
Singapore	-Tax abatements - Cash grants - Equity/capital investment	**Strong** – Singapore has had tremendous success using its combination of aggressive economic development, strong talent base and significant sovereign wealth fund resources to win major projects
Eastern Germany CEE	-Tax abatements -Cash grants -Loan programmes	**Moderate** – Because cash grants are based on capital expenditures, grant values can be relevant in regions that are eligible to provide structural funding. Many areas of Germany will be phasing out of convergence status
Western Europe	-Cash grants -R&D tax credit	**Low** – Some programmes are available. However, the cash value is usually minimal except to R&D in specific countries
USA	-Refundable tax credits -Training assistance -Property tax abatements if located within Enterprise Zone -State income tax abatement	**Low/Moderate** – Refundable tax credits are similar to cash and generally based on capital investment and job creation. By US standards would be strong, but poor to moderate when compared globally.

Src.: Key enabling technologies (KETs) open day on micro-/nanoelectronics 18.10.10 Brussels. Deloitte Consulting LLP

2.5 Data summary

The relevance of micro- and nanoelectronics as a key enabling technology for nearly all branches of the European high tech industry and for the solutions of today's societal and consumer demands is beyond dispute. In several typical European domains, European semiconductor companies and equipment and material companies are world leading and contribute to the global dominance of the relevant European systems houses.

An important factor for this strength is the effort spent for R&D. But, nevertheless, from a general market perspective, Europe is losing ground and approaching a critical situation. This is due to the fact, that other regions in the world follow a very appropriate industrial policy to strengthen their key enabling technologies.

The identification of nanoelectronics as one of the key enabling technologies for Europe and the installation of its high-level expert group opens the possibility for addressing this unbalanced situation and to propose specific measures above and beyond pure R&D programmes.

To summarise: **Europe needs a strong pan-European approach to R&D and a coherent industrial innovation policy.**

CHAPTER 3: DEFINING A STRATEGY

3.1 Leveraging on the Changing Landscape

The three major indigenous European micro- and nanoelectronics companies are members of technology alliances which develop very advanced More-Moore basic platform processes (see section 2.3); these platforms would be too expensive for individual companies to develop. Being part of such alliances strengthens European innovation capabilities and makes the worldwide lead markets accessible. Indeed, without mastering the basic CMOS platforms, it is considered almost impossible to enter the new avenues of technology – the so called More-than-Moore domain (see section 2.3). The answer is therefore not More Moore *or* More than Moore, but rather More Moore *and* More than Moore developed together comprehensively. In More Moore, the European players create value by differentiation in specific process steps and in product design. In More than Moore, they lead the change, acting on the entire value chain.

Today differentiation in the emerging markets is based on integration of technologies, design capabilities in hardware and software, and the intimate understanding of systems through close co-operation with equipment as well as systems and service providers. These reasons underline the necessity for European R&D actors to continue to invest in micro- and nanoelectronics. **Public-private partnerships (PPPs)** are a concept with a proven track record that reinforces the close co-operation of all stakeholders in the value chain at the European level in a focused and efficient way.

European centres of excellence – Silicon Saxony in Dresden, Minalogic competitiveness cluster (pôle de compétitivité) in Grenoble, the Nijmegen-Eindhoven-Leuven area… – create suitable ecosystems, offer the possibility for new applications to be developed, new SMEs to be started and new patents to be generated, and thus enlarge the positive effect of the silicon industry. They are a major asset for Europe and should be further strengthened, for example through collaborative programmes mobilising their individual competences and by targeting even more ambitious goals at a European level.

Europe has a leading position in several domains including multi-market and industrial applications – such as lighting, robotics, automation and motor control – and chip cards and security, mainly based on More-than-Moore technology. Here, the value of existing cumulative knowledge and skills is extremely high and is exploited through an evolutionary and also revolutionary approach. This will result in market penetration with innovative technologies and products.

To summarise, industry will continue to create substantial differentiation through broad co-operation – including co-opetition: the co-operation between competitors. The European micro- and nanoelectronics industry considers that public-private partnerships are key enablers for this.

3.2 Focusing on the Right Topics (Applications) - Work Areas 1- 5

In domains like security, defence and avionics Europe cannot depend from other regions. Any new development here should be mastered in Europe and in our vision this is embedded on the work area's detailed below. This chapter elaborates on the before mentioned 2 pillar strategy. It defines 2 focus work areas (1-2), where the industry continues to build on its existing position (1st pillar of the strategy) and 3 focus work area's (3-5) where it positions itself at the forefront of emerging markets. (2nd pillar of the strategy). The next chapter will address the technological enablers for these 2 pillars by defining 3 technology work area's (6-8).

1. **Automotive and transport**: Innovation in the car industry is, by and large, based upon micro- and nanoelectronics as is the case in other transport domains such as aviation, railways and shipping. The automotive domain is pivotal for our transportation needs. But aviation, railways, shipping and co-operative transportation solutions are becoming increasingly important. Elements such as sensors, power electronics and embedded multicore processors are key enablers for sustainable and energy-efficient projects. Safety, security and automatic mobility-assistance systems, road pricing and virtual offices are other key innovative solutions that affect our needs for mobility.

2. **Communications and digital lifestyle**: An efficient, omnipresent, green and economic network for communications is an important infrastructural enabler. Wireless is and will remain the buzzword for future communications. Modern and mobile communications as well as broadband tools will be key elements for many new applications – such as medical and the future Internet.

3. **Energy efficiency:** One of the most important and urgent conditions for safeguarding our future is the responsible use of energy resources with a concurrent limitation of worldwide pollution. In the global energy strategy, developing sustainable energy sources and enhancing energy efficiency for energy management and transportation as well as for energy consumption is key. Smart energy solutions – smart buildings, smart appliances, smart systems, smart grid, … – use semiconductor-based technologies such as sensors, communications chips, memory chips, microcontrollers or microprocessors and power-management chips. A huge (multi-)market is emerging in the domains of energy-efficient lighting, energy-efficient houses, remote metering and power control, alternative energy sources and smart, energy-saving motor controls for private and industrial applications.

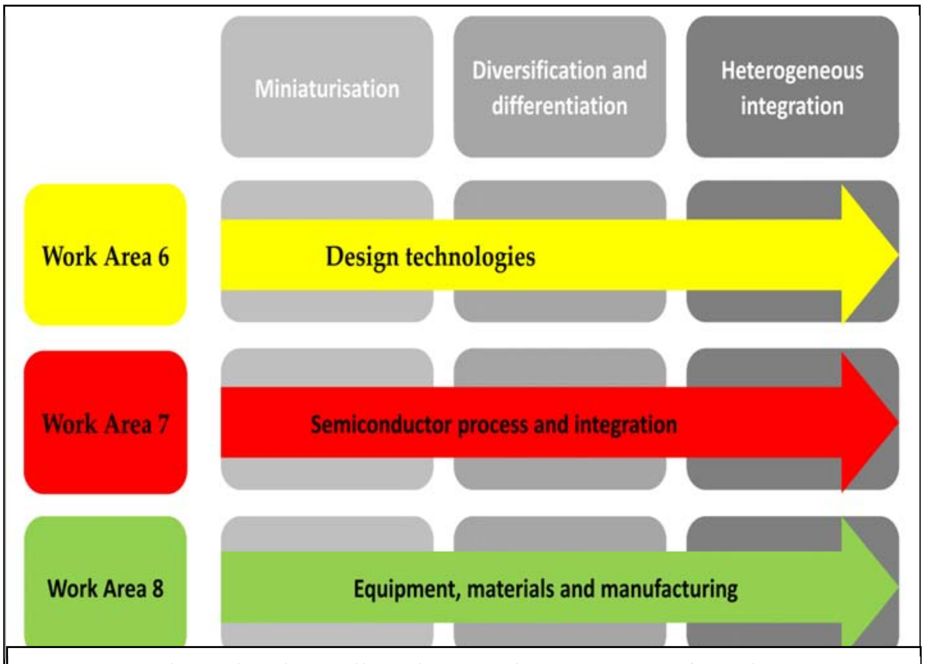
4. **Health and ageing society:** Society is ageing as a result of a declining birth rate and longer life expectancy. This phenomenon causes increased competition for a qualified workforce. It also represents a huge opportunity for the development of entirely new applications and services derived from technological R&D in medical electronics, intelligent drugs, biotronics, measurements and diagnostics, and ambient-assisted living

(AAL). The key challenge is to encourage specialists from varied disciplines to work together and demonstrate the overall financial and social benefits offered by this area – such as remote diagnosis from home versus expensive stays in hospital.

5. **Safety and security:** The increased complexity of European society calls for innovation in the protection of consumers and citizens, information and goods and privacy, and, at the same time, for homeland, energy, complex machinery, trustworthy identification and communications, secure and safe transport of people, data and money. Such innovation must also strive to address the exploding costs associated with safety and security.

3.3 Maintaining and improving Technology Excellence, Work Areas 6-8

The availability of new semiconductor solutions, enabling European key applications, is mostly based on strong and steady progress in three generic technology directions: "miniaturisation", "diversification and differentiation", "heterogeneous integration". These three technology directions are strongly interlinked and interdependent. As schematically shown in the figure below, progress in all three of them is depending on major efforts in R&D and innovation in the working areas: "design technologies", "semiconductor process and integration", "equipment, materials and manufacturing".



Generic technology directions and competence / work areas

In the following, the generic technology directions are described:

a) Miniaturisation, doubling integration density every two years, reducing cost by about 30% a year and power consumption per function is known as More Moore. The More-Moore trend is crucial for digital data processing and storage, using mostly CMOS technologies. It is the prerequisite for new solutions, which require ever-increasing integration, functionality and complexity. This miniaturisation is obtained by reducing the critical dimensions, and by breaking the current physical barriers through the introduction of innovative materials, processes and devices.
b) Diversification and differentiation of the technologies, which allows a richer functionality in the integrated system. This may include new memory concepts where dedicated applications require specific process solutions. Such diversified technologies are required for interfacing with the outside world and managing the energy needs and power consumption of the electronic system – the More-than-Moore technologies. For every technology generation, a greater variety of semiconductor devices and technology options needs to be integrated into the technology platform.
c) Heterogeneous integration of components from different origins and technologies in a single package. This approach allows the integration not only of electronic functions, but also of many more functionalities performing for example mechanical, optical or biochemical tasks.

It is only by combining and mastering these three technology directions that the European nanoelectronics industry can offer competitive systems solutions which address European needs. Depending on the application, the miniaturised and diversified technologies will be integrated as system-on-chip (SoC) devices at the wafer level or in a package – system-in-package (SiP).

Gaining world-class competence and leading position in the three earlier introduced competence / work areas is a prerequisite for reaching the targets. The work areas are shortly described in the following:

6. **Design technologies**: Increasing levels of system integration, involving the combination of complex IP and different technologies in a single chip or package imply the capability to handle complex architectures and require advanced tools, design flows and methodologies. At the same time, deep submicron effects, 3D integration and heterogeneous technologies call for a strong convergence between design – hardware and software – and fabrication technologies to overcome design-process limitations and to improve yield and reliability. Miniaturisation and complexity progress more rapidly than design capability, creating the famous design gap. In addition, the increased weight of early architectural choices, involving also embedded software, on final performances requires new approaches such as higher representation/abstraction levels, tools and methodologies to handle hardware/ software co-design and 3D architectures, and open standards for IP and subsystem integration. Increasing efforts are needed to develop adequate design capabilities, leading to

new design tools and methodologies, improving the 'handshake' between system and chip design.

7. **Semiconductor process and integration**: A strong European R&D programme on advanced CMOS is essential to master and access the latest technologies, ensure manufacturing competitiveness and thus secure further growth in new applications and European lead markets. The guaranteed access to leading-edge More-Moore technology is enabled through alliances as a consequence of the extremely high costs of generic developments for future technology nodes. In addition, a More-Moore manufacturing capacity in Europe is crucial to master these technologies. Such capacity will also help the future European More-than-Moore manufacturing capacity to grow. Differentiated technologies will build upon this generic CMOS excellence. Today's More-Moore fabs capacity will be tomorrow's More-than-Moore capacity. Moreover, heterogeneous processes including photonics and organics will emerge in the following five years. These specific developments needed for differentiating strategies are performed in European platforms and projects. By developing generic expertise in fields such as analogue, mixed signal, RF and smart power, and leveraging its historical strong links between applications, systems and processes, Europe will be in a position to lead in differentiated markets. With the emergence of new approaches – such as 3D – for the heterogeneous integration of diversified technologies, there is a clear opportunity for Europe to develop a SiP supply chain by setting its leadership in the heterogeneous integration of complex systems.

8. **Equipment, materials and manufacturing**: Competences create competitive advantages in the domain of equipment, materials and manufacturing. This is the case for More-Moore as well as for More-than-Moore technologies by breaking the current physical performance barriers with the introduction of innovative materials and process technologies provided by advanced equipment. This sophisticated advanced technology requires the development of specific metrology, characterisation and failure-analysis methodologies, tests and tools. To improve competitiveness in manufacturing, it is necessary to reinforce manufacturing-science excellence. The 450-mm production standard will provide new opportunities for European equipment manufacturers in the medium term.

CHAPTER 4: THE ROLE OF THE INDUSTRY AND THE R&D ACTORS

In the chapters 4 & 5 the "roles" of Industry and Public Authorities are elaborated. It should however be emphasized that the fulfilment of the mission will only be achieved if this is in the first place considered by all stakeholders as a shared responsibility. However, to get focus, the following chapters elaborate specifically the roles of the Industry and the R&D actors and the Public Authorities in their shared responsibility.

If, in the following, the role of European R&D actors is described, this is of course not limited to industry alone, but to all players in the field – including SME and academic research. However, industry shall clearly be in the lead and shall be key element and in the centre of nanoelectronics eco-systems either of local or of cross-border character.

4.1 Role of the Industry

Technological challenges in nanoelectronics are too complex to be solved by any single player in Europe, be it industry or country. The comprehensive R&D efforts needed to resolve these challenges require joining forces across industry and country borders. This has been recognized by European industry and governments already more than 20 years ago, when collaborative R&D projects have been adopted as an effective means to accommodate such R&D. These projects have enabled substantial economic growth in this sector with a rate that was substantially above the average for Europe.

Industry will continue to invest in collaborative nanoelectronics R&D in Europe and would even be ready to invest more than in the past; a clear signal is given by the large number of proposals for collaborative projects. Industry will also continue to invest in innovation and industrialization to capitalize on this R&D. This innovation will address both the supply and the demand side of the European value chain. Investments in collaboration have demonstrated in the past to create substantial leverage and it is the firm belief that such leverage will continue to exist. Through such collaboration the European Industry will continue to demonstrate above average economic growth. Next to growth, this collaboration will continue to provide a fertile breeding ground for SME development, including starters, spin-offs, and spin-ins (=acquisitions).

4.2 Eco-systems around European nanoelectronics R&D actors

The industry takes the responsibility to create and maintain healthy nanoelectronics eco-systems in Europe including other R&D actors in the nanoelectronics domain.
Sometimes, the ecosystem is shaped as a consortium or a loose connection of cooperation between large corporations, SME's, public research institutes and universities. It can be ad-hoc

for specific projects, but in practice, due to cooperation in the past in similar projects, that were supported by public private partnerships, the ecosystem becomes more intertwined and companies and institutes benefit mutually from each other's expertise and from the trust that was created by fruitful cooperation. In particular for SME's such cooperation has proven to be very useful.
Often, however, the ecosystem has a more formal character, either bound by location or by organisation. Famous are the clusters of companies, institutes and public authorities in Grenoble, Dresden and Eindhoven/Leuven, but there exist more examples of such geographically bound excellent co-operations. Quite a few SME's (often not so small anymore!) have been created within this context. Industry commits to continue to support these initiatives. Non-geographical, but organisationally bound clusters can be found in public private partnerships like CATRENE and ENIAC. The initiatives leverage the potential of Europe as whole and their importance for the industry can hardly be overstated. In return Industry guarantees exploitation of the results obtained through these clusters to the benefit of Europe and of the position of the European based R&D actors in the global competition.
Ecosystems and clusters have an R&D scope from very advanced research to product development. They are excellent "tools" to ensure that very advanced results (as obtained mainly by Academia, Research Institutes and Universities) find quickly and efficiently their way towards integration in products and manufacturing methods of members of the same eco-system.

4.3 Role of the R&D actors

In short, the role of the R&D actors is to realise the vision, as formulated in the beginning of this paper:
"The European Micro- and Nano-electronics industry value chain will guarantee the controlled access to Information technology, applications and products for a smart, sustainable and inclusive European 2020 Society."
To realise this, the R&D actors will identify continuously and proactively the research topics that need priority. The words "guarantee" and "controlled" in the vision put a heavy responsibility on the R&D actors.
With the same priority, the R&D actors have to realise their mission:
"The mission of the European Micro- and Nano-electronics industry value chain is to progress and remain at the forefront of state of the art innovation in the further miniaturisation and integration of devices while dramatically increasing their functionalities."
"Remain at the forefront" and "miniaturise while dramatically increase functionality" is clearly a prerequisite for realising the vision. Achieving the vision and mission is only possible by an excellent cooperation throughout Europe between universities, scientific institutes and R&D departments of companies. The additional costs associated with such cooperation are a good investment and need to be spent to fulfil the vision.
The vision and mission statements as cited above demonstrate also the two-fold role and

responsibility of the R&D actors. They need to develop strategies derived from the pan-European societal needs and – at the same time – technology platforms and competences, which enable the respective industrial solutions.

4.3.1 The role of R&D actors in realising the vision

4.3.1.1 About "Guarantee" in the vision statement:

Because the enabling character of the industry, choices for R&D priorities have to be made in very early and uncertain stages, where societal needs are not yet very clear. It is the role of the R&D actors to find the optimum balance between "guarantee" not missing technologies or applications and being cost conscious. R&D actors will fulfil this role by continuous interaction with their stakeholders: customers, shareholders, employees and public authorities. As already stated in the introduction, the R&D actors commit to contribute out of their own resources their share in the costs. They will, whilst interacting with the same stakeholders, also continuously indicate and evaluate "what needs to be done" (and by consequence what risks can be taken) in order to ensure the "guarantee".

4.3.1.2. About "Controlled" in the vision statement

European industry has a responsibility to keep control over critical elements of our high-tech society. This is not only the case for security and military applications, but also for applications in the field of health-care and environment. These are domains, where Europe is actually leading – and this not without reason. Europe is one of the first regions in the world facing a dramatic demographic change and Europe has the highest awareness with respect to climate changes and to energy saving. But, to make sure, that Europe can realise its challenging targets following its own roadmap, it needs the control over the sensitive parts of the respective value chain.

Europe does not have time. It needs to act urgently to safe its environment. It needs to increase the efficiency of its medical staff to respond to the upcoming dramatic changes in its age pyramid. It also wants to influence matters related to safety in conformance with its own cultural values. For these and many more reasons Europe cannot "wait" until technologies developed elsewhere, will over time become available. It needs to create a control point in order to make solutions available on time and at proper conditions. Because of Europe´s outstanding R&D facilities and know-how it can also pave the way towards world-wide solutions that most probably will also fit into extra-European environments. Not only will such a move contribute to Europe's own prosperity; it will also help fixing a couple of global challenges.

. Europe has unique characteristics in very different areas like attitude to privacy, average distance between its population centres, age pyramid and political landscape. In many aspects the complexity of "Europe" is higher than elsewhere. This makes solutions working for Europe probably adaptable to other parts of the world. Also for this reason Europe should take control and show leadership in initiating and steering the needed developments that will enable future societal solutions.

The R&D actors will take leadership and control by initiating the R&D in European PPP's, executing the R&D in vast majority inside Europe and above all having the resulting know-how and applications embedded into the European culture. These elements will guarantee controlled access by Europe to needed technologies.

4.3.2 The role of R&D actors in achieving the mission

4.3.2.1. About "Remain at the forefront" in the mission statement

The experience that Europe has in R&D in nano- and micro-electronics matches, and in most cases surpasses, the R&D capabilities elsewhere. Europe is at the forefront of many technologies, both established (like automotive or communication) and emerging (like medical- or energy-efficiency related research). Europe is therefore in the somewhat luxurious position that it can write in its mission "to remain at the forefront" rather than "to become at the forefront". Nevertheless, the worst thing to do is underestimating the competition. A healthy European industry is a prerequisite for achieving the mission. To "remain at the forefront" cannot be done by Universities and Scientific Institutes alone. Neither can it be done without their contribution. Also here a partnership is the preferred solution.

The "food chain" is rather long in case of Nano- and Micro-Electronics. As a consequence, a plurality of technologies and their applications will be needed to address 2 or 3 different ICT-services or to address a few societal needs. The VMS is the answer of the R&D actors on the question what actions need to be taken with highest priority to "remain at the forefront". The answer, in the form of 25 grand challenges, is not "pick and choose". It is an action-plan that needs to be executed in its totality to achieve the mission. Although the R&D actors will focus in specific time slots on some of the grand challenges, they will at the same time make sure that the total package can be timely executed.

4.3.2.2. About "Dramatically increase functionality" in the mission statement

From a shareholders perspective there exists a need for continuous miniaturization with simultaneous increase of functionality. This is also a need from the customer perspective. Perhaps even more important, this combination determines the dynamics of the industry as a whole. Looking backwards, it is an achievement of the industry since its existence. Looking forwards, the options, which become imaginable when extrapolating the trend of miniaturisation and increasing functionality, are mind boggling. They are one of the most important reasons for the attractiveness of the industry and in particular the R&D for young people. The promise to continue on this track is the very reason for the strategic importance of the industry. This promise is the "adrenaline" for the R&D actors in the field.

4.3.3 Additional tasks on innovation infrastructure

One of the key priorities of Europe 2020 is to develop an economy based on knowledge and innovation. European R&D actors need to construct and implement in shared responsibility with Public Authorities a concerted view on how to close the gap between academic research and industry through a European Nanoelectronics Infrastructure for Innovation. The objective is to get a better structure for the European R&D activities in specific and focused technological domains from which innovation can emerge and to serve advanced applications, which are strategically important for Europe[14].

4.3.4 Summary of the role of the R&D actors

The industry will continue to invest in average 15-20% of its turnover in R&D. Thus it will create global leadership through growth and this holds especially for SME's. Cooperation in Europe between Industry, Universities and Scientific Institutes will be intensified. This powerful combination of investment and cooperation is a guarantee for Europe for access to the technologies and applications that it will need and meeting the grand challenges will be the insurance that Europe will stay at the forefront of the strategic miniaturization with dramatic increase of functionality of systems and devices. Investment and cooperation will therefore consolidate and expand the top ranking positions, which European Industries occupy in many segments.

[14] Emerging initiatives are under consideration at the time of writing of this document

Chapter 5: PUBLIC AUTHORITIES' ROLE

The challenges are complex and need to be addressed by all actors, including public authorities. Such activity should not be limited to financial support aiming at restoring a level playing field for European actors but also includes political, regulatory and standardisation actions which mainly focus on setting priorities and creating frameworks. This support includes:

5.1 Fixing Global Priorities for Europe

Since its origin, the semiconductor industry has been considered a guarantee for sovereignty by major economic forces and has benefited from intense political support worldwide. Defence applications and the space race were the main drivers when the semiconductor industry first took form in the early 1950s. Later, when professional and consumer applications became dominant, public commitment and industrial policy continued to determine the competitive position and attractiveness of the various players or countries. The economic environments – including fiscal incentives – structure the semiconductor industrial landscape. Asia has demonstrated a strong political commitment to its domestic industry by massively supporting new investment and research programmes as well as by elaborating a long-term industrial strategic plan and policy.

The EU Europe 2020 strategy recognises that mastering smart growth requires improvement in the quality of our education system, strengthening our research performance and promoting innovation and knowledge transfer throughout the EU. Innovative ideas from the laboratories can be swiftly turned into new products and services that create added value as well as industrial jobs by making full use of ICT. "*Agreeing on thematic priorities of the Europe 2020 strategy and calling on all parties and stakeholders to help implement the strategy, working in partnership by taking action in areas within their responsibility*" is considered to be a key element for success.

It is very important for a competitive Europe to conclude rapid and firm agreements jointly between the EU and Member States on priority segments where the convergence of the micro- and nanoelectronics technology capabilities with emerging societal needs is able to generate high value-added market opportunities. (= 2nd pillar of the strategy) These opportunities can be fully exploited at the dimension of the European market while even creating new opportunities for global leadership in some of these new markets.

5.2 Providing the Right Framework Conditions

The micro- and nanoelectronics industry functions in a globalised sector and must choose the localisation of its activities to be able continuously to improve competitiveness and performance.
It is the responsibility of the public authorities to establish an industrial policy that creates the best environment and framework conditions to maintain and develop a strong and competitive industrial base in Europe.

The Europe 2020 strategy proposal combines different instruments including smart regulation, modernised public procurement, competition rules and standards setting, affordable access to finance, promotion of internationalisation – especially for SMEs – and improved conditions for enforcing IP rights as well as a reduction in the administrative burden on companies and improvement of the quality of business and labour legislation.

This is reinforced by the European Semiconductor Industry Association (ESIA) 2008 Competitiveness Report (see chapter 2): "*Europe should revise its industrial policy, using the complete set of political tools (as done by many countries, including the newly developed Asian ones), considering also the regulations and provision aimed to facilitate access to capital and to generous incentives in order to restore better parity to competitive chances on a global level playing field*".

A set of regulatory and legislative supervisory measures is required to shape the future. These should aim to limit disadvantageous currency distortions, create a labour policy that anticipates and manages change better, and contribute to the removal of roadblocks surrounding the introduction of new technologies and systems in the environmental health and safety arena. The measures must leverage the public R&D funding potential that exists in Europe, help maintain and renew Europe-based manufacturing capabilities and encourage the role played by education as the foundation of intellectual innovation capital and of a solid science base.

5.3 Supporting the Creation of Lead Markets

Apart from manufacturing equipment and material, Europe has consistently lost share of the worldwide semiconductor market even though semiconductors continue to be the key enablers for nearly all high-tech innovations. To reverse this trend, it is imperative to focus on and develop further areas where Europe has recognised strengths, as well as new market opportunities.

This can be achieved through:

- **The extension of current markets where electronics opportunities are steadily expanding and improving in existing application areas**. Examples of European excellence and leadership are mainly found in the domains of:
  - *Automotive*, with ever-growing electronic content linked to emissions reduction, lower energy consumption using hybrid and electrical power trains, safety and security, zero defect quality, comfort, telematics and infotainment; and also
  - *Communications*, which represents 40% of the total ICT market where fixed and mobile broadband networks are evolving towards higher speeds, together with the emergence of direct and intelligent communications between different appliances, systems and man-machine interfaces in local and residential networks.

- **Venturing into new application areas** where increased use of electronics is about to create new market segments – such as energy efficiency, health and ageing society, and safety and security – and where the convergence of technology capabilities with emerging needs can generate high added value and market growth. Further development of revolutionary products and services is also expected in automotive, transport and communications.

Especially in the second case, there is a very good opportunity for a win-win situation in the partnership of public and private efforts. Responses to identified socio-economic challenges require a very significant degree of innovation which is first and foremost based on solutions enabled by micro- and nanoelectronics devices. Micro- and nanoelectronics represent 20% of the cost of electronics systems but assure close to 100% of their performance, which translates into unprecedented functionality at an affordable cost.

EU and Member States public authorities can trigger and support such developments by proactively establishing regulatory frameworks that set standardised targets for the industry that focus on achieving appropriate solutions in specific critical areas, supported by stimulus packages to accelerate the development and diffusion of required innovative technologies and products within a defined time horizon.

5.4 Managing Human Capital

Europe should boost its prosperity by making better use of its most precious resources – its people. Much of the intellectual property embedded in future European products will be the result of partnerships between education, business and government agencies. Motivation, commitment, dedication and readiness for hard work are important qualities that allow business to improve continuously its innovation capacity and productivity.

Therefore, Europe should strengthen its position through specifically-initiated programmes for education to provide a solid science base for future generations of researchers and engineers. Europe should further facilitate the mobility of highly-skilled experts in science and technology (S&T) disciplines by increasing the attractiveness of Europe for high potential individuals and creating an open innovation environment.

5.5 Ensuring adequate infrastructure

In addition, European governments should sustain the creation of new and the improvement of existing research infrastructures such as science parks, incubators and venture partnering to support the creation of new, high-tech SMEs.

CHAPTER 6: THE RATIONALE FOR PUBLIC-PRIVATE PARTNERSHIPS

The micro- and nanoelectronics value chain has specific characteristics which justify an approach differing from more traditional industry segments and the need for public-private partnerships.

6.1 Enabling role and systematic relevance

Micro- and nanoelectronics are pervasive and constitute the engine for innovation in many areas. Those nations and regions mastering these technologies will be at the forefront in managing the shift to a low-carbon, knowledge-based economy which is a precondition for ensuring the welfare, prosperity and security of its citizens. Europe must safeguard its capability to design and produce products following its own standards of high quality, sustainability and environment friendliness.

Key enabling technologies, such as micro- and nanoelectronics, are knowledge intensive and associated with high R&D intensity, rapid innovation cycles, high capital expenditure and highly-skilled employment. They create process, product and service innovation throughout the economy and are of systemic relevance. They are multi-disciplinary, cutting across many technology areas with a trend towards convergence and integration. Fields such as micro- and nanoelectronics and photonics therefore require immediate policy actions given the position of the European industry in global competition.

6.2 Growth

Although there is some decline in the rate of growth, the micro- and nanoelectronics industry is still very much a growth segment with a growth rate considerably above the European GDP average. Moreover the micro- and nanoelectronics industry is the enabler of some 10% of the total GDP of Europe. Public-private partnerships are the recipe for addressing the grand challenges of R&D in this industry as areas of priority. Because the strategy behind these partnerships is based on both industrial and societal needs, its projects will propel the industry segment in the right commercial direction. As such, public-private partnerships contribute to the realisation of economic growth in general.

6.3 Collaboration

Europe must ensure that the research can be executed here to maintain high added-value skills and jobs. This requires a shift from the linear model where research results were transferred from universities to institutes and industry, into a model where research is carried out in partnership, deeply embedded in the industrial web supporting the knowledge ecosystems.

Such collaborative research must produce sufficient critical mass to allow for sharing of costs associated with the access to expensive state-of-the-art infrastructures.
Collaborative research will also support the European industry and its researchers in acting globally as global co-operation between the different research actors is becoming an increasingly important prerequisite for success.

Technological challenges are manifold. As technologies shrink in the nano domain, research is becoming increasingly multi-disciplinary. Bringing European competences together is essential for future progress. The growing complexity to overcome technological roadblocks requires increased human effort and expensive infrastructure. The mobilisation of all resources and worldwide co-operation is required to realise important milestones. It is also expected that traditional miniaturisation will reach its limits within 15 to 20 years.
Activities have to be started to prepare for going beyond the traditional scaling of devices. Segments of R&D will have to focus on improving the efficiency of production. The capabilities to design new products are lagging behind technological progress. The European research fabric will need to redirect itself to grasp better technological opportunities such as architecture, platform design and software, and will need to invest more in applied research. This requires a fundamental shift from single science, technology thinking into multi-disciplinary system thinking.

6.4 SME creation (spin in, spin out, embedding in ecosystem)

Fostering co-operation will also encourage the inclusion and creation of SMEs in the most demanding and promising fields. Such co-operation will expand the size of the ecosystem and make it more attractive to all participants, thereby effectively and significantly increasing the threshold to move to locations outside the ecosystem. The continuous spin-in and spin-out of small and medium-sized companies to larger ones make the ecosystem even more attractive. Notably, the creation of highly-competitive SMEs is often the consequence of research results from universities and the sharing of know-how and facilities within an ecosystem or region.
Similarly, the presence of large industries in a region or ecosystem often depends on SME suppliers. The customer-supplier intimacy within the ecosystem greatly contributes to the stability of the industrial activity in a region. A focus on SMEs in public-private partnerships will therefore also be beneficial for universities and large companies.

6.5 Risk compensation

Public-private partnerships ask the industrial partners to take some financial risks to prioritise results that are desirable from a societal point of view. Among others, the partnership has a role in lowering barriers and making these risks more acceptable from a shareholder point of view.

6.6 Continuity of knowledge infrastructure

The semiconductor industry, its suppliers and customers operate in a highly cyclical economic environment. In times of economic downturn, public-private partnerships help to guarantee the continuity of a knowledge infrastructure and ensure fast recovery.

CHAPTER 7: IMPLEMENTATION

7.1 Key Steps to Achieve Expected Results

7.1.1 Opportunities to increase the effectiveness of projects development

To maintain a high speed and achieve competitive costs, industry must avoid the multiplication of tasks. Working together in precompetitive areas – horizontal projects – is the best way to accelerate studies and optimise solutions.

Gathering the most experienced organisations, with their expertise and market knowledge, within co-operative projects provides the consortia with the best view of market needs in terms of functionality, user interface, performance, cost/price and the technologies needed for the solutions. Such co-operation secures results and ensures that these will be the most advanced and the first available on the market for all essential innovative/added-value parts in the value chain – vertical projects.

Projects can contain risks for several reasons such as betting on a standard, determining when the market is ready, assuring the stability of consortium partners and technical uncertainties. But the evaluation of risks and priority settings is far more efficient within multi-experienced-partner-based projects. Such evaluation reinforces the efficiency of the analysis of proposals benefitting from – or depending on – legislation, strong standardisation or governmental strategic purchasing/procurement.

7.1.2 Building consortia for co-operative work

Building a strong consortium of R&D organisations – large and small companies, research institutes, universities and the resources that these organisations provide – is the basis for successful and innovative projects. Public-private partnership projects are well adapted to this as proven in the EU Framework Programme (FP) and the EUREKA Clusters.

The criteria for a good co-operative project include: clear content/scope, well-articulated state of the art versus grade of innovation in terms of goals and targets, complete market evaluation with open exploitation and dissemination, a high level of involved skills and completeness of the consortium with a detailed work plan and organisation. Experience shows that the quality of project management is key to maximising efficient co-operation and adapting to a market that can change over the lifespan of a project.

7.1.3 Complementary approaches

Content can be structured in two ways:

1. The top-down approach derive its actions, applications and technologies based on societal needs and the political priorities of a country or a region such as Europe; and

2. The bottom-up approach starts from technology roadmaps, products or markets and then selects the lead applications to develop the required technologies, platforms and prototypes.

Both approaches are necessary and complementary to cope efficiently with market and societal needs within the focuses set by the public authorities. The top-down approach requires a longer commitment from the stakeholders to remain focused even if market developments do not reach expectations. The bottom-up approach needs more flexibility in adapting the projects to the needs of the market and competition in the short term. Both approaches need to be organised in programmes that have a planning horizon and managed through institutions that can help the consortia through a set of directives, procedures and tools and also by organising evaluations, monitoring of projects and an efficient reporting system towards the different stakeholders.

7.2 Making It Happen

Co-operative projects performed within European funding programmes have to demonstrate their quality and have to be allocated to the adequate funding scheme. The tools for making the right selection are the evaluation and delineation criteria.

7.2.1 Assessment criteria

The volatility of the field and the medium-term uncertainty of technological evolution and of market developments require a multi-annual strategy which offers a sufficiently broad range of options to be explored. This, together with the demand for a focused approach, sets assessment-criteria constraints for projects supporting the strategy defined.

In addition to technological soundness and proper project management, the following criteria will be applied:

- Contribution to economic growth in Europe in line with the Lisbon policy;
- Addressing societal needs and the associated grand challenges;
- Stimulating the creation of industrial standards;
- Creation of healthy ecosystems – including SMEs and start-ups; and
- Promotion of university-industry interactions.

Here we are emphasising large projects, preferably combining enabling-technology topics with those from lead applications. The total ecosystem value will be leveraged by involving all the players in the product and knowledge supply chain.

7.2.2 Delineation principles[15]

The strategy outlined in this document for European R&D in micro- and nanoelectronics that can be supported by the different funding instruments, each having its specific strengths in offering the best possible co-operation schemes. Delineation is a pragmatic approach to help industry and public authorities in deciding which instrument is best suited for supporting specific projects and policies. Consequently, such delineation will ensure that proposers make the right choice at the beginning of a project development and submission process.

Delineation will not prevent effective links between themes in both ENIAC and CATRENE, when appropriate. A limited overlap can also be desirable for flexibility.

Content:
The two programmes on nanoelectronics aim at strengthening the competitiveness of Europe and its industry, and at offering innovative solutions for Europe at large.

It is agreed that:
- ENIAC JU should address mostly applications and socio-economic challenges of pan-European interest; while
- CATRENE should address mostly technologies and challenges involving a smaller number of Members States and/or partners.

Synergy between the two schemes is required to strengthen the value chains in Europe.

Role:
ENIAC JU must follow a top-down approach, where projects have to fit within a predefined annual work programme (AWP). This AWP should reflect priorities at the European level to the benefit of a large number of European countries.

CATRENE will continue to follow a bottom-up approach, with projects in which the number of countries involved is limited, and where specific and dedicated national support and funding schemes are often necessary.

Type of projects:
ENIAC JU projects should be of global interest to Europe and to most European countries. These projects should mostly be dedicated to addressing key socio-economic challenges for Europe. They should have a medium-to-long-term vision. In principle, they should seek support from a

15 The delineation principles described here have been created by a working group set up by the CATRENE Public Authority Directors during their meeting in Noordwijk in November 2009. They have subsequently been communicated to the CATRENE and AENEAS support groups in January 2010.

large number of countries, working together in a common approach and towards a common goal, to solve these challenges and to define a unified European approach. For the definition of the key topics of innovation, it is vital to bear in mind the complete value chain which ranges from technology developments to commercially-successful products. Examples of such topics could be: hybrid and electric cars, energy efficiency and healthcare.

CATRENE projects are more focused with limited partnerships and should mostly deal with key technological breakthroughs. These projects normally have a short-to-medium-term objective. Some very large projects of great industrial importance to a limited number of countries have clearly their place in CATRENE. The objective must be to maintain corresponding knowledge about technologies and design techniques in Europe with the aim of paving the way for the envisaged application solutions. Examples of such projects are in the area of “silicon process and integration”, related “equipment, materials and manufacturing” and “advanced CMOS”.

More details on the delineation according to the sub-programmes of ENIAC and work areas of CATRENE are shown in the annex[16].

Implications of delineation:
Both instruments need to have a clear role in supporting the overall nanoelectronics vision/ strategy. Both instruments have different characteristics and have, therefore, to be used to the best of their possibilities. This is the aim of this proposal. The delineation and prioritisation of strategic goals between ENIAC JU and CATRENE will be more effective if all the stakeholders involved actively support the underlying principles.

16 This annex is available with the document, but not reproduced here.

Part C: Work Area Chapters

CHAPTER 1: AUTOMOTIVE AND TRANSPORT

1.1 Introduction

The intention of the following chapter for Automotive & Transport is to introduce and to describe three grand challenges in Research and Development for the next five years.
The current view on the Grand Challenges in Automotive & Transport is:

Grand Challenge 1 - 'Intelligent Electric Vehicle',
Grand Challenge 2 - 'Safety in Traffic',
Grand Challenge 3 - 'Co-operative Traffic Management'.

These three Grand Challenges should broaden the horizon from the focus on the 'pure' electric vehicle towards a more holistic view on future sustainable traffic solutions in Automotive, Railway, Aviation and Shipping.
The Grand Challenges cover the most urgent Research and Development priorities in the field of Automotive and Transport which could be significantly driven by innovations in the European micro- and nanoelectronics industry. The focus on e-mobility will persist.

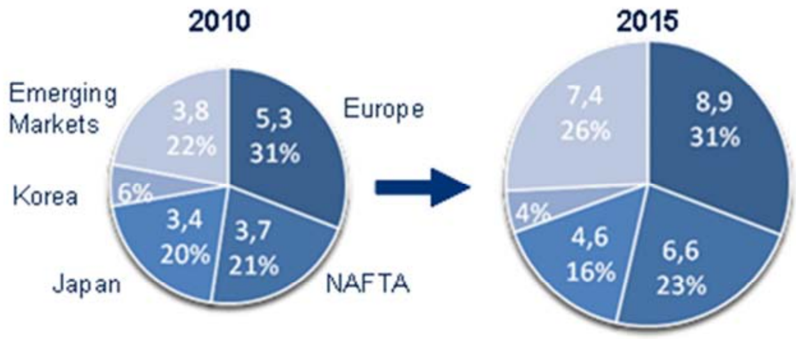
1.2 Relevance for Europe

1.2.1 Competitive Value

The EU is not only the home of 15 international car manufacturers producing around 20 million vehicles a year but is also home of the world leading automotive electronic semiconductor and system suppliers. The value of 2009 automotive semiconductor revenues billed in Europe reached €4.5 billions[17]. The European automotive semiconductor suppliers represent more than 30% of the world market.

---

[17] STRATEGYANALYTICS, April2010

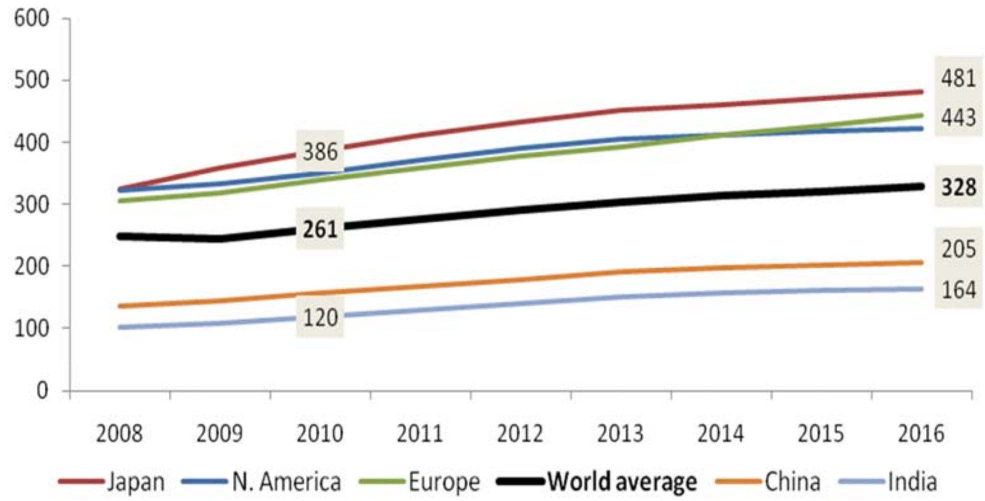


Source: Strategy Analytics, June 2010

Figure: Automotive semiconductor market 2010, forecast 2015 by regions (USD bn)

Electronic components have reached 20% (of which Microelectronics is 44 %) of the car value, and the figure is growing to about 25% (Microelectronics even growing faster to 55%) in the next five years. In total Automotive components represented 20% of European electronic component market in 2009[18], with a stable growth rate of approximately 3.5%.

Vehicles in Europe with a conventional power train are currently fitted in average with semiconductors worth around 250 €. In hybrid and electric vehicles, this figure will increase to 750 €.



Source: Strategy Analytics, June 2010

Figure: Average Semiconductor Value (in USD) per car in selected Regions

18 EECA ESIA , June 2010

To enable electric vehicles to make the transition from a niche product to the main-stream, two things must happen: a massive reduction in cost and the creation of an intelligent power distribution infrastructure – a smart grid and nanoelectronics will be a key innovator in the field of electric mobility.
Nanoelectronics will also give an essential contribution to the integration of all other modes of transport (air, rail and waterways) that are projected to form the largest part of freight transport and to contribute significantly to passenger traffic in year 2020.
Finally the innovation in micro- and nanoelectronic should lead to standardization initiatives and de-facto standards. Examples are *ASIL* for safety, *Flexray* for communication and *AUTOSAR* for a standardized modular SW-stack in Automotive.

1.2.2 Societal Benefits

Mobility is not merely the visible expression but particularly the source of our economic and societal prosperity in Europe.

It serves key roles in the transportation of people and goods in a local, regional, national, European and international context. On the other side it is a major cause of energy consumption and casualties. In Europe, road transportation alone accounts for 21% of fossil fuel consumption, and 60% of all oil.
There are 5 deadly accidents every hour, and road accidents are the main cause of death in the under-45 age group. It becomes obvious that the ambitious target to cut into halves the number of traffic deaths in Europe between 2001 and 2010 could not be reached. Consequently, this means the improvement of road safety by electronic-based driver-assistant systems remains as high priority target.
The addressed enabling technologies aim at a radical reduction of both the overall emissions and primary energy use. An integrated approach that links all modes of transport (air, rail, road and waterway), is essential for ensuring that sustainable and competitive transport solutions make a visible and positive difference for Europe, its citizens and its industry.
In an aging society, the number of senior citizens is continuously growing. Assistive systems, driver monitoring and alerting can be leveraged to mitigate cognitive shortcomings due to age-caused disabilities. Such systems will increase security for all road users, and at the same time extend the mobility and self-determined independence of the elderly.
Mobility and safety are clear societal needs for the future intelligent road.

E-mobility based on electric vehicles will be the key element to make it possible to maintain individual mobility.

1.3 Grand Challenges

1.3.1 Grand Challenge 1 'Intelligent Electric Vehicle'

Description:

Grand Challenge 1 'Intelligent Electric Vehicle' should be considered as the refinement of the previous Grand Challenge 'Full Electric Vehicle'. The Intelligent Electric Vehicle should be embedded in complex traffic management and logistic systems and should cover all available electric drive concepts especially the full electric drive but also hybrid technologies (e.g. parallel hybrid, plug-in hybrid, serial hybrid, and range-extender).

High Priority Research Areas:

- overall concepts for EVs covering cruising range, energy management, reliability and safety enabled by nanoelectronics
- energy efficient power electronics for the electric drive train (new voltage classes)
- electronics to control advanced storage technologies (innovative battery cells, hybrid batteries, fuel cell)
- introduction of multi-core technology for real-time control
- heterogeneous system integration inclusive thermal management
- advanced reliability research (e.g. EMC)

The identified areas request fundamental research on semiconductor technology, device level and assembly/packaging technology.

Competitive Situation:

At present European companies are at market position 1 in conventional cars and position 3 in electric cars. In Automotive, Europe has three players in the top five: *ST*, *NXP* and *Infineon*. There is a realistic potential to become number 1 also for electric vehicles, especially in integrated e-mobility systems (vehicle and infrastructure integration for (H)EV). Full market penetration will stabilise employment and has potential to even increase it.
The full electric vehicle will create an estimated world-wide market in the multi-billion Euro range. For 2015, it could be around 50 Billion Euros , and in 2020 around 100 Billion Euros.
Recent market trends show a fast introduction of e-bikes and e-cycles in order to get fast on the e-mobility learning curve and to pave the way for mass introduction of e-cars.

Expected Achievements / Innovation Foreseen:

The well-known economic and ecologic reasons will push the introduction of the full electric vehicle. A significant CO_2 emission reduction from today >120g/km to around 45g/km is expected, proving that electric energy is generated from low carbon resources.
Nanoelectronics based solutions will be expected for a significant progress in the fields of energy efficiency, reliability and lifetime at reasonable costs.

Therefore innovative application systems are expected like:

- interconnection systems for secure connection of the electric vehicle to the grid for remote identification, diagnostics, charging and metering,
- intelligent on-board traffic management and navigation in order to achieve maximum efficiency and driving range,
- innovative advanced driver assistance systems.

This should be accomplished by new innovative components (sensors, multi-cores,…), system-in-package technologies and design and verification methodologies.

1.3.2 Grand Challenge 2 'Safety in Traffic'

Description:

The Grand Challenge 2 'Safety in Traffic' should cover the different layers from vehicle up to complete management systems in terms of safety.
The importance of improved safety inside and outside the vehicles and in complex traffic infrastructures is self-explanatory. The public and legislative demand for safer cars and safety in traffic is increasing. Safety in vehicles will become a key condition for market penetration. The same holds for security if networking increases. In urban traffic especially, 50 % of the fatal accidents shall be avoided.
The estimated global market for the safety in traffic challenge is the total vehicle market and the complex traffic infrastructure like traffic management systems, vehicle-2-vehicle, vehicle-2-X, logistic systems etc.

High Priority Research Areas:

- innovative active safety systems
- reliability and safety from component (e.g. sensor) up to complex traffic safety management systems
- reliability and safety in operation and control and communication

- initiation of European standardisation for deployed technologies, safe communication protocols, certification and test
- European introduction of automatic emergency calls (e-call)

Competitive situation:
Especially in the European countries, the automotive industry plays a central role for the internal market as well as for export. Concerning conventional vehicles and the safety of vehicles, European companies are currently in a clear leading position. In addition to this, there is also a very strong aeronautic industry (*Airbus*) and railway industry. The success of Europe in these transportation domains is strongly dependent on the latest technology – especially for improving energy efficiency, safety and comfort.
If Europe safeguards its good market position by including innovative and effective safety features, many jobs in the automotive industry will be conserved.

Expected Achievements / Innovation Foreseen:
New innovative traffic safety management concepts and systems with a holistic view on all kind of transportations are expected as well as new active safety and driver assistant system in electric vehicles driven by safe components like sensors, actuators and multi-core processors. The expected progress in the overall safety system will strongly support the European target of decreasing fatal accidents by 50%.

1.3.3 Grand Challenge 3 'Co-operative Traffic Management'

Description:
The Grand Challenge 3 'Co-operative Traffic Management' should be considered as multi-modal and also covering trustworthy communication systems. This grand challenge aims to introduce at a higher level efficiency, prediction and reliability in traffic and transportation by using data from different sources as GSM, UMTS, GPS, WLAN, DSRC, navigation systems, vehicle-to-vehicle communication and others. Distributed sensor networks, communicating through RF and broadband info-busses have to be analysed according to their deployment in Automotive & Transport. Appropriate multi-access / multi standard gateways for seamless interaction with other domains have to be developed. Of particular interest will be the standardisation across Europe of interfaces between components from different suppliers.

High Priority Research Areas:
- intelligent traffic flow management covering efficient use of energy resources and time
- real-time-traffic-information by using the cars as moving sensors
- appropriate multi-access/ multi standard communication gateways
- intelligent high performance data processing
- intelligent electronics for security and privacy protection

- concepts and introduction of pro-active communication (e.g. for e-cars: accidents, road blocks, dangerous situations, availability of charging stations, active route planning)

Competitive Situation:
The European industry is in a clear leadership position in terms of complex embedded systems. New standards for electronic vehicle architecture (AUTOSAR), communication (V2VC) and co-operative traffic management concepts (e.g. EU projects Safespot, CVIS, Coopers) have been developed. This is leading to a holistic approach on Intelligent Traffic Systems for improved safety, for vehicles and vulnerable road users, efficient traffic flow and low energy consumption (incl. EV and grid management).
The strong position of the European industry in nanoelectronics and embedded technology will be a major enabler for the breakthrough of this technology.
The implementation of multiple bus systems and distributed ECUs war driven by European OEMs, such as CAN, LIN, Flexray and MOST. Future requirements will lead to partial networking (distributed intelligence and stand-by of transceivers and processors). These car networks will interact with the environment in the future.

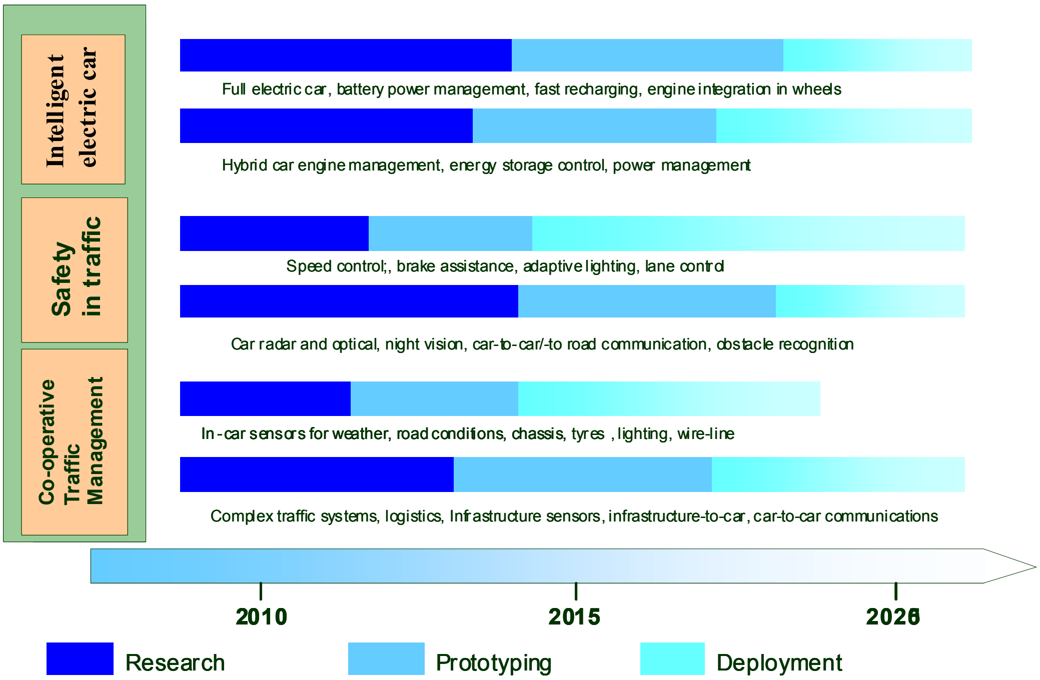
Expected Achievements / Innovation Foreseen:
New innovative concepts and prototypes of co-operative traffic management interacting with systems in other application domains like Internet or logistics are expected. Such systems will strongly support the improvement of the efficiency of the traffic by reducing traffic jams, reducing average time needed for public transport and multi-modal goods transport. Extending the car network to the road community will offer new features. Intelligent traffic management systems, automatic emergency calls and road tax systems for all vehicles will require safe, interactive telematic modules, which will become part of the automotive architecture, including smart driver interfaces. These innovations will set the ground for saving time, energy and CO2 emissions due to traffic jams and road congestions, while saving additional lives.

1.4 Conditions for Success

ENIAC/Catrene will be capable of achieving the ambition because they develop a focussed and strategic approach, which combines competencies sourced across Europe for all R&D topics concerned. A limitative factor will be of course the available R&D budget. The total development effort (drive, battery, integration, energy management) needed for the next decade will be 2 to 5 Billion Euros per year, of which around half a Billion will be "real R&D".
Another aspect is that the effort for preparation and administration of projects should be well balanced with the research work itself.

1.5 Timeframes

The general approach is that research topics should be transferred into product development within a 5 year timeframe.



1.6 Synergies With Other Domains

The general ubiquitous expectation of our modern information and communication society is to take advantage of all existing services regardless where we are – in the office, at home or on the way.

This strong request leads on the one hand to the multi-domain deployment of various applications, basic technologies, methodologies, architectures and on the other hand to new cross-domain applications. Seamless connectivity and interoperability becomes more and more important.

This should be supported by cross-domain use of *Design Technologies, Semiconductor process and integration and Communications.*

In contrast to other domains *Automotive & Transport* is characterised by its harsh real-time environment and very limited energy resources available for applications. To meet these requirements robust technologies and domain-specific implementations of the same functionality are requested.

Another specific characteristic of *Automotive & Transport* is the different significance of non-functional aspects like *Safety and Security* or *Energy Efficiency* in comparison to other application domains.
The challenge for nanoelectronics is to develop solutions with almost no degradation in performance and comfort.

CHAPTER 2: COMMUNICATION & DIGITAL LIFESTYLES

2.1 Introduction

The changes in telecommunications and digital lifestyles were driven in the last decades by the market (deregulation, globalisation, and privatisation); change today is driven by usage thanks to the opportunities offered by the technology and endless innovation. The ubiquitous access to all types of media, data, audio or video is becoming a reality. **In the pursuit of ideal communication, and associated multimedia services, the key evolution which is going to dominate is the continuation path towards convergence between fixed and mobile networks and impacting device features as well.** This will have a strong impact on making system definition and development extremely complex as more conflicting parameters have to be very carefully managed, making trade off much more difficult than ever. The connectivity and the number of new devices, on top of standard PCs, now accessing Internet with a wireless link also brings another dimension in complexity. **Driven by the progresses in microelectronics these dynamic changes towards a broadband ubiquitous society will offer new services and create new market opportunities for the benefits of individuals, enterprises and governments**. Broadband benefits society and economy enhancing efficiency, productivity, and sustainability as well as social and personal life.

2.2 Relevance for Europe

2.2.1 Competitive Value

Communication and digital lifestyles are crucial basis for the development of personal efficiency and are the foundations of economic development and growth. The digitalization of all aspects of communication combined with new technologies of transmission, especially in the context of Internet, have made possible the emergence of broadband services, offering the possibility to access all applications regardless of devices or services. The advent of LTE and LTE-A will accelerate this trend furthermore. The convergence of telecommunications and entertainment electronics unifies features in television and mobile phones.

With the strong position of Europe today in communications the European R&D actors will reinforce this position to guarantee European competitiveness and ensure the industry based on nanotechnology, and all the value chain relying on it, will remain a substantial source of value and employment.
In the entertainment domain Asian companies, mostly in China, with strong industrialisation capacities, and with low labour costs are managing the assembly of a large part of the related equipments at a price that is not possible to reach inside the European Union. But most of the value remains in the hand of ICs manufacturers and European manufacturers still have a leading position. European R&D actors are willing to keep this leading position, through the development of innovative new equipments and applications allowing them to get an easy access to a whole new range of features, applications and knowledge.
To keep ground in this industry, Europe has to continue to play a key role in the definition and application of standards. In fact Public funding helped developing standards that are now widely used such as, for example, MPEG-2; DVB-T/S/C; H264, GSM, HSPA, 3G etc … These standards and the associated patents are still bringing European companies important revenues through the licensing and the development of ICs or IP blocks.

2.2.2 Societal Benefits

The emergence of new challenges such as global warming, energy saving, aging population, will require more and more nanotechnologies and adapted communications solutions and services to address these issues most efficiently. The strong need for "Machine to Machine" communication (M2M), user interface as well as the "Internet of Things" ranging from actuators, sensors to controllers makes broadband communications and nanotechnologies the main key technology assets to master to address a variety of applications ranging from health and lifestyle, automotive, smart building and connected home.

2.3 Grand Challenges

In the context of convergence and in order to address all the technical issues in the most efficient way, the R&D activities will be organized around Four Grand Challenges with a long range planning effort and close cooperation along the whole value chain. The objective is to spur development of innovative and cost effective technologies enabling designing and manufacturing in high volume silicon systems solutions for the communication and digital life style market. The Four Grand Challenges are namely: INTERNET MULTIMEDIA SERVICES, EVOLUTION TO A USER DIGITAL LIFESTYLE, SELF ORGANIZING NETWORK and SHORT RANGE CONVERGENCE.

2.3.1 Grand Challenge 1: "Internet Multimedia Services"

Vision:

Towards the convergence of application devices and networks , the Internet Multimedia Services challenge aims at developing innovative silicon solutions offering the possibility to manage in the most effective way the amount of data requested by the implementation of broadband services.

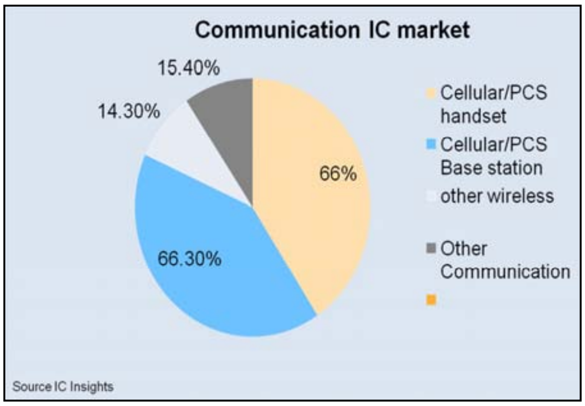
Description:

The convergence scenario of consumer, computer and communication electronic systems drives an exponential growth of code and data in all electronic systems. At high level "convergent" electronic system performances are measured in term of bandwidth, in order to speed up Internet connection, and in term of reduction of the power consumption, in order to enhance the portable use. Power reduction also has a strong impact on consumer-grade devices (STB, tablets…) because of new power usage standards and cost aspect. The continuous introduction of new multimedia formats impact the processing capabilities because of the decoding / encoding requirements (access to any content requires spatial and temporal transcoding). Ease of use also has a strong impact on the processing capabilities and memory requirements, as "making it simple" for the user is not at all simple on the design side.

Competitive Situation:

Worldwide Communication MKT by product type ($B) 2007-2013 (Fcst)		
Logic	27.8	42.5
Analog	11.6	13.2
Memory	10	16.9
Micro	7.2	5.2
TOT	56.5	77.9

After dropping 12% in 2009; IC insights forecasts that the Telecommunication market will register a 9% growth in 2010 to reach $370 billion. For the period 2009-2013 we should register a CAGR of 8%. This market includes cellular mobile phones, cordless telephones, cellular base station equipment and switching equipment (BS&SE), pagers and two way radios. Other communications systems include wireline systems. The figure shows that cellular phones will be the largest market for communication ICs. Growth for the IC communication market should continue well beyond 2010 to reach a total of $77,9 billion. The former n°1 is *Qualcomm* (US); the other major suppliers are *Samsung*, *ST-Ericsson*, *Texas Instruments*, *Mediatek*, *Broadcom*, *Infineon*, *Renesas* and *Numonyx*.



As part of the telecommunications market, the global silicon photonics market is expected to reach $1,950 million in 2014 from $10 million in 2007 with a CAGR of 105.3% from 2009 to 2014. In 2008, the wavelength division multiplex filters contributed $7 million or 30.4% to the global silicon photonics market. Photo detector is the second-highest market and it contributed 21.3% and then comes optical interconnect with 18% and optical modulators with 17%. In 2014, due to the high growth rate in telecommunications and sensing markets most of the silicon photonics products are expected to attain full integration and commercialization. The key players in the silicon photonics market are in Europe: *Alcatel-Lucent*, *STMicroelectronics* and *Innolume* and in the US: *Luxtera*, *Hewlett-Packard*, *IBM*, *Intel* and *Infinera*. (Source: MarketsandMarkets).

Expected Achievements/Innovation Foreseen:

- *System Memories*

The memory system design has to support the increasing requirements in terms of bandwidth and power consumption reduction, and to that respect non volatility solid state is the best way for reducing power consumption. Multimedia and Data Storage integration require to secure European leadership and competitiveness also in the memory-field both from architectural and technology point of view. Memory Systems will have to offer the bandwidth needs of the final device, cache structures and the use of different memory technologies being the forecasted solutions. Due to the limit reached in the scalability model which was up to now the driving solution to achieve more powerful and less expensive memory systems; in the next decade it will become impossible to continue to shrink actual NVM Flash. **New memory technologies are needed like PCM (Phase Change Memories), which will offer further scalability, low cost per bit, and improved performance.**

Since critical computing applications are becoming more data-centric than compute-centric high-performance, high-density, and low-cost NVM technology with access time much lower than hard Disk Drives and close to the order of magnitude of DRAM Memories are indentified to offer the memory system solution for the new computing applications.
So the challenge for solid-state memory technology is also to meet the demand of future storage server systems, modifying actual storage-memory hierarchy.

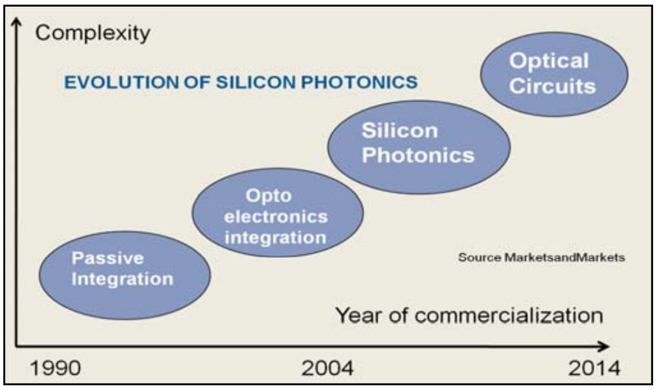
- *Implementing New Computing Approach*

Multimedia broadband services are moving from pure voice connection to audio, video imaging and graphic. In particular video content for real time or streaming applications are growing fast with more and more demand for higher quality driven by HDTV. The challenge is to develop advanced video compression techniques optimising the amount of bandwidth. The emergence of HDMI output for a mobile device brings as well new features and new problems to address as it connects it to a TV set. This has the side effect of introducing in a mobile device some issues existing only in the digital TV domain like user interfaces on a wide screen. The support of new HD format in the device brings very complex problems related to processing power as the amount of data to process is dramatically increasing **leading to solutions integrating more and more processors cores** making the programming tasks even more challenging than ever.
To make the situation even more complex, the new solution will have to manage efficiently a big part of the software legacy already existing in order to have silicon systems solutions compatible with aggressive time to market constraints. The integration of very heterogeneous blocks of IP makes interconnection issues very critical as it has a strong impact on viability and

performance of a solution. Today due to the size of the chips it is clear that integration can happen only in connecting asynchronously synchronous islands. In such conditions the **solutions like NoC** (Network on Chip) are very important.

- ***Photonics, At The Heart Of High Speed Broadband Services***

The enormous performance of today's communication network is based to a large extent on optical communication technologies which allow for highest bit rates in it's backbone and increasingly as well in it's fine ramifications of the access network connecting the residential areas.



The ever-growing demand for higher traffic in the communication network involves higher bit rates in future WDM optical transport backbone surpassing bit rates of 100 Gbit/s per optical channel. Electronic circuits dealing with such high data rates will be highly sophisticated designs based on most advanced Silicon On Insulator (SOI) CMOS or even high performing SiGe BICMOS technologies. Circuits intended for usage in the passive optical (access) network (PON) will face lower speed performance requirements ranging up to several Gbit/s in PON, but face extremely challenging low cost targets. Similar requirements hold for optical backhaul systems solutions for base stations in wireless access network. The conflicting needs for performance increasing and reduction of energy dissipation are demanding for high efficient system solutions. As a consequence **future high performing systems will increasingly be based on photonic system concepts, which promise a significant higher performance at reduced energy budget.**

Integrated optics and CMOS circuits, based on Silicon On Insulator (SOI) wafer technology is going to become the new process mainstream opening the road for a pervasive high speed communication at low cost and low power: such a process technology is well known as "Silicon Photonics". The possibility to merge, on the same substrate and package, optics with the most advanced CMOS / BiCMOS offers a unique possibility to miniaturize the today high speed applications by reducing cost and power by a scaling factor of two decades with respect to the interconnections based on copper. In fact it is now possible to envisage solutions where electrical interconnect can be replaced by very high-speed link on silicon. Such technologies are already emerging in server markets for die-to-die connection but will soon be a mandatory solution in SoC on SiP. Such a very high bandwidth link will have an important impact on architecture and system partitioning and for sure will become a gating factor to new high end multimedia system in the future.

The Silicon Photonic can therefore be seen as a disruptive process technology that will remove the bottlenecks in high-speed intensive computing, data communication, telecom and high-end storage applications.

2.3.2 Grand Challenge 2: "Evolution To A Digital Life Style"

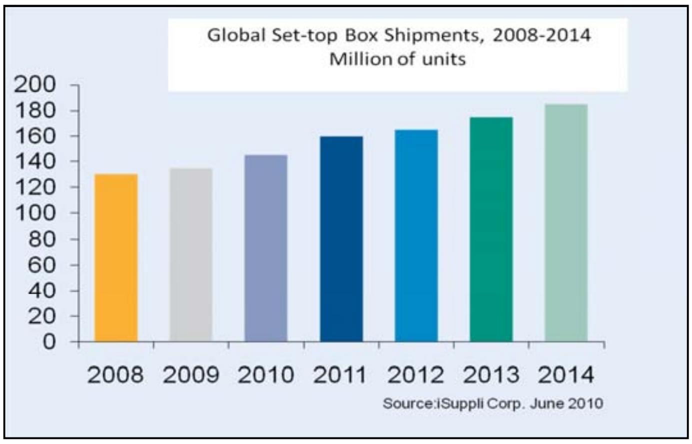
Vision:

The new "Digital TV User lifestyles" aims to bring an easy, ubiquitous and fun access to media, information and knowledge to European Citizens.

Description:

Consumer Electronics devices are becoming more and more complex. The number of features they embed is growing exponentially. The large number of possible interfaces to the outside world, the new applications and the list of standards they have to support are adding to this usage complexity. **Keeping complex devices easy to use is very challenging but it has a strong societal impact**. This must help less-technological friendly European Citizens accessing to the digital world and to the associated knowledge. The "lamda" user wants to have an easy and seamless access to these advanced features. The consumer must be able to move its screen/tablet/TV without noticing the way the content is transmitted. The switching from a digital wired network to a wireless link should be transparent for the user with an efficient management of the associated bandwidth constraints. The easy access to the contents leads to an increase of data exchange and data computing that must accomplish with latency in line with the user expectations.

Competitive Situation:



The consumer electronics market continues to move from the analog to the digital world offering the possibility to connect the home to a large range of multimedia services. Towards a digital connected home, the set-top box is playing a central role in offering multimedia services and despite the economical environment, this market driven by the demand in emerging regions, is showing solid strength. The total shipment should be in the range of 180 Million Units in 2014, representing large opportunities for the semiconductors industry including audio/video processor, memories, demodulator and tuner ICs. *Pace*, *Motorola* and *Technicolor* are the top three set-top box suppliers. As far as the digital market is concerned, IC Insights forecasts the market for DTV semiconductors will reach $8.25 billion in 2010. Chip revenue for DTVs is expected to increase from $7.25 billion in 2009 to $13.0 billion in 2013, representing an average annual growth rate of 16%.

Expected Achievements/Innovation Foreseen:

New Video Sources and Content Management:

The next 5 years will see the deployment of the 3DTV, the emergence of the Ultra High Definition, the generation of new content with immersive video in which virtual content and reality are merged together. The management of all these new content and video formats, on various devices (TV, set top box, mobile phone, tablet), represents a real technical new challenge.

Ubiquitous Access to The Content

This means, "access to my content anywhere, anytime, on any device". The user is not interested in format transcoding, content rights protection or bandwidth issues; he/she only wants to watch/listen to his/her content. As a consequence there will be a need for high bandwidth multiple entertainment streams that have both the DRM content and the individuals' privacy protected. Also fast video search engine to search a video sequence in a huge video data bank will be needed.

2.3.3 Grand Challenge 3: "Self Organizing Network"

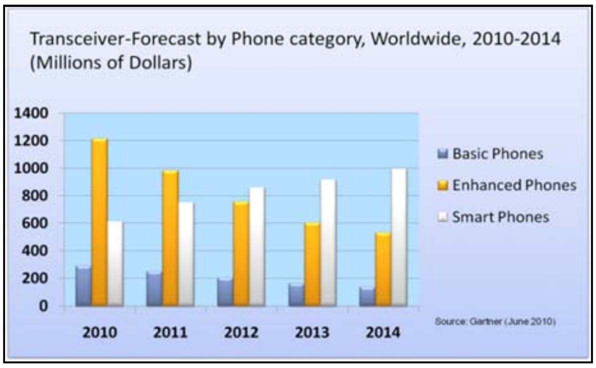
Vision:

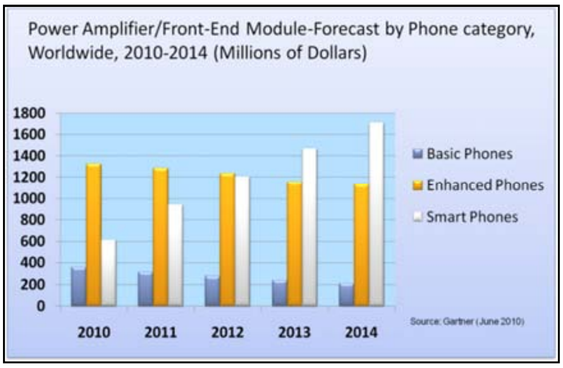
"self organizing network" aims to introduce new flexible and energy efficiency design architectures able to support multi-band and multi-mode cognitive applications.

Description:

In the past 10 years the wireless connectivity has really exploded as devices are now connected to a large number of systems and networks that were previously separate. Different technical worlds are going to merge and this will apply to fixed and mobile networks, for public and for private networks, for telecom and information technology. In this converging world, the main driving factors are the mobility, continuity/quality of service. The data exchanged Convergence requires that connectivity links, targeted originally for fixed or pedestrian terminals (WiFi standard 802.11 a/b/g), can be extended to mobility, (introduction of mobility in WiFi standard e.g. 802.11p). The associated increased demand for data traffic is driving the need for high data rate, high spectral efficient and low power consumption. Latest Connectivity technology is moving toward the exploitation of new spectrum region, in the range of mmWave (i.e. across 60GHz, actual WiFi systems being in the range of 2.4 or 5 GHz), as recently addressed by the standard IEEE 802.11ad or other consortia (Multi-Gigabits Wireless system, …).

Competitive situation:





The rapidly growing broad band communications market and the development of advanced RF CMOS and Si/SiGe technologies are driving the development of new generations of transceivers and Power amplifiers requested by the cellular phone market. The enclosed figures show that the total both markets are estimated at $ 2.7 Billion in 2014.Power amplifiers and transceivers are expected to perform very differently during the forecast period. Power amplifiers are benefiting from the transition from 2/2.5G to 3G/3.5G and the move to multimode baseband processors, and are expected to grow at a CAGR of 8.5% from 2009 to 2014. The transceiver market is expected to decline over the forecast period with a projected CAGR of -6.4%. After transitioning from separate transmitters and receivers into integrated transceivers, transceivers are increasingly being integrated into the baseband processor system-on-chip (SoC) for low-end and midrange mobile phones.

Expected achievements/Innovation foreseen:

Towards the convergence of fixed and mobile networks, the first k**ey challenge is to develop RF components capable to handle 2GHz bandwidth** (today WiFi RFs have to handle up to 200 MHz if compatible with 802.11 n Standard) that could be allocated to each single link. Further consolidated trend is the adoption of Multiple Antennas Transmitting and Receiving (MIMO = Multiple Inputs Multiple Outputs) with the aim of increasing robustness and or throughput of the link such as recently addressed by IEEE W-LAN 802.11n. Due to the number of interfaces to integrate in a low volume device, the RF problem is becoming a real headache in mobile systems. The increasing data throughput linked to multimedia and Internet browsing is making the situation even worst. New solutions are absolutely needed. Fully flexible Tx/Rx chain with regard to protocol, modulation and spectrum and highly programmable Rx/Tx chain have to be developed. Agile radios are very important, as it is a way to manage diversity in term of radio interfaces while maximizing hardware and software resources. Agile radio solutions while being able to monitor the radio spectrum utilisation will adapt dynamically the transmitted data rate according to the available radio resources and will offer the best usage of the spectrum. The complete system knowhow (agile radio solution associated with specific algorithms and protocols) s then crucial, as it is a way to sense the environment and to optimize the quality of service parameters in a crowdie RF spectrum. **The convergence scenario of consumer, computer and communication systems requires more communication protocols to be**

supported by a single device, with more multimedia operations executed in embedded processors, more security checks should be offered, etc. The paradox is that in order to cope with a green policy, the required power dissipation for operating these devices represent the most challenging design constraints and will require the best in technological solutions (Deep architecture analysis with focus on ultra low power solutions, best in low power technologies, most advanced power management solutions, 3D packaging…)

2.3.4 Grand Challenge 4: "Short-range convergence"

Vision:
The ubiquity of mobile devices and the deployment of wireless network open large scope for innovation. The aim of "short range convergence" is to develop new class of energy efficient single-chip system able to sense, communicate, reason and actuate.

Description:
Recent advancement in wireless communications and electronics has enabled the development of low-cost low-power, multi-functional sensor nodes that communicating over a short distance. Tiny sensor nodes, consisting of sensing, data processing, and communicating components, carry this out. Sensors are to detect sense information, and to recognize signs expressed by human and to monitor environments. For example, biometric information sensor monitors body temperature, pulse, perspiration, and detects emergency. On top of wireless sensors**,** M2M is said to grow fast. This is actually a sector where the knowledge of the application field is essential to succeed, allowing the creation of many different niches and business opportunities. In other hand, in a **mobile terminal,** the Near Field Communication (**NFC**) and Radio Frequency Identification (**RFID**) capabilities **are boosting the applications that the can perform**. The intuitive nature of the NFC enabled mobile phone is prone to a large acceptance in the public, for all ages in particular. The small distance between the tag and the RFID reader is allowing some confidentiality. The SIM is adding the security for the commercial transaction. The potential applications are endless: Transportation (Navigo on the phone), Travel (Ticketing, Car and Hotel room reservation), and Dependant people (services to for drug prescription).

Competitive situation:
Global shipments of short-range wireless ICs (Bluetooth, NFC, UWB, 802.15.4, Wi-Fi) **are expected to surpass two billion units this year**, increasing approximately 20 percent compared to 2009. Shipments are forecast to total five billion in 2014, according to new market data from ABI Research. In fact, driven by the development of smart autonomous wireless sensors and "Machine to Machine" communication, radio devices are increasingly in demand for short range wireless applications like building application, home systems, and industrial control, medical and commercial transaction.

Expected achievements/Innovation foreseen:
All these applications have a specific profile but all face common challenges when it comes to a large deployment and acceptance.
For all these applications, **a paradigm shift is needed in energy management domain**. Further research is needed for ultra low power analogue interfaces and radios as well as the digital part and harvesting energy from the environment should substantially enhance the autonomy of the systems to reduce the battery requirement. The second area to consider is linked to the necessity to increase the functionality of sensors nodes and their **capability to work in harsh environment** and with limited energy resources. Low complexity and real time algorithm have to be developed to improve the performances of smart autonomous systems and new network protocols need to be developed and implemented to operate in specific harsh environment like car or industrial with the best efficiency in order to save energy requirement. This also means that sensor network protocols and algorithms must possess self-organizing capabilities Therefore, the design of the sensor network is influenced by many factors, including fault tolerance, scalability, production costs, operating environment, sensor network topology, hardware constraints, and power consumption. Other important aspects are higher data rates with the networks and between the base station/routers as well as connectivity with the public network, the Internet

2.4 Conditions for Success

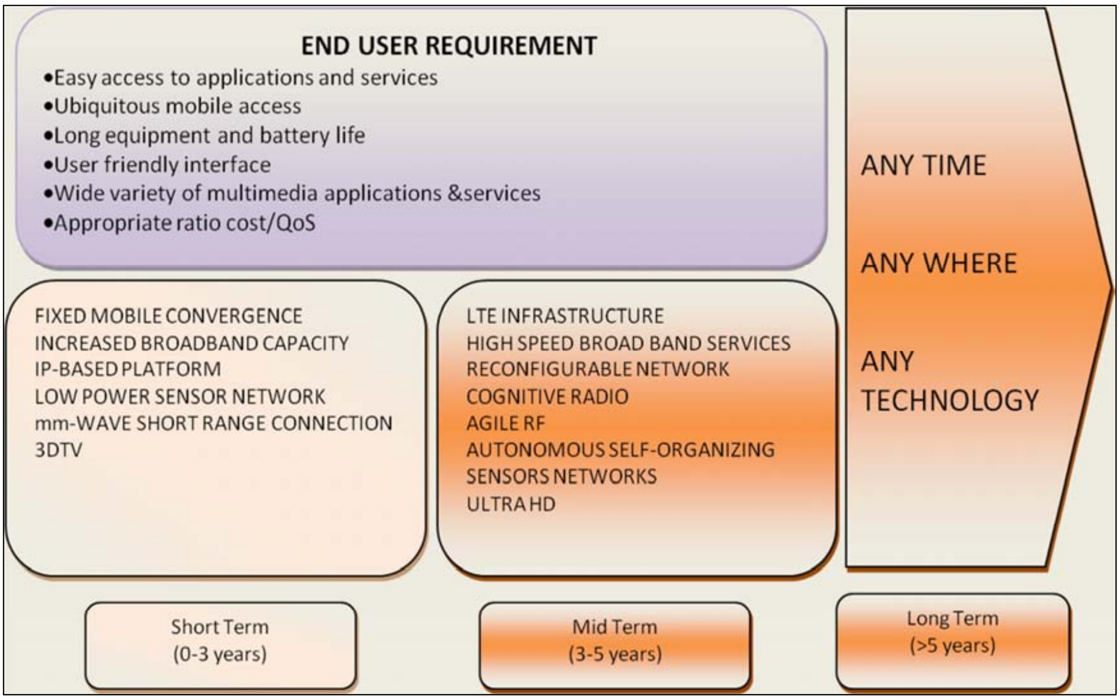
The convergence scenario of consumer, computer and communication electronic systems requires an exponential growth of code and data in all electronic systems. In this context, the progress in digital CMOS, (logic & memories) technology will be a key determinant of success, but the traditional Moore's law based integration increased will be only a part of the solution to a complex problem. Because of power consumption, flexibility, size and cost, the next generations of communication electronics systems will require new technologies and architectures that combine adaptability and performances in a novel way. To tackle these new challenges, a specific attention has to be paid on CMOS ultra low power, CMOS compatible 3D processes, thin film technologies, (SOI, Thin FET…) RF and Analog mixed signal and memories technologies as well as silicon photonics. The trend is to support multi standard with increasing frequencies and higher efficiencies. The need of high gain /high Frequencies transistors able to operate in the 50 GHz to 100 GHz range coupled with a suite of high quality passive devices (capacitors, Inductances, antennas) for the same frequency range is an unavoidable. These challenges will not be efficiently addressed by only one type of technology (i.e. CMOS only). Whenever the need for high-emitted power, low noise, and high efficiency is needed, Bicmos Technologies will have to be developed purposely. The never-ending demand of new integrated functions should also be helped by the development of the 3D integration allowing stacking several chips in the same package. The availability of this capability will for example enable to stack function-dedicated chips for the realization of systems in package. One of the trends in mobile is the multistandard compliancy, which means multistandard Rx-Tx chain capability. The solution will be Rx-Tx integration up to the antenna to maintain low cost while offering the

high number of standard compliancy. Technologies based on SOI enabling high RF isolation Switches capabilities while enabling good analog devices integration with digital should be developed to serve such type of demand.
The other key determinant of success is the memory chips. This is true for cell phone handsets, broadband devices, and networking. In the past memory technology was associated to a specific market segment (Computer & DRAM, mobile communications & Flash NOR, Consumer DSC & Flash NAND). Now memory systems include stacks with different Non Volatile and X-RAM memories (often with μController to facilitate interfacing and managing of the overall memory) in order to fit the need of "convergent" application - wise electronic systems.

The memory system, with his implications in terms of densities, technology performance, packaging and interfacing, becomes more and more of interest in order to improve the overall electronic system performance.

2.5 Timeframes

The advent of a ubiquitous network society will be made possible with the convergence between fixed and wireless networks. This requires continuous progress on communication and nanoelectronics technologies. The roadmap proposes a guideline regarding the major technological steps to be achieved in the chase of ideal communication offering the possibility to access to all applications regardless of device and network.



2.6

Synergies with Other Domains

The synergies with the other chapters are as follows:

- Low Power and RF design can find synergies with design technologies and specific cooperation with the semiconductors process integration domain.
- Heterogeneous 3D integration requested to perform the next generation of cellular phone and sensors networks will be an issue at design technologies level as well at process level.
- Silicon photonics solutions are requesting specific silicon technology improvement and have to be developed in strong relation with the semiconductor process domain.
- "Self organizing network" and "short range convergence" will be essential for "Health and aging" as well as "Energy efficiency" projects.
- "Internet Multimedia services" will be also an issue for "Automotive and Transport" projects, especially in the light of car to car communication.

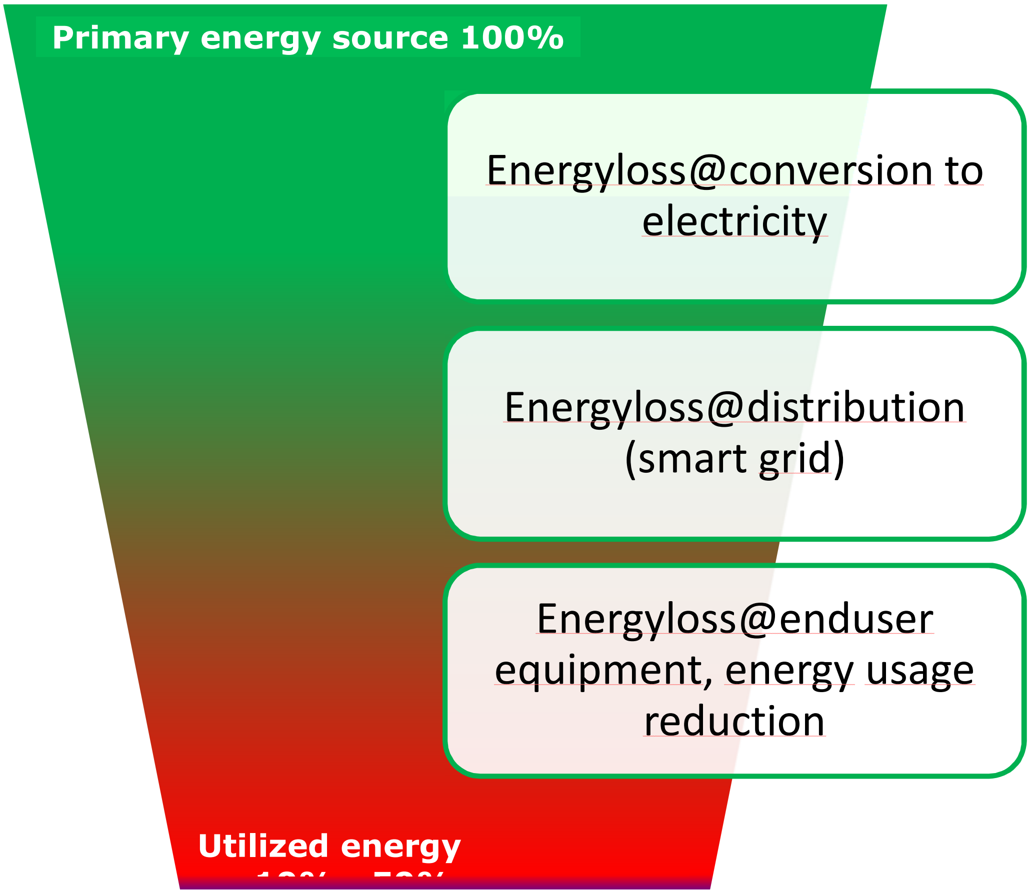
CHAPTER 3: ENERGY EFFICIENCY

3.1 Introduction

One of the most important and urgent conditions for safeguarding our future is the responsible use of energy resources with a concurrent limitation of worldwide pollution. In the global energy strategy, developing sustainable energy sources and enhancing energy efficiency are the key foci. Currently, global primary energy usage is characterized by a moderate growth of energy consumption with a relative large growth in the use of renewable energy sources. However, today's renewable energy sources account for only ~10% of worldwide energy consumption. For improved energy efficiency, it is clear that most energy is converted into electricity where semiconductor-enabled technologies are necessary for providing solutions to the most critical energy-saving issues.

Energy solutions that are described as "smart" – smart buildings, smart appliances, smart systems, Smart Grid – make use of semiconductor-based technologies (e.g., sensors to monitor one or more parameters including temperature, activity, speed or voltage; communication chips to receive and transmit data; memory chips to store information; microcontrollers or microprocessors to process data; and power management chips to analyse consumption and control energy distribution). Smart grid technologies also enable a more cost-effective deployment of decentralized yet cleaner renewable energy resources such as solar panels and wind turbines, which are also enabled by semiconductors. Smart grids may also enable plug-in hybrid cars to augment cruising distance, and provide battery storage units for European electricity generation systems.

By focusing on micro- and nanoelectronics approaches, efficient power supply and intelligent energy control in new products can reduce electrical energy consumption in Europe by 20% to 30% by 2020 with a concomitant increase of functionality and convenience while safeguarding the energy supply. This will reduce CO_2 emission by an order of magnitude that is compatible with the Kyoto protocol targets and will limit the energy cost increase.



Energy efficiency research is needed in all three grand challenges

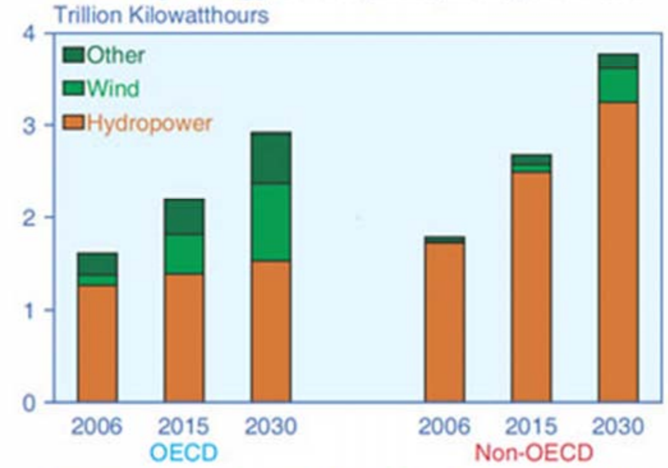


Figure 7. World Renewable Electricity Generation by Energy Source, 2006, 2015, and 2030

Sources: **2006:** Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

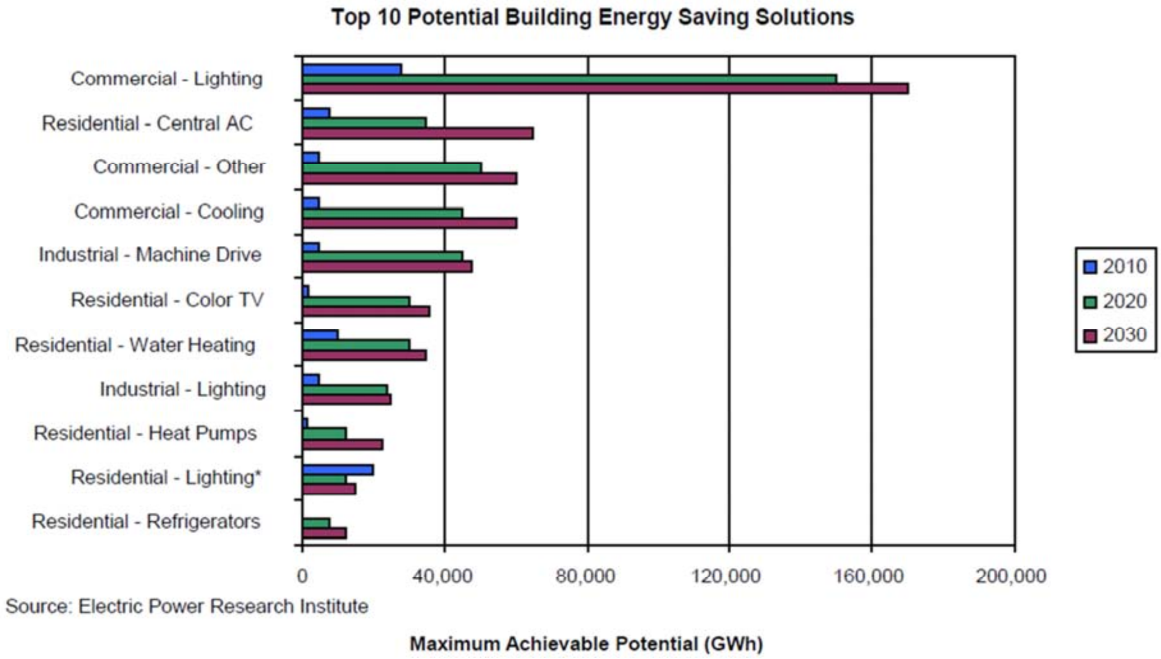
3.2 Relevance for Europe

3.2.1 Competitive value

Increasing from 3.1 million GWh in 2003, Europe will need electrical energy of about 3.6 million GWh in 2020 according to a 2009 study by the IEA (International Energy Association). In the last several years, it has become apparent that semiconductor-based innovative technologies have enabled the savings of more electrical energy than the growth of demand in the same period. In addition to the on-going implementation of renewable energy sources like solar, wind or hydropower, 0.7 million GWh can be saved by 2020 with the use of intelligent and innovative electronic components and systems. This will significantly support the energy policy and industrial competitiveness in Europe. A few examples for the energy saving potential in different applications are:

- Lighting - potential savings > **20%** (excl. replacement of incandescent bulbs)
- Drive System - potential savings ~ **20%**
- Power Supply - potential savings ~ **20%**

The global market for power semiconductors is in the range of 10–15 B€/year, not including controls nor the replacement market for breakthrough technology for power-saving equipment. Market penetration is supported by legislation (elimination of incandescent lighting, limitation of standby power consumption in consumer products) as well as the consumer demand for reduced-CO_2 products. In most of these topics (industrial, lighting, control and management of energy), Europe has a #1 position and the number of jobs being created in these domains is increasing. It is therefore critical to support these efforts and build upon existing strengths of the European economy. To reach new levels in energy efficiency, outstanding technical excellence will be needed based on increased R&D efforts of multi-disciplinary, multi-company, multi-national and multi-application types.



Realistic achievable energy savings potential by end-user

3.2.2 Societal Benefits

Energy efficiency has multiple impacts on European society, affecting all domains (private, industry and public), and the efficient use of energy is indeed the political, social and technical challenge of the next decade. The primary goal is to protect natural resources and the environment in Europe in a sustainable manner. A clear target is the reduction of CO_2-emission by preventing energy waste by carelessness and by the use of obsolete equipment. Focusing on micro-/ nanoelectronics approaches in particular, the challenge to reduce electrical energy consumption in Europe must be met if the 20% to 30% reduction in energy consumption by 2020 will be achieved.

The European microelectronic research and development sector must therefore provide innovative technologies and associated ICT solutions as a basis for new energy efficient products and intelligent power management solutions. A back-bone for intelligent power management is – besides the local improvements – the implementation of the “Smart energy-grid”. The value of a Smart Grid cannot be overestimated: As electricity networks are amongst the most critical infrastructures in our countries, the Smart Grid will help countries remain autonomous by guaranteeing continuous access to electrical energy while reducing the dependence on fossil energy sources. Last but not least, energy will stay affordable for everyone. Through consequent and combined efforts at European level there is a historical opportunity to extend the technological leadership of the European industry in this field and to strengthen its competitiveness. This will also have an enormous impact on high-qualification jobs in Europe.

3.3 Grand Challenges

A consequent strategy for reduction of energy loss and for most efficient use of energy must define actions along the whole energy cycle (generation, transport and consumption). Therefore, the "Grand Challenges" for Energy Efficiency have been identified as described below.

3.3.1 Grand Challenge 1 "Sustainable and Efficient Energy Generation"

Description:
The topic of Energy Generation can be divided in two main application fields, one being the traditional energy generation (e.g. coal or nuclear power plants) and the energy generation based on renewable sources. In both cases, "raw energy" is produced in a form, which cannot be transmitted or used without conversion. Examples are non-continuous energy sources like wind-mills and like solar cells. Using old-fashioned electronics for rectifying, transforming or converting (AC/DC or DC/AC) the currents, only about half of the energy could be used. New, much more dedicated and efficient components have to be used, which partially will be based on new materials.

Competitive Situation:
The relevance of a high efficient energy conversion for new energy sources can be demonstrated by the example of wind-energy. The actual trend, that wind capacity doubles every three years, still continues (Source: World Wind Energy Report 2009). All wind turbines installed by the end of 2009 worldwide are generating 340 TWh per year, corresponding to 2% of global electricity consumption. A few impressive numbers: The wind sector in 2009 had a turnover of 50 billion € and employed 550'000 persons worldwide. In the year 2012, the wind industry is expected for the first time to offer 1 million jobs. European discussions about a super-grid connecting offshore wind farms of the countries around the North Sea seem to offer promising prospects for this technology opening a large field of research in efficient energy conversion, distribution and management.

Expected achievements / innovation foreseen:

- Energy conversion with efficiencies of 90% and more will allow an even better use of renewable resources. Industrial research has to be done, to find solutions to make these efficiencies affordable. Once demonstrated, it's still a long way to achieve "higher efficiencies at lower system cost".
- Another aspect is research in terms of reliability and long lifetime. This market needs lifetimes of power electronic solutions of 20-30 years. The combination of new materials like silicon carbide (SiC) or Gallium Nitride (GaN) which enables highest efficiencies and extreme long lifetime is challenging.

- Developing and integrating semiconductors-based solar energy technologies with solid state lighting applications will enable not only sustainable energy resources but also energy efficient lighting applications.

3.3.2 Grand Challenge 2 "Energy Distribution and Management – Smart Grid"

Description:
An enormous potential for energy saving is the management, storage and distribution of (electrical) energy. The existence of European wide energy distribution networks is today only visible in case of problems producing large area "black-outs". The challenge is to bring intelligence into the power distribution system. The power grid of the future is one of the most challenging visions. Gigantic wind farms in the sea and enormous solar fields in the desert are to generate the bulk of our power in the years to come. But consumers and companies are also producing energy with mini-power plants in their own basements and solar panels on the roof. And intelligent and efficient appliances are saving energy in our homes: washers, dryers and refrigerators that communicate with each other wash, dry or cool when electricity is cheapest.

The "smart energy grid" will combine management of incoming power, of distribution of power and of outgoing power. This could include also a network of (at this moment) un-used batteries of millions of electrical cars. But, the "smart energy grid" will only work "smartly", if it is not only a power-network, but at the same time a communication network, which contains security features, grid monitoring and payment features. This "smart energy grid" should be constructed at the building, district and city levels, to ensure maximum energy efficiency of the overall systems.

Competitive Situation:
As the discussion about energy supply and about its environmental aspects is conducted all over the world, the competition is very hard and indeed there is a world-wide race for the first real smart energy grids. Europe is in a rather good starting position as all necessary elements are available and Europe has a leading in research and in market penetration of most of the needed elements. European companies have acknowledged strengths in power electronics and in communication, and the respective R&D is very active.

Expected achievements / innovation foreseen:
- Energy conversion with efficiencies of 90% and more will allow a transformation of the produced electricity into currents/voltages, which are adequate for the respective type and length of the power lines.
- For efficient energy transmission over long distances, very high voltage (HVDC) lines will be installed (e.g. 800 kV). Similarly, for integration of renewable energy systems (such as

solar or wind) with DC-based lighting technologies, low voltage lines in buildings are required. Highly effective AC/DC/AC conversion will be needed for entry and exit of energy.

- To effectively measure and communicate energy consumption in buildings, cities and districts, user profiles or future needs, dedicated sensors and communication networks have to be developed.

3.3.3 Grand Challenge 3 "Reduction of Energy Consumption"

Description:
A first, but not negligible, contribution is the reduction of power consumption of the electronic components and systems themselves. Well-known examples are the limitations by heat development of microprocessors as used in computers or the demands for mobile electronic equipment.
A more important – indirect - contribution is the energy savings on system/applications level. Research on advanced semiconductor technologies and energy efficient systems and solutions will enable industry to provide technologies and products to drive energy saving of end-equipment and the social system. Some examples are: intelligent lighting, motor control for home appliances, industrial applications and automotive, mobile applications. These areas feature healthy growth while being conscious that energy efficient systems and solutions are key factors for the Green society.

Competitive Situation:
Having the whole value chain present and in world-wide leading positions, Europe has a rather good chance to build up a healthy "green industry" around tools and goods for reduced energy consumption. European companies have acknowledged strengths in power electronics and in nearly all of its applications. Market studies show strong positions of Europe in the whole field of power electronics, but even dominance in power semiconductor modules for renewable energies. Also, the related R&D is very active.

Expected achievements / innovation foreseen:

- Lighting: In the near future, incandescent and fluorescent lighting will be replaced by LED technology, which is still being improved by remarkable R&D efforts. Two essential innovations are needed: One is focusing on high performance (>150 lm/W efficacy), reliable and low-cost LED system integration, wherein LED devices, optics, drivers, controllers, sensors, cooling solutions, and other essential components should be seamlessly integrated into a compact and smart opto-electronics sub-system. Another focus is to create and add intelligence to the LED light engines and sub-systems to provide optimal lighting solutions for a much large lighting system (such as buildings and outdoor spaces), to maximise energy saving and user needs. Supported by adequate sensors, algorithms and software systems an efficient and smart lighting control system will enable important energy saving in the private, industrial and public domains, and be able to be integrated with other systems and environments.

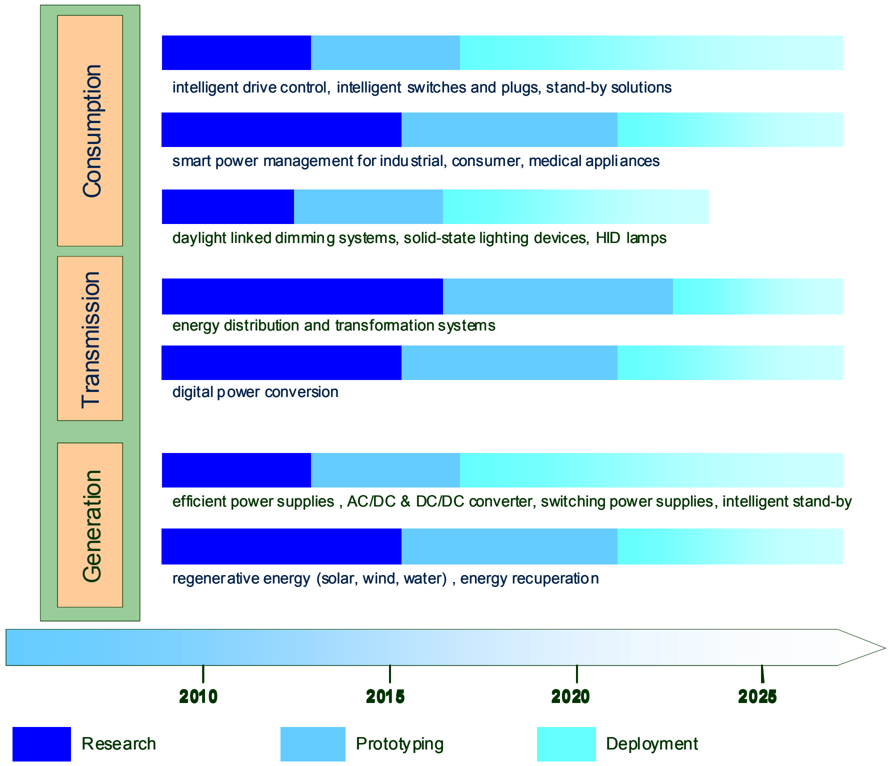
- Intelligent drive control: Technology, components and miniaturized (sub) systems will be developed addressing the challenges at system and device level for highly efficient controlled engines and electrical actuation in industrial applications. The need for R&D includes new systems architectures and circuit designs; new components and power electronic technologies; innovative module, interconnect and assembly.
- Efficient ("in-situ") power supplies and power management solutions: They will be supported by an efficient voltage conversion and an ultra-low power stand-by. The need for R&D includes new systems architectures and innovative circuit and package design concepts and specific driver ICs and power components for lighting and industrial equipments. Examples for the application of highly efficient "in-situ" power supplies are portable computers and mobile phones and stand-by switches for TV, recorders and computers.
- Medical applications: They will show very good energy efficiency - guaranteeing a long lifetime and low weight for the portable units. Improved energy management is also key for cost-effective imaging systems in medicine.

3.4 Conditions for Success

At least six conditions for success have been identified for progress in energy efficiency:

- Technical excellence in the domain of power electronics and communications. In order to achieve this excellence, quite a lot of research has to be done on innovative topologies, enabling highly efficient power conversion in all user domains. This includes new materials, innovative system design and high level quality measures for the new semiconductor technologies and circuit topologies.
- Adequate public support for the necessary R&D work.
- Worldwide standardisation for allowing rapid and effective market penetration.
- Regulatory frameworks for "motivating" the introduction of energy efficient systems and applications.
- Establishment of SSL standards related to thermal, mechanical, electrical and optical interfaces to ensure fast product development and system interoperability.
- Acceptance by the citizens; this can be achieved by a combination of energy efficiency with affordable price, high quality and safeguarding the comfort and ease to use.

3.5 Timeframes



SSL modules and smart large lighting systems

3.6 Synergies with Other Domains

There are many synergies with "Automotive and Transport" (Drive Control), with "Communications" (Smart Grid and Mobile Applications), with "Equipment, Materials and Manufacturing" and "Design" (Design and production of specific components for energy saving applications), "Healthcare" (Mobile Applications)

CHAPTER 4: HEALTH AND THE AGING SOCIETY

4.1 Introduction

Healthcare is a topic that affects us all personally. In general, adequate healthcare and wellness services are among the prime societal needs. In order to safeguard and increase the quality of life in the ever more ageing society, difficult societal challenges have to be solved. The nanoelectronics industry can play an important role by delivering innovative products as part of the solution.

This chapter covers the three Grand Challenges for the nanoelectronics industry to address healthcare in an ever more ageing society.

4.2 Relevance for Europe

4.2.1 Competitive value

OECD Health Data from 2009 (Figure 1) shows that Europe is the first large region to encounter the effects of the aging society. This will lead to a large new home market, giving the European industry a head start to the rest of the world in answering these societal challenges. Joining forces of the ICT and Healthcare industries will lead to leadership in the emerging healthcare markets ensuring sustainable growth.

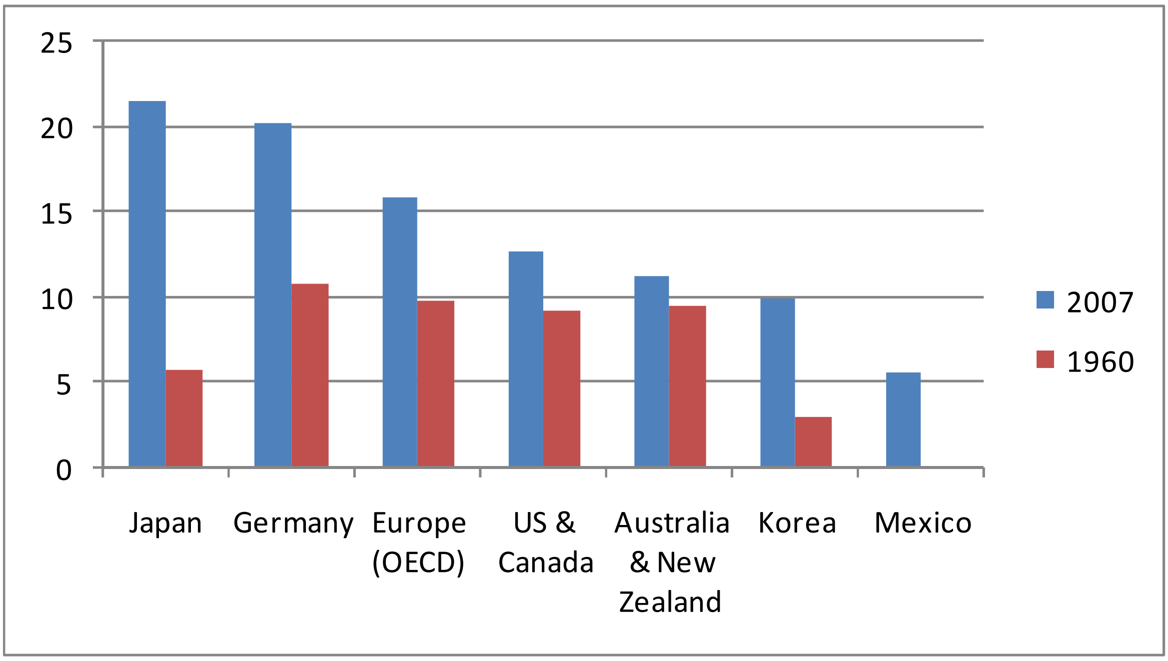


Figure 1 Share of population (%) age 65 and over. [OECD Health Data 2009]

4.2.2 Societal Benefits

Dramatic changes in demographics have to be faced: the population is aging. By 2045 more people will be over 60, than under 15 years old, rising from 600 million to 2 billion [OECD Health Data 2007]. In combination with the development in medical technologies and changes in lifestyle due to global economic growth, the prevalence of diseases affecting mankind is drastically changing. There is a strong increase in age-specific, chronic and degenerative diseases, like cardio-vascular, cancer, diabetes, Alzheimer's and Parkinson's. Thus we are moving towards a chronically ill society with its associated cost. Already now healthcare costs are surging: worldwide healthcare spending expected to grow from 9% of global gross domestic product (GDP) in 2006 to 15% by 2015.

In addition, global economic growth increases spending on health related services, access to healthcare for a larger number of people and the awareness of available healthcare options. This higher demand in combination with the ageing society leads to shortage in healthcare professional staffing. Significant innovations in efficiency and efficacy are required to address this inherent societal threat.

4.3 Grand Challenges

The overwhelming societal challenge of keeping the cost of Healthcare and the Aging Society manageable can be split in three grand challenges:

1. Prevent institutionalization of elderly, impaired and sick people: "**Home Healthcare**";
2. Reduce time and cost of hospitalization: "**Hospital Healthcare**";
3. Increase the speed of pharmaceutical development and body fluid sample analysis: "**Heuristic Healthcare**".

These challenges are shown in Figure 2, which also visualizes the trend towards people centric healthcare. The key requirements per grand challenge are shown in Table 1.

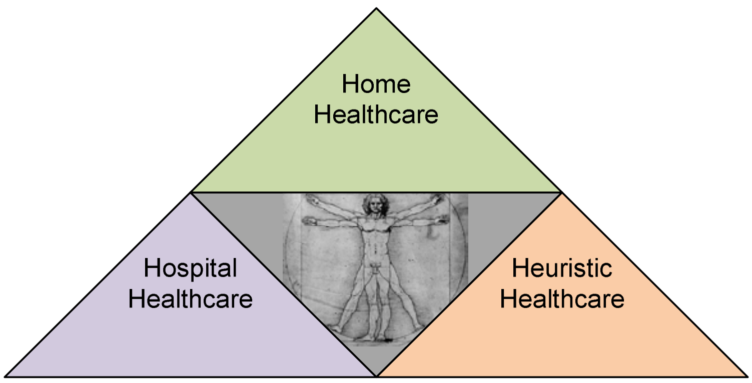


Figure 2 The three grand challenges for patient centric health in the aging society

	Home Healthcare	Hospital Healthcare	Heuristic Healthcare
Low-cost	X	X	
Accurate		X	X
Efficient		X	X
Easy-to-use	X	X	

Table 1 Key requirements for the Grand Challenges

4.3.1 Grand Challenge 1 "Home Healthcare"

Description:

Highest quality of life and lowest cost for society are obtained if elderly, impaired and ill people can fully function, independently from human support, in society without being institutionalized ("Independent living"). Electronics will assist people with limited mobility, sight or hearing abilities and with limited cognitive abilities, like elderly people suffering from dementia or people with mental health issues. Next to wellness at home, home care and home treatment will be an essential part of modern, integrated and patient-centric healthcare. Instead of a traveling patient, his data will travel on a secure basis and full attention by healthcare services is guaranteed (Figure 3).

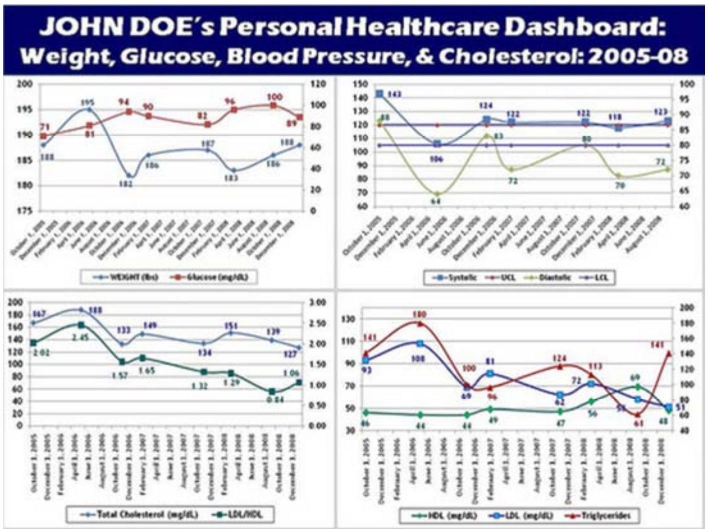


Figure 3 Continuous tracking of important patient health parameters

Competitive Situation:

The primary driver for a health related monitoring of vital signs is the demographic change, due to the increased prevalence of chronic diseases in an aging society. A study published in 2008 estimates the number of potential end-users of telecare solutions aged 65+ for the year 2020 in the 25 countries of the EU as ranging between 3 and over 15 million, depending on the development of the market penetration.

ICT-based therapy for mental health management improves healthcare productivity and access to care as it provides therapy with 80% savings in therapist time compared to conventional therapy (Marks & Cavanagh, 2009). As mental health problems are largely under-diagnosed (Katon, 2003) and few are able to obtain expert consultation, there is a clear need for improvements.

If only we consider the people suffering from chronic conditions, which should maintain a healthy life and monitor continuously their condition, the market size is huge. Accounting for 59% of the 57 million deaths annually and 46% of the global burden of disease, chronic diseases are the major cause of death and disability in Europe and worldwide. As the population is ageing, the number of people suffering from one and, very often, multiple chronic conditions increases. This poses an increasing burden on health care and social service systems and affects the quality of life by inducing both physical disabilities with frequent hospitalizations and social impairment.

As a result of the enormous economical impact that the increasingly ageing population will have in Europe and the rest of the world in the next decades, there is a potentially growing world-wide market in the area of Independent Living services and ICT for healthcare.

Expected achievements / innovation foreseen:
The introduction of Remote Sensing applications into the Public Health systems will contribute to the workload reduction and diminished waiting lists thanks to its improved features: rapid parameter analysis, multiple analyses assessment and ICT-related features. This fact will bring to physicians (anytime, anywhere) more information than current and dispersed analytical equipments about their patients. As a consequence, improved monitoring and diagnosing practices will be established. Therefore, patients will be more confident with public health systems due to several factors:
a. Individualized information on his/her disease progress
b. Reduced time to treatment and disease-oriented decision making
c. Optimized health resources and government taxes employed.

Of course this requires the development of cheap screening solutions for early diagnostics, biosensors and cheap mobile monitoring of biologic samples and parameters ("The doctor in your pocket"), as indicated in "Heuristic Healthcare". One of the ways this can be done efficiently is to integrate the tests into a mobile phone application linking to a patient centric database. Testing in real time individual response to drugs will help to tune the therapeutic protocol and reduce side effects in conjunction with telemedicine for a better patient coaching.

These Remote Observations systems also include fall prevention and fall detection electronics for the elderly and impaired. For people with limited mobility, sight or hearing abilities electronic assistants will be developed. In general the wellness of the elderly and impaired will be increased.

Smart devices will also help to monitor the healing process (e.g. e-Inhalers for rapid and accurate dosage of drugs, also using smart band-aid with impedance changes for wound healing). In the same way smart automated drug-delivery systems, based on MEMS actuators coupled with low power control logic and energy scavenging, will help to apply therapy where and when it is needed.

The efficient use of health technology embraces several key areas in every country health system. From the social perspective, it influences to the informal care-givers or family caregivers which can be overloaded due to its emotional link and for its lack of health specialization. From the economical side, this initiative permits health care attention at home which discharges assistential pressure at the hospitals as well as it improves the satisfaction of older persons to increase the degree of "independent living", even in cases of dependency on long-term care. Finally, the remote supervision keeps track of key clinical parameters close to real-time providing the basis for decision making and even, if necessary, immediate intervention. For the latter fast localization will be implemented.

4.3.2 Grand Challenge 2 "Hospital Healthcare"

Description:
Hospital effectiveness can be increased by early and improved diagnostics. Efficiency can be increased with targeted therapy, where image diagnostics is combined with therapy in Image Guided Intervention Therapy (IGIT), see Figure 4 for an impression.

Figure 4 Research setup for interactive and interventional procedures

Competitive Situation:
The global market for medical imaging (diagnostic and interventional imaging) is estimated to be 20.1 B$. (2007 TriMark study). The European market is about a quarter of this total and the US market almost half. The medical imaging market records solid growth percentages. Depending on the modality, the average compound annual growth rate (CAGR) is about 4% (for interventional imaging this is 8%). There a few specific areas where growth is markedly higher than average:

- Image-based software applications that support intervention processes in healthcare.

To illustrate these growth opportunities:

- o The European market for 3D/4D imaging software has a CAGR of 14% from 2004-2014
- o The global market of CDSS (Clinical Decision Support Systems) grows from 159 M€ to 289 M€ during 2006-2012 (Frost & Sullivan)

- The integration of medical imaging with delivery systems (e.g. robotics) and therapy devices. This trend alone creates an entire new market space for IGIT procedure solutions. Ultimately this market will unify the market of interventional imaging, delivery systems and devices and therapy solutions. It is expected to be 10 times the size of the interventional imaging market today and it also enjoys higher growth figures and gross margins (based on US market data).

The global competitive players in the medical imaging industry providing both hardware and software are General Electric (GE) Healthcare (US based), Philips Healthcare, Siemens Healthcare (both Europe based) and Toshiba Medical Systems (Asia based). Emerging are Chinese suppliers, which now focus on the local market, but can be expect to expand internationally in the future. The market shows also innovative technologies developed by companies focused on specific segments such as EEG and represented by Nihon Kohden in Japan and GTech in Europe.

Expected achievements / innovation foreseen:
Improved and combined image detectors lead to efficient, more precise and earlier detection of diseases. These improvements incorporate increasing the resolution, supporting larger data rates, and being more precise in the properties of the signals that are detected. In addition, the detection of other kinds of signals can lead to earlier detection of symptoms, and/or reduce the harm to the patient. In this context, more precise and earlier detection also allow for significant dose reduction for a patient. For screening purposes, imaging systems without radiation have to become cheaper, faster and more accurate.

More targeted therapy will be achieved by combining imaging with therapy. Image guided intervention will help in medical diagnosis, planning and treatment of patients by minimally invasive placement of diagnostic and therapeutic devices such as catheters, stents, but also heart valves inside the human body, enabled by medical image analysis and navigation methods. Testing in real time individual response to drugs will help to tune the therapeutic protocol and reduce side effects in conjunction with telemedicine for a better patient coaching. Specific techniques like deep brain stimulation and neuronal communication will particularly benefit from miniaturization of control logic and real-time patient specific protocols.

Localisation techniques support the freedom of to be supervised persons and the management in large hospitals in knowing where the nearest experts and expensive equipment is located.

4.3.3 Grand Challenge 3 “Heuristic Healthcare”

Description:
“Heuristic healthcare” focuses on parallelization of analysis tools. On one hand it considers (educated) trial-and-error methods used in screening chemical compounds for drugs. On the other hand it involves (multi-parameter) bio-sensors, Figure 5, for early diagnostics (“the doctor in the pocket”) and in the real-time response measurements to drug delivery.

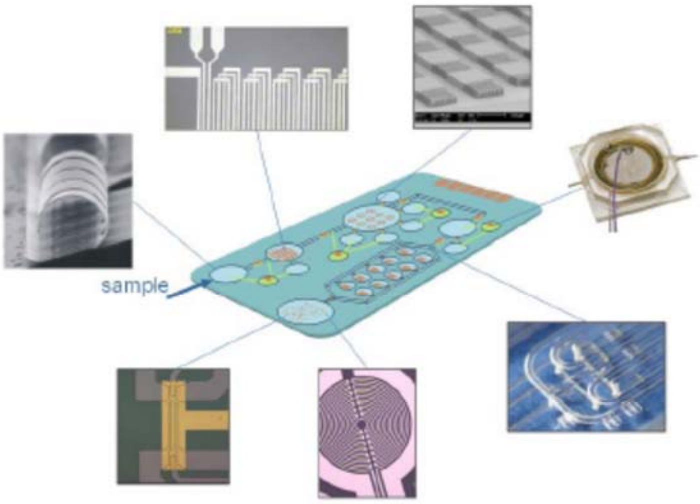


Figure 5 Illustration of a diagnostic cartridge based on heterogeneously integrated MEMS-based modules on a common breadboard

Competitive Situation:
Three markets are approached, the pharmaceutical industry (compound screening), the home healthcare market ("the doctor in the pocket") and the hospital with minimal invasive real-time response to drug delivery via bio-sensors.

The potential for parallelization and performance of the nanoelectronics is huge and will directly benefit the analytical and research laboratories in providing tools which are order of magnitude more efficient. This status will enable rapid progress in healthcare techniques thanks to a more efficient screening of potential drug compounds using bio-electronic devices, creating synergy between high volume laboratory-based systems for advanced treatments, and more cost effective home based systems.

Estimations are that the total in-vitro diagnostics market will grow from EUR 3.3 billion in 2007 to EUR 17.7 billion in 2018. Traditionally, the European molecular diagnostics industry is strong, but increasingly threatened by Asian and especially American companies. While still leading in the traditional markets, Europe is behind in new, upcoming diagnostics markets, American governments and companies have done major investments in next generation integrated diagnostic platforms due to the bioterrorism defence programs as well as in next generation biomarkers and assays which in some cases is driven by the 'never event' healthcare policies in the majority of American states as well as by the strong US Life Sciences R&D. The US is therefore currently leading in this field with companies like Cepheid, Life Technologies, Illumina, HandyLab, Caliper, Celera and Rosetta (MSD). Europe however has the broad (nano)technology base and the clinical application knowhow to become a leading player in the next generation genomic assays, especially when forces are bundled

Expected achievements / innovation foreseen:
The exams to determine real-time response to drugs and for quasi-continuous health monitoring ("The doctor in your pocket") must be minimally invasive to avoid repeated traumas inducing non compliance. This goal requires the screening of the most promising fluids starting from saliva and sweat, arriving to peripheral blood. For the development of biosensors this means: (1) finding new, and more reliable panels of disease markers, (2) finding specific receptors for these markers (3) integration of the testing components in a cost-effective testing package, which enables quantitative results in a short time (a few minutes) for the whole panel in question (e.g. micro-fluidics and polymeric packaging) and (4) evaluation of the results and (5) wireless interlinking with a patient-oriented database system.

Highly reliable tests will identify those pre-disposed to certain diseases, allowing them to enter preventive programs that will identify early onset of the disease.

High-throughput platforms addressing the discovery of new drugs through screening procedures play a role in the segments with higher economic growth, such as immunotherapies and other biological drugs. Detecting toxicities on as many classes of cells as possible, while supporting the required therapeutic effect requires the implementation in parallel of many thousands of assays. This task includes the handling of delicate cells to detect the desired effects. It has to be explored if quantum effects can give a further boost to this field.

4.4 Conditions for Success

The grand challenges cannot be solved by technology alone. Before application of new nano-electronic solutions a regulatory framework has to be in place and business models have to be worked out. These will be country specific and in general European market fragmentation is a severe hurdle that is hampering market penetration. Without significant convergence between European markets the industry will be exposed to the absence of economies of scales, even though the overall European market is second largest (Figure 6).

The resistance to use new ideas in the personal health sphere or inside the medical staff environment can be quite large. When designed with applicability (size, usability, automatism, cable free, identity secured, ..) in mind nano-electronics and micro-fluidics and actuators can help overcome these resistances.

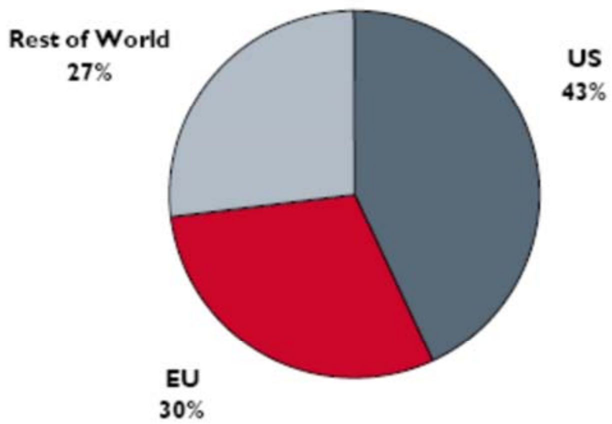


Figure 6 Global markets for medical devices in 2005
[Innovation financing in the European medical device industry, 2005]

4.5 Timeframes

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="3">Grand Challenges</th></tr>
<tr><th>Home Healthcare</th><th>Hospital Healthcare</th><th>Heuristic Healthcare</th></tr>
<tr><td rowspan="15">TECHNICAL CHALLENGES</td><td>Prevention</td><td>For falling, accidents and (wellness) diseases</td><td>For infections</td><td></td></tr>
<tr><td rowspan="3">Early diagnostics</td><td>Telemedicine</td><td>Screening Imaging Systems</td><td>Biosensors (demonstration 2016)</td></tr>
<tr><td></td><td>Improved image detectors</td><td>High reliable tests</td></tr>
<tr><td></td><td>Clinical validation</td><td></td></tr>
<tr><td rowspan="5">Targeted therapy</td><td colspan="2">Smart automated drug delivery</td><td></td></tr>
<tr><td colspan="2">Implants (e.g. deep brain stimulation)</td><td></td></tr>
<tr><td>Smart devices (e-inhalers, bandages)</td><td>Image guided Intervention</td><td></td></tr>
<tr><td colspan="3">Real time response to drugs (2020)</td></tr>
<tr><td colspan="2">Patient safety (automation)</td><td></td></tr>
<tr><td rowspan="3">Remote supervision</td><td colspan="3">Multi-parameters sensors</td></tr>
<tr><td>Secure/private tele-monitoring networks</td><td></td><td>Polymeric packaging</td></tr>
<tr><td>Monitoring and emergency alert</td><td></td><td></td></tr>
<tr><td rowspan="2">Fastest access</td><td colspan="2">Localisation techniques</td><td></td></tr>
<tr><td colspan="2">Personalized health data</td><td></td></tr>
<tr><td>Fast drug screening</td><td colspan="2"></td><td>Efficient screening of drug potential with bio-electronic devices (subset in 2015, robust platform in 2018)</td></tr>
</table>

The work on bio-sensor is expected to be carried out initially for chemotherapies, expensive drugs with significant side effects. The ambition is to provide a tool that reduces costs and improves the therapeutic effects of cancer therapy by 2020. The clinical model explored will begin with the personalized monitoring of drug pharmacokynetics to define the most appropriate dosage. Other toxicological issues will be investigated in a second stage of the activity. The working principle of the biosensor and associated bioassay will be defined to encompass a significant class of drugs and will be demonstrated as early as 2016

The importance of nanoelectronics in high speed drug screening can be demonstrated by showing in 2015 a subset of key procedures selected in cooperation with the pharma industry and demonstrated using a prototype that shows the scalability of the approach. The ambition is to demonstrate robust discovery platform by 2018 aimed at the field of monoclonal antibodies.

4.6 Synergies with Other Domains

From this work area on "Healthcare and the Aging Society" there are possible synergies with:

- "Automotive and transport" as car safety can be improved by enabling wellness applications in an automotive environment (such as a sensor network that can monitor the driver's vital signs and act accordingly). Also, imaging systems can benefit from new power electronic devices developed for electrical and hybrid vehicles;
- "Communication and Digital Lifestyle" as the availability of cheap and wireless communication links can be essential in the realization of home patient monitoring and for improvements in advanced imaging systems for screening. Additionally, there can be synergy on the technology for LTE terminals to support safety on the road and safety at home. Additionally, exchange of high resolution life images and data may require optical broadband access technologies.
- "Energy Efficiency" as low-power techniques can be essential for monitoring systems that use portable or on-body devices, and new materials, devices and equipment for solar energy conversion can be beneficial to develop new radiation conversion detectors and efficient power converters for imaging systems;
- "Design Technologies" as integration of heterogeneous technologies, low levels of acceptable energy consumption and high levels of reliability are required for the complex heterogeneous systems for Healthcare applications;
- "Silicon process and integration" and "Equipment materials and manufacturing" to create the best solution as a More than Moore spearhead for low-cost cartridges and platforms for microfluidics and gas sensors to monitor the body and environment
- "Safety and Security" as drug deliveries and operation become automated intrinsic safety has to be guaranteed. The large amount of patient (and non-patient) data has to be collected, transmitted and stored securely. Privacy needs to be supported.

Figure 7 Source: www.seppo.net/e

CHAPTER 5: SAFETY & SECURITY

5.1 Introduction

Safety and Security are needs covering personal security, financial security, individual information privacy, health and well-being, safety against accidents or violence and their adverse impacts. This chapter presents the nanotechnology items to make available as part of European secure and safe solutions.

The new application needs for broadband communications, easy mobility with safe transportation, smart energy distribution, trust in critical applications like control units in cars, industrial plants or e-payment, consumer and citizens security which require new technologies are described in this chapter.

5.2 Relevance for Europe

5.2.1 Competitive value

Statistics show that we live in a much safer world, yet there is still constant demand for increased safety and security in virtually every aspect of our lives. Ubiquitous security is a major challenge for the information society, as tremendous amount of data circulate and is stored all over the world, available from anywhere at anytime. It is clear that security, trust and safety not only constitute a major market in themselves. There are also generic enabler for many other applications and support related services.

Europe has always been strong in security and safety : in large country based or European level applications set up such in e-payment, e-health and ID, with large system companies active in security and safety, and with core European and worldwide leaders semiconductor actors leader in the enabling technologies for USIM card and secure microcontrollers..

This security and safety must also be based on standards and technologies on which European public authorities can rely for keeping their own independence regarding other continents, i.e. generally based on standards accessible to open market, or open source, and not in the hands of a single organization

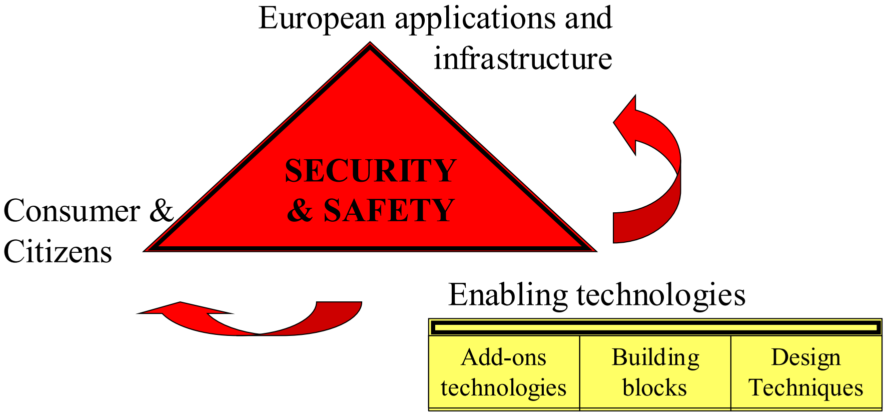


Fig 2. Relevance of security and safety enabling nano-electronics for European citizens and for the European applications and infrastructure.

In this context, three major challenges are issued for Europe solutions

- Consumer and citizens security
- Security and safety of European new applications and infrastructure
- Enabling technologies and building blocks for trust, security and safety

5.2.2 Societal Benefits

Security, trust, privacy and safety are common concerns and requests by European citizens and Public Authorities.

- about IT security and privacy, everybody is aware on new threats every day. Statistics show: how high worldwide Internet users are exposed to identify theft, how much malware infect of the personal computers and citizens loss in Interned fraud

- It is clearer and clearer every day that, if not desiring to "pay for security", consumers are avoiding to use new services whenever they do not have the relevant level of trust in the whole chain. This applies in the personal devices, but also in the existing and future infrastructure such for transportation

- Security reflects itself in citizens demand for security and safety at home and in mobility, and for public authorities led protection from crime and terrorism. However this is always accompanied by the need of personal protection without restriction of liberty or limitation of privacy, which means that safety and security systems need to be reliable, easy to use and capable of safeguarding the privacy of end users.

- Safety with electronic systems is to prevent dangerous failures and to control them when they arise. Examples are anti-lock braking and engine management in cars, signaling systems in railway or traffic, aircraft flight control, production plants monitoring… but also many individual life sensitive applications such health-related devices, etc…

Fig 1. Picturing Security and Safety demands in a global world.

5.3 Grand Challenges

5.3.1 Grand Challenge 1 "Consumer and Citizens Security"

***Vision:* Maintain and Develop the European leadership in security enabling nanoelectronics for Consumers and Citizens**

Description:

European Citizens are living in a technological society where most of the communications and transactions are done electronically. People are living in a society which depends from the errorless operation of embedded computing systems in transportation, wireless, industrial plant and of some critical infrastructures (airports, public transportations, utilities, networks, distribution,..). Both electronic systems, goods, and critical infrastructure are highly vulnerable to various threats. Europeans citizens are acting in an open society with very high mobility of people in both their personal and professional activities. The final end-users and the society as a whole need to be protected against fraud and information attacks, deficits in modern highly complex installations and endangerment of critical infrastructure. In addition privacy of the end user's data needs to be ensured .As a consequence we have to provide systems which protect from vulnerability in an cost/effective manner and we need to target security without restriction to mobility of the people and without disturbance of their daily life.

Competitive Situation:

Europe strategic independence in key security technologies serving citizens is essential. Europe has always been leader in our evolving digital society in order to provide secure personal devices such as SIM , credit cards , electronic passports but also secured servers and associated infrastructure & services .

Considering the growing demand for mobile connectivity, identity and data protection of citizens, health & transport services, e-banking & e-government and moreover for global security as a whole, it is essential that Europe maintains and enhances its technical leadership and continues to provide for millions of people means to communicate, travel, buy and work everywhere in an enjoyable and secure environment using key, but also to make available products which convince their users of their quality, functionality and resistance against external and internal errors and influences.

Expected achievements / innovation foreseen:

Communication technologies

- Secure spontaneous networking
- New architectures:P2P, M2M, Cloud Computing, IoT
- Security of wireless protocols (IEEE 802.X,…UWB, RFID,..)
- Trust and integrity

Secure servers and personal devices

- Very high-cryptography bandwidth
- Multi-level security
- Trusted virtualization and compartmented operation systems
- *Smart personal devices*
- Smart-cards and secure tokens
- Privacy-enabled Trusted Personal Devices (Fixed, mobile)
- Integrated trust and security hardware and firmware features for embedded computing platforms

Smart-sensors and actuators

- Integrated authentication against fraud
- Wireless enabled
- Adjustable local intelligence/remote monitoring
- Data fusion algorithms

Privacy-enabling technologies

- Anonymisation
- P3P (Platform for Privacy preferences..)
- Digital signatures

Identity management technologies

- Federation
- Biometry (Multimodal)
- Authentication
- Digital signatures

Embedded SW agents

- Configuration , profile management
- Privacy, security
- Integrity and reliability

5.3.2 Grand Challenge 2 "Securing the European challenging Applications"

***Vision:* Take advantage of European leadership and expertise in electronic security to define, develop and implement the needed security in European new challenging application domains and stay ahead of world competition.**

Description:

In all new fields of application, electronic control and data exchange show an obvious need for more security. Protection like simple guarantee that software program integrity is preserved during product life, solid mutual authentication of communicating parties, data confidentiality are key targets. What ever the application domains, similar concerns are appearing, but the overall definition and implementation may change significantly according to the ecosystems, regulatory environment (may be very different in transport and health care…) and targeted cost and budgets.

Energy Efficiency and smart energy grids

In that field, key application will be the definition and use of the smart grid system so that the overall distribution network is managed and protected from undue external control. Liked with that customer usage profile data collection, distribution and usage has to be severely protected in order to protect privacy, avoid massive fraud. Remote control by users or by the overall management systems has to show resilience to many threats or associated risks covering security (wrong access, billing fraud…) but also safety (people at risk if home equipments are incorrectly driven either by fraud or failure). Energy networks are also a matter of critical infrastructure (the prosperity and existence of our communities depend on them at a large scale); they need protection against foreign emissaries as well as natural system deficits due to e.g. design and software errors.

Health & Ageing Society

Keeping elderly or dependant people at home, or minimizing the level of institutionalization will require permanent monitoring of activity, vital functions and others useful parameters.
Collecting this information, communicating and filtering the contents will require highly trusted chain of systems with fully dependable electronics and strong data protection.
When life sustaining equipments are to be used control (local or remote) of such equipment will be highly critical and the highest level of security has to be achieved. In that domain the ecosystem include both medical professional and insurances (either private or public). They will be key in defining the proper requirements and setting budgets, but European, nation or even local regulation may contribute to solution definition.

Automotive & Transport
In transportation – automotive, city transportation, railways and airplanes - safety is critical. Security now combines with trust and safety requirements. System integrity and traceability are also mandatory. The increasing mobility and traffic require more safety in traffic. Electronics are the enabling technologies to develop smooth access control when traveling, more safety in traffic and co-operative Traffic Management. New and increased use of protective technologies is necessary to protect todays complex systems against bad internal and external influences and errors. New DSM technologies bring new technical challenges, such in signal integrity, reliability, trust and safety/security compliance.

Communication
A new security paradigm is requested by more and more communicating applications, more mobile users and more distributed data. Thus securing services or data and providing proper protection evidences is becoming increasingly important and difficult in advanced, open wireless and fully mobile devices. End-users, OEMs, ISVs, content owners, service providers and operators have different, sometimes diverging needs and should have differentiated privileges towards terminal resources. Robust stakeholders' segregation, security policy enforcement and mutual assets isolation is a challenge in increasingly open "computing" devices exposed and vulnerable to everyday new malware, software and hardware attacks. Increasing interoperability, trust and flexibility requirements are bringing standardization and security evaluation challenges. Finally the ever-increasing security complexity should remain transparent to the end-user, which is stressing the security performance and efficiency dimensions.

Other leading applications
Other new applications for trusted Future Internet, new e-Payment, e-ID … are also developed at European level. Security is a core technology for these applications.

Competitive Situation:
Europe has always been a leader in developing new large applications at European level, based on their industrial OEM and system industries such in automotive, energy management, transportation, health, and security. However new applications such as security and smart

energy grid have shown early initiatives and starts in US and Asia in the same growth or even faster than in Europe. However the involved industries start recognizing the absolute need for trust and security, which is an opportunity to be developed by European actors if we are fast enough.

Expected achievements / innovation foreseen:

- Identity and secure authentication as part of new applications
- Trusted execution and trusted computing for embedded systems and complex netted information and computing systems
- Validation, verification and proof of safe and secure devices
- Tagging and tracking goods, Counterfeiting protection techniques
- Secure execution, management, personal privacy in new European wide applications.

5.3.3 Grand Challenge 3 "Enabling Technologies for Trust, Security and Safety"

Vision: ***together with the European semiconductor actors and the security experts, develop the Building blocks and Technology trust, security and safety add-ons to provide secure and safe enabling devices.***

Description:

Semiconductor technologies and nano-electronics have direct relevance to security and safety capability as part of Information Technologies, Consumer goods and citizens practises, Payment, Wireless Communication, Energy distribution, Health individual information, Transportation, complex Machinery and equipment and Secure access.

While at the same time, the semiconductor process and integration and the design technology are contributing to the advancement of the core capabilities (sensing, data & signal processing, computation and communications) needed for IT and embedded systems, some critical features and building blocks are required for the foundation of secure and safe nano-electronics devices.

Security and Safety being generalized in any applications, a methodology for integrating basic security bricks in more complex systems (microsystems such as SoC or macrosystems) with capabilities of proof, early validation, simulation, etc has to be developed; Secure by Design approaches are generic terms for these developments.

Trust has to be achieved by measuring the integrity of hardware and software of processing platforms and thus constructing trusted platforms, where the integrity can be preserved during operation also in a networked environment. Trust is necessary to protect secure systems also against advanced attacks and report their integrity status to the companioning system parts. Trusted implementations are coming up to protect PCs, mobile communication and servers but also e.g. embedded systems like car control or industrial control systems against attacks from the outside as well as to protect against error propagation from the own error sources (like residual software implementation errors).

Because any product is produced by assembling subcomponents from various sources, trusted or not, controlled or not, subcomponents authentication and integrity checking is a key elements to fight against piracy. The subcontracting of part of the systems or the fabless companies, are sometimes used for fraudulent modification of the products (troyan like).

Competitive Situation:

Semiconductors companies in Europe are worldwide leaders in providing secure and industrial devices in line with the European OEM leaders. With the globalisation, it is important for European actors and stakeholders to maintain a technology mainstream and to develop the security and safety add-ons.

The European industrial machinery, production systems, transportation, security, healthcare and automotive industries develop solutions with a continuing increase in complexity to full fill customers expectation and users needs worldwide, which results in a continuing worldwide market share. For continuing enhancement of such systems we need integrated trust and safety to give our industry a differentiating advantage against other economic regions.

Expected achievements / innovation foreseen:

Enablers to be developed on top of the baseline semiconductor technologies

- Attack and probing resistant silicon cells and design processes
- Silicon ageing of DSM technologies to be examined versus duration of life required by industrial applications
- New generation, large and secure NVM memories to protect the confidentiality and integrity of information during storage. Include extensions from multiple-key management to public-key encryptions
- Tamper resistant packaging

Building functions

- Embedded Sensors technologies for security and safety
- Very small area integrable security algorithms e.g. for authentication and digital signing
- Component authentication such as PUF technologies (Physically Unclonable Functions)
- Secure new high data rate interfaces for MtoM and RFID

- Internal architectures for intrinsically resistant components (resistance to fault injection, flat signals emission, etc)

Design techniques

- Security CAD,
- Tamper resistant design
- Trust and security protocols and algorithms. And influence the related standardization
- Configurable and integrable Trusted Modules (TPM) for embedded systems
- Design for Reliability DFR
- EMC protection

5.4 Conditions for Success

The new applications bring engineering challenges and require new technologies to be defined and assessed together with the Application ecosystem actors such in Energy distribution, Communication and transportation infrastructure, Health and e-Governmental applications.

Of course it is proposed to capitalise on the existing European technologies and to develop them further in these brand new contexts. Increased cooperation with high level research institutes for influencing and developing worldwide standards shall benefit for European export industries capabilities.

Trust depends also on the capabilities of evaluating the security level of devices and systems. Europe is the worldwide leader in this domain by its technical capabilities, by the existence of an ecosystem (National certification authorities, evaluation laboratories, stakeholder groups for the standardization, etc). This ecosystem has to be supported and the added value of certificates has to be highlighted.

5.5 Timeframes

The 3 challenges of security & safety domain get to be developed in parallel with different timeframes

- Challenge 1 requires continuous and incremental to provide added trusted solutions to citizens and customers
- Challenge 2 is to developed in line with the new applications such to allow their safe and secure deployment.
- Challenge 3 timing is to be developed jointly with both the actors for European semiconductor process & integration and design technology domains. The technology items are short and medium needs.

5.6 Synergies with Other Domains

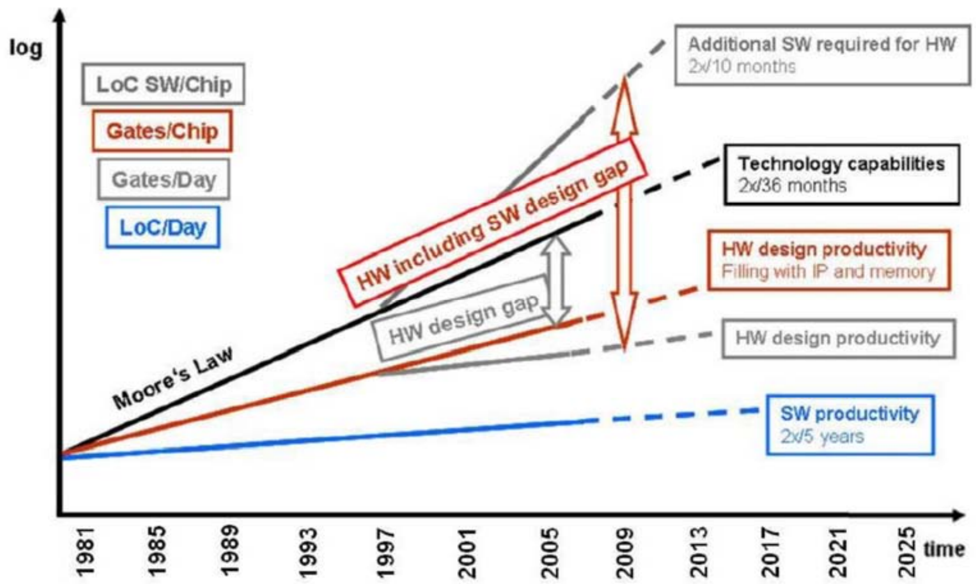
Safety and security domain is transversal to all application domains and the related technologies need to be developed together with the semiconductor process and integration and design technology domains.

CHAPTER 6: DESIGN TECHNOLOGIES

6.1 Introduction

Design technology enables the *specification, concept engineering, architectural exploration, implementation*, and *verification* of microelectronics-based systems. It includes design flows, *tools, libraries, IP, manufacturing process characterizations,* and *methodologies*. Design technology is the key link between technology and the world of applications, transforming ideas and requirements of the electronic systems designer into manufacturable and testable representations, by increasing design productivity, reducing the development costs and time to market and insuring the achievement of the requirements of safety and reliability.

If ICT is considered one of the key factors for the economical and social growth[19], it is through the design of new semiconductor components and their introduction on the market that the impact of ICT is realized. However with the increasing complexity of targeted applications, design capabilities and design cost are becoming the limiting factors for the future technological development, as indicated by the design gap, which is widening between what technology offers, and what design can use.



The requirements that applications are putting on Design technology are constantly increasing due to the increasing complexity of systems to be integrated, the growing weight of parasitic and statistical effects coming from deep submicron technologies, the inclusion of heterogeneous

[19] Europe's Digital Competitiveness Report
http://ec.europa.eu/information_society/newsroom/cf/itemlongdetail.cfm?item_id=5789

functions, the trend to system-in-package integration, requiring 3D stacking, the increasing demand for energy reduction and for better reliability

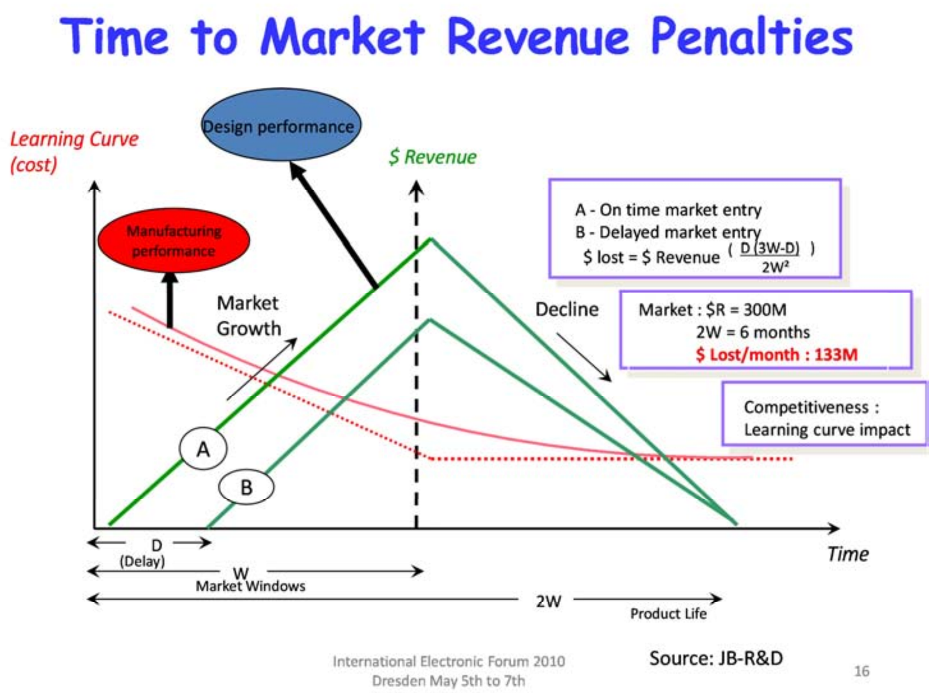
6.2 Relevance for Europe

6.2.1 Competitive value

To quote ITRS: "*The process of designing and implementing a chip requires a large collection of techniques, or tools, and an effective methodology by which a designer's input predictably leads to a manufacturable product. While considerable attention is given to the tools needed, the equally important subject of design methodology is often neglected.*" While EDA industry is active in developing and improving tools for the most general design problems, the definition of the methodology and the exploration of new tools is left to leading edge system and semiconductor companies, with the support of SME's and academia. Large scale cooperation among all actors is needed to standardize solutions and to spread the benefits throughout all the European design community. The importance that European semiconductor and system companies are giving to Design Technology, is also demonstrated by the support given since several years to a quite extensive initiative to define a European EDA Roadmap, now at its sixth edition.

There is no clear data about the weight of design resources spent in Europe. Total sales for EDA tools in Europe (licenses plus assistance) were around 0.9 B$ in 2009 which indicate a total of 40-50 thousand IC designers in Europe, distributed between semiconductor companies, fabless design houses and IP providers, and system companies. With a ratio 1:3 between EDA tool investment and other costs (salary plus design hardware), we can assume that total investment in design by European companies has been around 3.5-4 B$, which represents an investment of more than 10% of the sales of European semiconductor industry. The support personnel of EDA companies alone was around 5000 people.

The proper use of Design Technology to reduce the development time of new products has also



a significant economic impact on semiconductor industry and on the system industry depending on the availability of dedicated solutions, as shown in the graph below.

6.2.2 Societal Benefits

Design technology has an indirect social impact, by enabling critical applications in field of social relevance, like Health, Security and Transport. *"Over the period 1995-2004, ICT drove half of all productivity gains in the EU, mainly through efficiency gains in the ICT sector and investment in ICT."* The impact of ICT has been particularly evident in specific high tech sectors, which are among the strong point of Europe, like Automotive, Telecom and Security, or of high growth potential like Health and services for Aging Population. All these sectors are critical dependent of dedicated design solutions, capable to integrate also non logical functions (like sensors) and are strongly demanding in specific performances, like reliability and low power consumption that require a tight integration between architectural design and technology. Properly applied design methods and tools will allow increasing the reliability of semiconductor devices, and reducing the costs of the final products making them available to the wider market. As an a example we can quote the reduction in casualties made possible by the widespread adoption of safety features in the car industry (ABS, airbag, EPS,..), which has been enabled by the reduction of costs and the increase in device reliability related to the continuous developments in silicon and design technologies. Another benefit is the possibility of job creation in high added value areas. Development of innovative devices and of specific tools is a field where the entry barrier is quite low, and where innovative SME's can easily find a space. Tight cooperation with user allows for keeping European leadership/employment in key areas.

6.3 <u>Grand Challenges</u>

6.3.1 Grand Challenge 1 "Managing complexity"

Description:
"Managing Complexity" aims at developing solution for managing the design of complex chips including billion of transistors and different types of I.P.'s, coming from different sources, with a large software component.

The trend towards the integration of more and more complex systems on chip or in package, made possible by the Moore's Law is becoming the main challenge for design, both in terms of system complexity related to the integration on chip of different logic functions (logic, multi-core processors, memories, dedicated functions) and in terms of silicon complexity, related to parasitic effects and variability in advanced CMOS. The insertion of programmable component to increase flexibility is adding a further level of complexity, introducing embedded software, and hardware-dependent software components as critical elements of design.

Architectural level design, and the possibility to evaluate different options and make choices at the highest level of abstraction, is becoming a critical issue in defining the performances of the final device. Since several large I.P.'s are required to compose the system, the possibility of I.P. reuse plays and the definition of open standards also play an important role in overall design cost and time.

Competitive Situation:
Large EDA companies are providing standard tools essentially for logic synthesis and layout optimization. Higher design levels are not well covered even if some initiatives exist to try to move design at higher abstraction levels:
The most critical issues to be covered are:

- Capture and verification of specifications;
- Tools and methodologies to handle multi-core design, taking into account both hardware and software and operating systems;
- Tools to verify hardware dependent software;
- Standard languages for high level design;
- Open standards for I.P. exchange and interfacing;
- Tools and flows to interface design cores coming from different sources and to handle communications among them;
- Tools and model to perform basic design evaluation for performances and power dissipation at the highest abstraction levels.

Expected achievements / innovation foreseen:
The main achievement that the projects should target is the establishment of a standard language for the high level design. A non-exhaustive list of required innovation is:

- Standardized description language;
- Flows and tools for model generation at high abstraction levels;
- Tools able to handle at the same level hardware and software;
- Tools for the formal verification of the design at different abstraction levels;
- Tools for generating interfaces among heterogeneous IPs.
- establish an OPEN standard ecosystem

6.3.2 Grand Challenge 2 "Managing Diversity"

Description:
"Managing diversity" aims at the development of design technologies to enable the design of complex system-in-package incorporating heterogeneous devices and functions.

The drive towards higher integration levels for semiconductor components, coming from considerations of cost, form-factor, connection speed/overhead, and reliability, has pushed towards the tighter integration also of heterogeneous non-logic functions, like power, communication (RF or optical) and sensors. System integration in package and 3D stacking of different devices are becoming mandatory to achieve the desired targets in terms of size and performances and to interface non-logic functions to data processing devices, when cost and reliability considerations limit the full integration of heterogeneous functions on a single chip, even if technically feasible. The total combination must be designed as a single system and tools and methodology are lacking. At the moment three main challenges exist:

- Standardized modelling tools also for non-logic components compatible with the design of the system at higher abstraction levels;
- An integrated design environments for PCB, package and chip design;
- Tools take into account parasitic effects like heat generation and propagation, related to the close proximity of components in the package and an efficient A/MS simulation capability on the large scale.

Competitive Situation:

At the moment major EDA companies are focusing mainly on tools and design flows for logic devices, which make up 75% of the world market. Specific tools exist for board design and package design, but they are not integrated with chip design, and nothing is available for System-in-Package integrated design. Support for non purely logical functions is also poor and limited to RF design and analogue/mixed mode design, with severe limitations for complex devices. Big companies normally use in-house developed partial solutions, which present standardization and support problems. The most important bottlenecks are:

- missing standards for bare-die-IP (e.g. interfaces electrical and mechanical)
- models of bare die IP and their integration into system simulation
- 3D floor-planning, place and route
- 3D-parasitic extraction methods (concerning stacked dies and/or bond wires)
- standardized design rule description (3D) on package level (enabling die and package DRC)
- test approaches on die and system level, especially for analogue and RF, with links to testing equipment.

The lack of a 3D design-flow for heterogeneous applications prevents the broad application of SiP and stacking technologies in domains as e.g. medical and automation.

Expected achievements / innovation foreseen:

A non-exhaustive list of expected achievements is:

- Initiation of standardization process for bare die I.P.'s;
- EDA compatible design kits for sensors, actuators and other heterogeneous system components;
- Creation of models for non-electrical components and interfaces for SiP design;
- Creation of intermediate, digital/mixed analog and RF levels of abstraction for EDA improvement and making most use of existing levels for verification, validation, testability and repair.

- Development of a platform that enables the delivery of reusable IP for microsystems and other heterogeneous systems and is compatible to existing EDA environments;
- Creation of a design flow for Heterogeneous functions;
- Technologies for chip, package and board co-design with multi-scale simulation tools.
- Technologies for implementation of heterogeneous SiP and 3D-stacks (3D parasitic extraction, 3D-DRC)
- Testing approaches for non-logic functions.
- Test strategy for SiP and 3D integration, considering also the interface to testing equipment.

6.3.3 Grand Challenge 3 "Design for Reliability and Yield"

Description:
"Design for Reliability and Yield" aims at the development of design technologies to compensate the effect of parameter variability, parasitics and aging effect on yield and reliability of semiconductor devices.

Following CMOS scaling to deep submicron regions, intrinsic device reliability of transistors cannot be any longer guaranteed due to the increase in electric fields and local power densities, and the large number of elements. At the same time critical applications in the field of Automotive and Aerospace, Security and Health require very high levels of reliability, often for limited production volumes. Yield, which is determined by the device functionality at time zero over the entire range of application and reliability, which is understood as the extrapolation of this functionality over lifetime, are becoming closely related and cannot be any longer guaranteed by process and design only. Testability, yield and reliability must be inserted by design, starting from the architectural level, and going down to cover parameter spread in the line and parasitic and reliability effects at device level. Therefore models and procedures are required to migrate reliability modelling from transistor level up to system/architectural level.

Competitive Situation:
At the moment variability in circuit design is handled mainly with Monte Carlo simulations, which are quite expensive and extremely time consuming, and some first approaches to include reliability and variability in compact models. Further progress is needed in moving to compact model-based simulation flows and to cover analogue and mixed-signal circuits in the presence of parametric degradations are directly influencing the performance of the block. Tools and flows should cover the interactions among components (EMC, thermal management) and allow interfacing reliability issues among the blocks that form the complete system. New design approaches must be developed to increase and verify device testability, also for non-logic functions, interfacing testing equipment.
Europe is quite innovative in the Design Technology and EDA area. CATRENE released in 2009 a new version of the EDA roadmap, which is internationally recognised. The innovations often

are coming out of IDM companies and from SMEs. Some of these EDA companies have achieved unique breakthroughs. They are focussing on supplementary solutions to large EDA tools in the area of design support in face of varying parameters, changing technologies, and parasitic effects. More approaches are available throughout Europe in academia, which are not covered by the mainstream tools from the big USA based EDA companies. These efforts should be strengthened in order to meet the special European needs (heterogeneous system integration and safety relevant applications) and to keep some independence of the large mainly US-based EDA companies.

Expected achievements / innovation foreseen:
A non-exhaustive list of main expected achievements:

- Methods to extract independent, uniform distributions out of device characterization data for e.g. Monte Carlo simulations;
- Faster simulations to handle complex circuits and large number of influencing parameters as well as methods to handle non-uniform distributions;
- Methods to transfer variability and reliability information over different levels of abstraction;
- Tools and flows to handle simultaneously in the design optimization both process variability and lifetime related parametric degradation;
- Design and testing approaches for failure detection, localisation and repair during application (and tools to verify them);
- Design and testing tools for fast and efficient yield learning

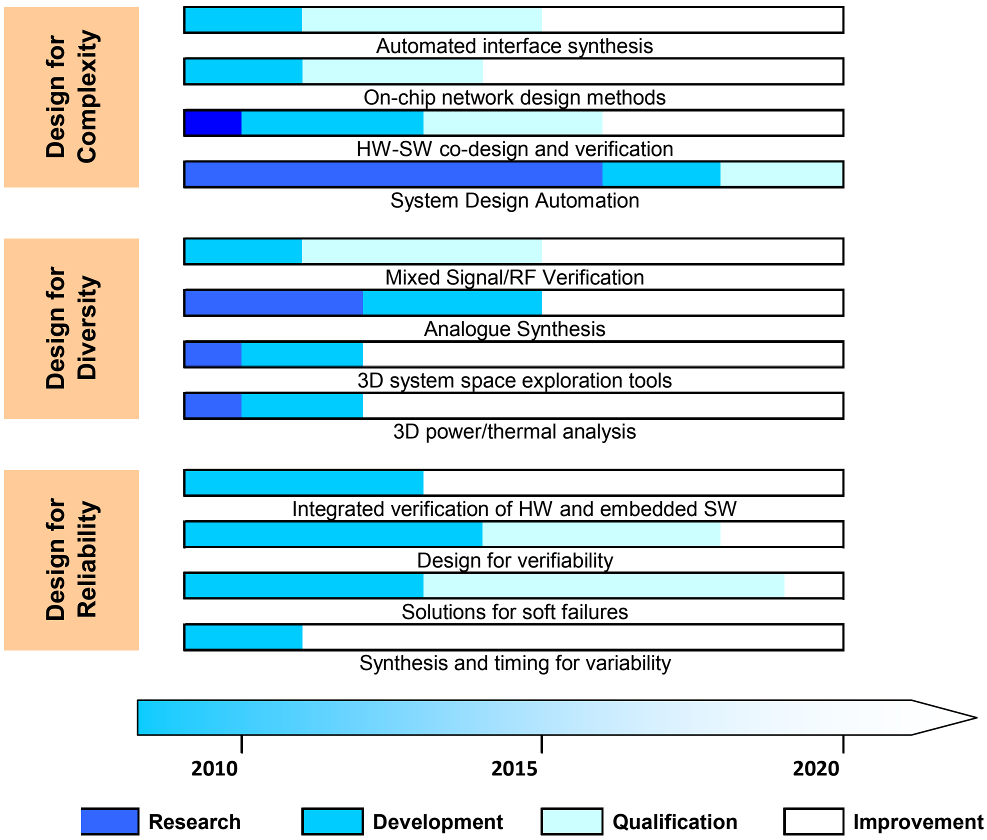
6.4 Conditions for Success

- Availability of funding for projects targeting the development of basic design tools and flows of wide use, and not related only to specific applications;
- Possibility of involving all needed actors to complete the supply chain;
- Wide European participation to get critical mass to standardize solutions;
- Project continuity in order to match the evolution of design methodology to the technology development and the increased demands from applications.

6.5 Timeframes

All three grand challenges need to be met in parallel, since all elements are required to design reliable new applications. A detailed analysis of the requirements of Design Technology is given in the European EDA Roadmap, periodically updated with the support of CATRENE organisation, that gives a roadmap for 16 main design technology components. An indicative roadmap of some major tools and flows, taken from ITRS 2009, is reported here below.

An indicative roadmap of some major tools and flows, taken from ITRS 2009, is reported here below.



6.6 Synergies with Other Domains

Possible synergy areas with other priorities are (not exhaustive):

- Design for Safety and Reliability with application projects in "Automotive and Transport" and "Health and Aging Society".

- Design for complexity includes tools for reducing power dissipation, which is essential for "Communications" and Health and Aging Society"

- Design for diversity includes sensor integration 3D and SiP design, essential for "Communications", "Automotive and Transport" and "Health anf Aging Society"

- Failure analysis and reliability procedures related to high temperature, high current/voltage operation will also be an issue for Sub-programme: “Automotive and Transport” and “Energy Efficiency”

- TCAD and modelling of device reliability and variability will be synergic to “Silicon Processes and Integration”

- Design for diversity implies strong cooperation with “equipment, Materials and manufacturing” especially on package modelling.

- Testing development, especially for 3D and heterogeneous components requires synergy with testing equipment development.

CHAPTER 7: SEMICONDUCTOR PROCESS AND INTEGRATION

7.1 Introduction

A significant part of the success of the semiconductor industry in the past decades is due to the fact that generic semiconductor technologies are used throughout a wide range of applications and that the associated R&D cost can be shared among many different markets. It does translate into the fact that in most cases the semiconductor process development in nanoelectronics is driven by pure technological progress and can't be linked to a specific application domain. There is thus a need to identify the R&D on generic semiconductor process and process integration as a cross-cutting priority.

Generic technologies develop along three directions:

- **miniaturization** bringing a much higher integration density along with a lower cost and power consumption per function. This trend – called 'More Moore' – is crucial for digital data processing and storage which represents more than 70% of the turnover of the IC industry worldwide (i.e. $153B in 2009). Its technical roadmap is defined on a worldwide basis by the ITRS [20] and will not be detailed further in this document.

- **diversification** and **differentiation** of the technologies, which allows a richer functionality of the integrated system. This happens for memories where dedicated applications ask for specific process solutions. This is strongly needed e.g. for interfacing with the outside world and managing the energy / power consumption of the electronic system (this 'More-than-Moore' segment stands for 15 – 25% of the microelectronics market)

- **heterogeneous integration** of components from different origins and technologies in a single package (the associated cost accounts for 5 – 25% of the total cost of a complete semiconductor product). This approach allows the integration not only of electronic functions, but also of many more functionalities performing e.g. mechanical, optical, biochemical tasks for optoelectronic or lab-on-chip systems.

The two later trends are not benefiting from a worldwide accepted roadmap and their technical content will be detailed below.

[20] The ITRS roadmap is available at http://www.itrs.net/.

It is only by combining and mastering these three R&D directions that the European nanoelectronics industry can offer competitive system solutions addressing the European needs. Depending on the application the miniaturized and diversified technologies will be integrated at the wafer level ('System-on-Chip' or SoC) or in a package ('System-in-Package' or SiP).

7.2 Relevance for Europe

The technical roadmap is global, but it is a clear priority for Europe to be state-of-the-art in all these directions owing to the enabling role of these generic technologies. It will allow not only progress of electronic goods in terms of cost, scaling, power / energy consumption and functionality, but also provide technical solutions to the major societal challenges. Developing and mastering semiconductor technologies will support a strong and competitive manufacturing in Europe inducing significant job creations.

7.2.1 Competitive value

Within the last 20 years Europe emerged as one of the key R&D players in nanoelectronics and smart system integration: this technical excellence and leadership should be maintained through a major program in generic semiconductor process.

By driving the development of generic semiconductor technologies Europe will have the potential to develop new standards addressing major emerging markets (e.g. electrical car, smart grid, etc.). Without this appropriation of generic technologies by Europe, the solution to major societal issues will critically depend on the good will of non-European region for supplying the appropriate electronic components.

7.2.2 Societal Benefits

The solutions to major societal challenges (energy, ageing society, security, digital divide, etc.) will critically depend on advanced semiconductor technologies for addressing them: mastering the development of these technologies will thus bring significant social benefits for Europe. Highly skilled personnel will be required to fulfil these objectives and Europe will benefit from the quality of its higher education system.

7.3 Grand Challenges

7.3.1 Grand Challenge 1 "Know-how on Advanced and Emerging Semiconductor Processes"

Vision: ***Develop a European know-how on semiconductor process technologies for mastering future applications.***

Description:

Mastering in advance the knowledge of emerging semiconductor processes is a key asset for developing new products with the right time-to-market.

This is especially true for **advanced CMOS** process where the pace of progress is staggering. Considering that:

- a technology push in advanced CMOS enables and drives high value-added applications
- there is a need to maintain R&D and expertise in Europe to specify and access the latest CMOS and memory technologies
- a critical size is obtained at the European level through the cooperation of the few leading excellence clusters in Europe
- in US and Asia there is a strong involvement of PA's for supporting this industry

it is appropriate to propose a major Europe-wide public initiative on core CMOS technologies in support of a more comprehensive European industrial policy targeting microelectronics. The technical program should be in line with the pace of the technology generations expressed by the ITRS.

Though the process development is mostly independent of the wafer size, the historical trend towards using wafers of **larger diameters** for cost efficiency should be acknowledged. Though the transition in wafer size is mainly equipment and material related (and thus included in the "*Equipment materials and manufacturing*" chapter) it is important to leverage the enhanced capability of the semiconductor processes on larger diameter wafers. More specifically many differentiated technologies are presently produced on 150mm to 200mm: a transition to 200 / 300mm wafers should enable new process integration schemes through more capable equipments. For leading-edge CMOS technologies a transition to 450mm should be taken into account.

A key capability for acquiring advanced knowledge is the availability of leading expertise in **characterization, modelling and simulation** of state-of-the-art semiconductor technologies and devices. This should be addressed not only for advanced CMOS but also for differentiated processes where added challenges appear like multiphysics, multiscale approaches.

Competitive Situation:

In the **advanced CMOS** domain major changes are taking place worldwide and were accelerated by the economical crisis. For Europe it is characterized by opportunities which need to be capitalized upon and trends which should be addressed to benefit to Europe:

- early research in this area is increasingly done in a multi-partner, consortia-level structure, because of cost and risk considerations (IMEC, Albany…). In addition, owing to the cost of developing the latest CMOS generation, some European companies which preserve in-house manufacturing capability in advanced CMOS execute the early R&D for these CMOS generations in clusters, such as the IBM cluster (one of the few major consortia worldwide developing the full CMOS process by gathering many US and non-US partners together). Still the preindustrial development and qualification are made in their European facilities: there is thus a need to *support the CMOS R&D in Europe for accelerating the technology appropriation in Europe*
- some European companies are going fablite or fabless: for them there is a need to *understand the next generation CMOS in order to specify according to their needs the technology nodes which will be implemented in foundries*
- while most of the foundries of advanced CMOS are presently located in Asia one observes the emergence of a state-of-the-art Western foundry producing in Europe: there is a new *opportunity for Europe to compete with Asia in the foundry business*
- at each new technology generation there is a risk that more production moves outside of Europe: it is thus important to *enhance the CMOS pool of expertises to attract more semiconductor production activities in Europe*
- best in class R&D centres are present in Europe which don't exist elsewhere in the world: there is a need to *maintain the viability and expertise of these R&D centres*
- in geographical terms and contrary to other nanoelectronic technology fields (see below) there are few leading regions / clusters in Europe where advanced CMOS technologies are developed. Owing to the cost and time needed to establish such excellence clusters, European programs and calls should acknowledge this situation and *encourage projects to form around the few excellence regions to benefit from the critical mass of expertise*. At the same time it should be a

clear channel to link with and benefit from the smaller research providers especially for exploring disruptive concepts. These clusters will thus induce an efficient spill-over effect benefiting the other European regions.

Characterization, modelling and simulation are a stronghold especially of the European research organization. Commercial activitiess[21] are less developed in Europe.

Expected achievements / innovation foreseen:

Innovations in electronics-enhanced systems and applications are enabled by advanced knowledge in technologies.

A strong European R&D program on **advanced CMOS** is a prerequisite to specify and access the latest technologies and thus secure further growth in European lead markets. Supporting this major program will allow staying state-of-the-art[22] and having a prescription power in the development of miniaturized technologies. It will allow creating value through differentiation in specific process steps and building blocks (see below) whose integration into a CMOS platform requires needs an in-depth knowledge of the development of the MOS transistors. More specifically funded programs should demonstrate advanced CMOS prototyping in line with or ahead of the ITRS roadmap (e.g. 12nm logic CMOS in 2016 or earlier, see Table below).

Equally important one should ensure that **no research gap** builds up between the shorter term projects considered in this document and the more disruptive approaches explored in the "classical" FP projects or other programs. A clear process should be set up to connect with the outputs of these programs such that we can extrapolate from the best projects in stretching "Moore's Law" while preparing a path to the "beyond CMOS" era. More specifically process modules applicable to the next two CMOS generation (i.e. modules for 10 and 8nm logic CMOS in 2016, see Table xx) should be demonstrated as an outcome of the funded projects.

Table: CMOS logic "nodes" according to the ITRS

	2012	**2016**	**2020**
CMOS prototyping	**22 nm**	**12 nm**	**10 nm**
CMOS process modules	18 nm	10 nm	8 nm
	12 nm	8 nm	6 – 7 nm

[21] We are not considering here the equipment industry which is addressed in the relevant chapter.
[22] GlobalFoundries and STMicroelectronics announced the availability of a 28nm process in the late 2010, showing that fabs operating in Europe have the potential to stay in the leading pack

Programs in **characterization, modelling and simulation** should lead to a worldwide recognized leadership of the European R&D players. More specifically some of the techniques developed through funded projects should become strong candidate for (de facto) standards[23].

7.3.2 Grand Challenge 2 "Competitiveness through Semiconductor Process Differentiation"

Vision: ***Develop European competitiveness through semiconductor process differentiation permitting different European business models and supply chains to succeed.***

Description:

Advanced memories are critical components in most systems (communication, automotive, consumer…). There is an opportunity for Europe to take the leadership in **disruptive technology approaches** bringing differentiation with respect to the mainstream technologies (Flash and DRAM). **Technology – system co-development** is another way to bring differentiation in taking into consideration the technology impact of system constraints (e.g. system bandwidth, power / energy consumption, etc.

It is not by chance that the ITRS didn't formalize a full-blown roadmap on **differentiating technologies** (dubbed as **"More than Moore" technologies**) which includes all the non-digital components of an electronic system. In contrast to the development of generic digital CMOS and memories, these technologies are much diversified and represent a strategic field for Europe. Their performance metrics are multifold, they are often driven by dedicated application domains and the target markets operate through different business models and supply chains. It is thus more difficult to give a simple and unified view of the many and often disruptive technologies which are likely to enable new applications and markets.

Most of these technologies are strongly linked to a given application which drives their development: those technologies will be addressed in the relevant application chapters of this document. Here will only be considered technologies:

- generic enough to leverage the high development cost and time on a broad range of applications
- prone to European cooperation among R&D players
- not enough supported in the "classical" Framework Programme

[23] As an example the present compact model chosen by the Compact Model Council was partially developed by Europe.

Following these guidelines this chapter suggests to promote a pan-European effort on generic technologies in the following (non-exhaustive) fields:

- enhanced process genericity for **sensors and actuators**
- **analogue / mixed signal technologies** (e.g. BiCMOS)
- **rf devices** (including passives, rf interfaces, antennas, tunable filters…)
- possibly **power / high voltage devices** and **smart power** though most of the projects are likely to fit within the "Energy efficiency" and "Automotive and transport" chapters
- and **mixed technologies** integrating e.g. analogue / mixed signal with rf and/or power

Competitive Situation:

The industrial landscape on **advanced memories** is evolving fast. It stands for 25% of overall semiconductor market, almost equally divided between DRAM and Flash and there is a strong trend for consolidation. Stand-alone DRAM industrial R&D disappeared from Europe, but innovative NVM companies are active in Europe. Furthermore embedded memories are critical parts in a CMOS chip. Finally Europe has significant assets in this field through world-class R&D centres which don't exist elsewhere in the world.

Europe has key competitive advantages in **differentiating technologies**:

- there is a historical synergy in Europe between system / application companies and component suppliers (incl. SME's)
- a strong R&D and manufacturing base exist and is widely distributed all over Europe

Expected achievements / innovation foreseen:

For **memories**, European industry can profit from the presence in Europe of major application drivers (smart cards, automotive, medical), and from an existing large competence base to further extend its market position, especially through new technologies (e.g. PCM, RRAM) and architectures (e.g. 3D stacking). The funded projects should demonstrate the industrial viability of the disruptive approaches.

By setting worldwide the pace of R&D in **differentiating technologies**, Europe can expect the same benefit as US (and recently Asia) did in aligning the world R&D efforts in the digital technology domain. By developing industrial differentiating technologies all over Europe and by maintaining the synergy between technology and applications one can expect to develop further existing and new markets. The applicability of the developed technologies to a wide set of applications should be one of the results of the funded projects.

7.3.3 Grand Challenge 3 "Opportunities in System-in Package"

Vision: ***develop a European SiP supply chain for innovative systems integrating advanced CMOS and European differentiating technologies through 3D and heterogeneous integration.***

Description:

Integrated complex systems need more and more to combine high performance computing and information storage with dedicated devices for interfaces and energy / power in a single package. While integrating on a single chip different technologies (the so-called "System-on-Chip" or SoC approach) can be useful in some applications, in other cases SoC doesn't bring any competitive advantage in terms of cost and size (e.g. integrating in a single die advanced CMOS having a high cost / mm^2 with large area sensors). Furthermore integrating heterogeneous part gives an added degree of flexibility in bringing in time new system solutions to the market and in adapting to evolving standards.

Considering the complex interplay between IDM, fables companies and foundries, it is expected that for a given system solution components will be supplied from many sources, part of them outside of Europe, enhancing the need to find cost effective solutions to integrate heterogeneous technologies in a single package.

In order to develop generic processes and 3D / SiP[24] standards applicable to many applications domains, Europe should address many technologies in a holistic approach, including:

- methodology and tools system-level co-design[25]
- advanced substrates (incl. embedded devices technologies, innovative antennas, printable wiring also on organic substrates, thick copper power lines, etc.)
- wafer-level integration
- module integration
- 3D integration (incl. TSV, thin wafer technologies, bonding, etc.)
- interconnection (electrical, rf and/or optical) & interposers
- assembly & packaging (incl. wafer dicing and encapsulation technologies)
- characterization and modelling (rf, optical, mechanical…depending on the application)
- test (incl. KGD)
- thermal management
- signal integrity, EMC and reliability

[24] 3D means three-dimensional integration of electronics components. SiP stands for "System-in-Package".

[25] addressed in the chapter on "Design, methods and tools"

Competitive Situation:
There is a clear opportunity for Europe to develop a European SiP supply chain and take a significant leadership worldwide:

- the supply chain of 3D/SiP is not firmly established yet worldwide
- standards for SiP are underdeveloped
- there is a historical synergy in Europe between system / application companies and technology suppliers (incl. SME's). As the technological solutions for heterogeneous integration will be driven by classes of applications a strong interaction between technology development and application domains is mandatory
- there are leading R&D centres in Europe

Expected achievements / innovation foreseen:

3D/SiP heterogeneous integration is expected to act as a key differentiating factor of complex integrated systems: in mastering its supply chain Europe secure its future in many application domains.

Classical assembly and packaging has moved mostly to the Far-East. Innovative technologies for complex packages are partly derived from IC manufacturing techniques and could benefit from the geographical proximity of R&D competence centres in SiP and from IC manufacturing lines: there is an opportunity for Europe to relocate part of the worldwide "back-end" supply chain by setting its leadership in the heterogeneous integration of complex systems.

7.4 Conditions for Success

For the first Grand Challenge a critical mass of funded research should be made available as a factor for success. Owing to the huge cost of building up and maintaining such a research effort – estimated at $1.3B for developing a 22nm CMOS technology[26] –, this public support should be significantly enhanced compared to the present situation and long term public commitment (e.g. 10+ years) should be insured – as done in the last 30 years – despites a fast changing industrial landscape.

Differentiated technologies are interrelated with advanced and emerging technologies. They are not likely to succeed outside of dedicated or niche markets if the first Grand Challenge is not met. Addressing topics outside of the traditional scope of the semiconductor industry (e.g.

[26] see http://www.eetimes.com/electronics-news/4084944/What-is-the-cost-of-fabs-and-R-D-at-22-nm-

biochips) is critical to build new competitive European differentiation factors. The coexistence of the different funding mechanisms should be maintained to accommodate the diversity of the technologies to be developed and to insure the maximum flexibility. The development of European lead markets and standards may help to enhance the existing synergy between European system houses and semiconductor suppliers.

For Europe regaining a significant role in the supply chain of system in package few lead markets should drive the technology with the potential emergence of European norms and standards.

7.5 Timeframes

The timeframe on advanced CMOS is defined by the ITRS roadmap keeping in mind that the most aggressive semiconductor manufacturers try to achieve results earlier than forecasted. It is still expected that a new generation of technology will be developed every 2 years.

For the differentiated technologies (besides memories, analog mixed signal and rf which are also covered by ITRS) it is by nature more difficult to predict few milestones in a domain where progress can be achieved in many different ways.

With respect to the heterogeneous integration of technologies major achievements should be achieved by the end of the considered timeframe especially on 3D integration and the way it redefines the supply chain.

7.6 Synergies with Other Domains

Addressing generic technologies this chapter is synergetic to the application-driven chapters ("*Automotive and transport*"; "*Wireless communications*"; "*Energy efficiency*"; "*Health and aging society*"; "*Safety and security*") in enabling innovative systems and applications.

Semiconductor process development and integration rely critically on the availability of equipments and materials. It is also fully consistent with the development of a competitive European manufacturing. As such it interacts strongly with the chapter on "*Equipment, materials and manufacturing*".

Interaction between design and technology is more and more central for successful products. Characterization, modelling and simulation are classical interfaces between the two domains, but growing interaction is expected between this chapter (especially in differentiating technologies and heterogeneous integration) and the "*Design methods and tools*" chapter.

CHAPTER 8: EQUIPMENT, MATERIALS, AND MANUFACTURING

8.1 Introduction

For semiconductor manufacturing, Europe has a long history of successful mechanical engineering, tailor made machinery, optical equipment, and chemical processing tools. In addition, operating supplies, raw materials, auxiliary materials and substrate materials were offered and developed in leading qualities successfully addressing the global market needs. This history led to a world leading position in several areas, foremost in lithography, metrology and silicon substrates, but also in thermal processing, cleaning and wafer handling. Furthermore, the research centres at IMEC, LETI and Fraunhofer offer world leading process development capabilities which are embedded in transnational development projects. Europe should never neglect its capability in the mainstream advanced CMOS, since it could bring this success story to an end. Mainstream CMOS technology is today somewhat a commodity, and the supply chain markets are solidified.

Figure 1. *Integration of projection optics in ASML TWINSCAN Wafer Scanner. Source: ASML.*

8.2 Relevance for Europe

8.2.1 Competitive value

The competitive value of the Equipment, Materials, and Manufacturing (E&M) industry is twofold. First, E&M products define big multi-billion €, self-sustaining markets. In these global markets, based on technical excellence, the European E&M players have achieved a world leading position in some domains, and act as a powerful European engine for economic growth by themselves. This is underlined by the growing number of more than 100.000 individuals[27] working in the European E&M industry today. Second, the products and technologies

[27] Source: SEMI.

developed by European E&M companies exhibit a high leverage and re-use potential for European core industries. Hence, the R&D activities of the E&M players strengthen the capability of Europe to maintain and develop a profitable and sustainable semiconductor manufacturing base of key strategic relevance both in economic and political terms. Accordingly, a close interaction of the E&M industry with European chip manufacturers and institutes is required to develop E&M solutions and standards that serve the semiconductor industry, e.g. by providing energy efficient manufacturing, and tailored E&M solutions. Figure 2 quantifies this twofold competitive value of the E&M industries noting that the 2009 crisis year numbers underestimate the future stand alone size of E&M markets: VLSIresearch expects semiconductor equipment sales to reach $47.6B in 2010 corresponding to a 95.8% growth from 2009.

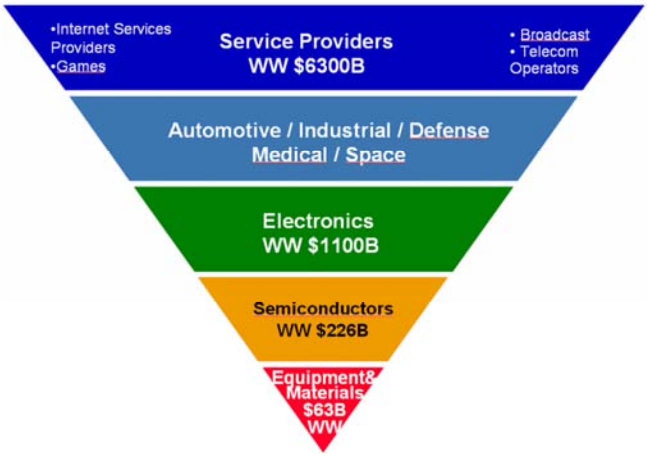


Figure 2. *Economic impact of the E&M industry on key downstream sectors showing the twofold competitive value. Starting from a substantial, self-sustained global market (red triangle), the E&M industry exhibits a huge lever to European key industries (other triangles. Source: ESIA & WSTS European Chapter - June 8th, 2010.*

8.2.2 Societal Benefits

The European E&M industry enables the semiconductor industry to provide new solutions for sustainable growth and key societal needs of the future including e.g. mobility, communication, energy efficiency and health care. With its highly-educated individuals, the European E&M industry provides solutions and innovations which are key to success for many other technology based European industries. Combining this large leverage with success in global E&M markets, the Europe’s E&M industry significantly contributes to an European economy which is based on knowledge and innovation.

8.3 Grand Challenges

8.3.1 Grand Challenge 1 "Advanced CMOS – 1X nm & 450mm"

Description:
This Grand Challenge targets to find new E&M solutions for advanced CMOS that shall enable (i) the nano-structuring of electronic devices with 1X nm resolution in high-volume manufacturing, and in fast prototyping, and (ii) to set common standards and strategies for 450mm E&M. The overarching goal of 1Xnm is to lead the world in shrinking by providing nano-structuring equipment ~2y ahead of the corresponding volume production as scheduled by the ITRS roadmap. Accordingly, research and development is needed to facilitate innovations among others in:

- lithography systems, in particular EUV technology for high-volume manufacturing including tools, optics, and source; as well as NGL technologies including e.g. e-beam and maskless lithography;
- mask technology including infrastructure, metrology, CoO issues, holistic optimization sustaining multiple mask technologies (Immersion, EUV, Mix&Match);
- infrastructure for the new nano-structuring technologies including e.g. materials, wafer, resist, and cleaning;
- metrology including e.g. mask & wafer inspection tools, litho metrology, and data handling;
- yield aspects in e.g. manufacturing science, defect engineering, test, and CAD;
- 300mm equipment & materials;
- nanometer process development including thin film deposition, and ALD processing, specific enabling materials such as copper sources, ALD precursors as well as specific etching and cleaning gases;
- wafer preparation: equipment and processes for polishing, cleaning, wafer thinning and laser marking; and finally
- materials as e.g. substrate materials, chemicals, gases and precursors for next generation processes.
- The overarching goal in 450mm is to create the ability to have European competitive 450mm E&M available when needed by the market. Accordingly, research and development is needed to facilitate innovations as for example in
- open platform technologies, including automation, handling, software, interfaces (hardware and software) and standards;
- SOI ;
- substrates, materials, and facilities ; as well as
- process and metrology equipment.

Competitive Situation:
In E&M for advanced CMOS – 1Xnm and 450mm, Europe has a world leading position in several areas, foremost in lithography, metrology and silicon substrates. The annual market size for 1Xnm is according to ASML at least 5 b€ where EUV lithography alone addresses a large market with an estimated annual volume of ~3 B€ in 2015. The substantial markets for metrology, EUV infrastructure and complementary 1Xnm patterning technologies are additional.
Also for 450mm a potential multi B€ annual market size can be expected as 450mm E&M may become a dominant segment in the world wide E&M market indicated in Figure 2. Forefront R&D for 450mm creates new opportunities to increase the European market share in this competitive domain.

Expected achievements / innovation foreseen:
The key achievements targeted in E&M for Advanced CMOS is to lead the world in shrinking ~2y ahead of ITRS volume production schedule, and to provide competitive 450mm E&M when needed by the market. In a timeframe of five years, European lithography systems shall provide solutions for 1Xnm patterning in high-yield, high-volume manufacturing, and the corresponding mask technology, processes and process control, infrastructure and metrology tools. Furthermore, first European E&M solutions and prototypes for 450mm chip manufacturing shall be available

8.3.2 Grand Challenge 2 "More than Moore"

Description:

More than Moore technologies will create opportunities and demands new skills and know-how, e.g. in 3D heterogeneous integration, new system on chip solutions by synergizing electronic- and biological- (medical) skills enabling aging society and carbon dioxide aware society. The over-arching goal of Grand Challenge 2 More than Moore is to enable European E&M companies to provide sensors, power electronics, rf-, and bio- technology according to market needs. Furthermore, the transition to larger wafer diameters (200, 300mm) is a challenge, and should enable new process integration schemes through more capable equipments.
Among others, More than Moore will address challenges in the fields of:

- back-end equipment: in particular for 3D packaging (wafer level and chip level) and novel approaches in die separation;
- advanced substrates;
- wafer bonding;
- alternative approaches for patterning, such as imprint or roll-to-roll;
- innovative control techniques and data handling based on different statistical basis and different requirements of the customers (e.g. automotive);
- process characterization tools, in-line and in situ metrology and sensors;

- advanced process control capabilities (APC) for high-mix low-volume environments;
- test tools;
- equipment for wafer size transitions;
- 3D high aspect ratio metrology; and
- new materials for packaging, thermal interface materials, and for added functionalities at reduced scales and associated enabling materials (precursors, gases).

Competitive Situation:
More than Moore can be partially sourced from past generation CMOS infrastructures, however new technology generations[28] require new capabilities which are still unsolved manufacturing challenges with large impact to energy efficient electronic systems and not available in advanced CMOS fabs. Furthermore, the constant trend in More than Moore solutions to decreasing feature sizes, with ever more features and interconnects packed on each IC, puts big demands on product validation and verification methodology and, to test equipment. Since to-days equipment is designed for high volume and endless lot production and is therefore less efficient for small lot production, the performance of More than Moore production tools must be enhanced to provide low CoO. This requires in general major modifications or even new design of the equipment.

Expected achievements / innovation foreseen:
More than Moore is creating future opportunity by addressing the increased request for new functionalities. Product volumes per function will be relatively small compared to classical semiconductor production, but in a much larger variety. This provides the European industry with the opportunity to creatively develop More than Moore solutions and so further exploit the wide experience in agile and market sensitive production. Furthermore, the production means must also be adjusted to this kind of market, asking the equipment suppliers to continue the tradition of highly sophisticated but cost-effective equipment. In addition, European E&M companies target to provide sensors, power electronics, rf, bio tech according to market needs. Finally, in order to create an industry wide basis for technology developments, a common More than Moore technology roadmap will be defined, and common standards shall be established.

8.3.3 Grand Challenge 3 "Manufacturing"

Description:
The Grand Challenge Manufacturing focuses on research and development of E&M to enable highly flexible, cost competitive, and "green" manufacturing of semiconductor products within the European environment. The over-arching goal is to develop new E&M solutions that support flexible and competitive semiconductor manufacturing in Europe, and supply world wide market including innovations for resource saving, energy efficiency, sustainability without loss of productivity, cycle time, quality and yield performance; to allow for cost reduction; and

[28] e.g. based on Silicon Carbide SiC or Gallium Nitride GaN or new metallization technologies based on thick copper

to invest in people competency in Europe. To achieve this, new E&M solutions are required in several fields, as for example:

- small and variable size lot manufacturing;
- automation robotics ;
- efficient solutions for data handling and analysis;
- high-performance computing platforms for process control systems and metrology tools;
- fab process control software;
- quality and process robustness ;
- world class yield and defectivity;
- manufacturing robustness (tools and facilities reliability); and
- production environment (people, tool, process).
- These innovative solutions for E&M might address new materials (e.g. quality, defectivity, functionality), new designs (e.g. functionality, robustness, reliability, running cost), new software and automation, new "environmental" solutions (e.g. energy consumption, chemical usage) and innovative human to tool interfaces.

The target is to develop new E&M solutions that support flexible, agile and competitive semiconductor manufacturing in Europe, and supply the worldwide market. Thus, innovations for resource and energy efficiency, sustainability, enhancement of yield and reliability without loss of productivity, cycle time and performance are required to allow for cost reduction and to invest in people competency and IP in Europe.

Competitive Situation:

The topics addressed in the Grand Challenge Manufacturing are of key importance for several fields in European semiconductor manufacturing. They consider both, the strengths, and the challenges of the European semiconductor environment. On the one hand, E&M developments should capitalize on the European strengths, as e.g. the world class level of R&D and engineering expertise, the large technology portfolio, the high expertise level, creativity and stability of human resources, the multitude of SME's operating on very narrow but highly technical fields, and, in particular, the world class level of some E&M suppliers who are creating ecosystem within their activity field. On the other hand, the European E&M developments should consider the European challenges, as e.g. the high cost environment (labour, logistics, services) mainly with regards to Asia, the lack of flexibility (e.g. regulations, employment), the lack of dimension of scale in many small operations, the global character of the E&M market, and the lack of incentive environment for manufacturing.

Substantial market potential is given in e.g. in advanced CMOS high-volume manufacturing solutions that have to be provided according to the ITRS roadmap, and market needs; in More than Moore manufacturing requiring high flexibility in usage of resources, material and equipment; in existing semiconductor manufacturing plants that still exhibit a high potential for energy conservation; and, finally, in new methodologies and information and control tools to enable IC production lines to efficiently manufacture small and variable size lots with the vision down to wafer level manufacturing for already existing fabs.

Expected achievements / innovation foreseen:
The new E&M developments shall support flexible and competitive semiconductor manufacturing in Europe, and be competitive to supply the world wide market. Accordingly, the innovations foreseen must enable solutions for productivity improvement (even at low production volume), resource saving, energy efficiency, and world class performances in quality, yield, and cycle time in all kinds of semiconductor fabs. In addition, cost reduction potentials shall be generated compensating some cost disadvantages of European environment. Therefore, the challenge is to develop generic solutions for current and future fabs which allow, both, the production of variable size lots at high productivity figures, and energy efficient, sustainable and resource saving production of advanced CMOS under high-volume conditions. For example, a successful outcome will be the creation of a high-performance, local hardware and software computing system for process control systems that are useful for multiple European companies. Accordingly, focus topics include among others factory operation methodologies, data acquisition and analysis concepts, factory information and control system, material transport as well as local storage and fully automated equipment loading/unloading.

8.4 Conditions for Success

Due to its profound competences in mechanical engineering, tailor made machinery, optical equipment, and chemical processing tools, and its world leading market position in several areas, Europe has excellent capabilities to become a leader in the world-wide E&M industry. Timing is of the essence, and high technology risks and upfront invests have to taken often many years before a first product reaches the market. Therefore, accelerated and massively intensified European research and development in the field of E&M is required and makes public funding a key success factor for the future of the European E&M industry.

8.5 Timeframes

Grand Challenge 1: Advanced CMOS – 1Xnm and 450mm
The1Xnm nano-structuring solutions to be developed in Grand Challenge 1 shall be available two years ahead of the point of time that the ITRS Roadmap schedules the start of high-volume IC manufacturing. For example, the ITRS roadmap schedules 16nm half-pitch FLASH / DRAM manufacturing for 2017 / 2019. Accordingly, the 16nm nano-structuring solutions enabling this technology shall be available from 2015 on.
The introduction of 450mm wafers to high-volume manufacturing is currently expected around the year ~2018. This means that first exploratory tools shall be available from the year ~2011 on.

Grand Challenge 2: More than Moore
The timing for the new E&M solutions for More than Moore is to be defined in the More than Moore roadmap which will be developed as part of this Grand Challenge. It is also important to

take advantage of other domains. The fast implementation and adaptation of new technologies will pave the way of More than Moore technologies for tomorrow.

Grand Challenge 3: Manufacturing

The new E&M solutions for Manufacturing shall be developed according to the market needs as defined in the ITRS roadmap and according to the state of art manufacturing practices mainly from Asia where semiconductor manufacturing is deployed at large dimension of scale and strongly supported by the stakeholders of semiconductor arena. Improving manufacturing efficiency, enhance yield and reliability is an ongoing task and has to be done in accordance with other domains More Moore and More than Moore.

8.6 Synergies with Other Domains

All Grand Challenges clearly exhibit synergies to the domain of “Silicon Process and Integration”. Furthermore, synergies exist to the domain of “Design”, in particular between More than Moore and package modelling, but also in the areas of design for test, and design for test tools.

ANNEXES

ANNEX 1: CATRENE

1. CATRENE: an EUREKA Cluster for micro-nanoelectronic R&D actors

EUREKA Clusters are a EUREKA success story. In terms of project funding they represent more than 70% of the EUREKA portfolio. They feature a high industrial participation, with an extensive – and increasing – level of SME participation. The success of the Clusters relies on the opportunity for member countries to support national companies in major strategic technology fields which are in line with domestic priorities. The willingness of member countries to provide funds is connected to the expectations in terms of economic impact, or contribution to resolving the "Grand Challenges" for their country in the short and medium-terms.

For more than two decades, the EUREKA JESSI , MEDEA, MEDEA+ and CATRENE programmes have made it possible for Europe's industry to reinforce its position in semiconductor process technology, manufacturing and applications, and to become a key supplier to markets such as, but not limited to, telecommunication, automotive and transport, industrial applications, equipment and materials while addressing the emerging societal needs.

Within EUREKA, Europe's industry has managed projects which provided the key technologies, equipment and design methods needed in order to keep and reinforce these leading positions.

CATRENE, the successor of the MEDEA+ programme, was labelled by EUREKA E !4140 end of 2007 for 4 years and specifically Public Authorities from Austria, Belgium, Finland, France, Germany, Ireland, Israel, Italy, Spain, Sweden, The Netherlands and Turkey expressed their interest to fund the CATRENE labelled proposals.

1.1 Connection with EUREKA Organisation and PAs

Recently CATRENE and other EUREKA Clusters decided to create an Inter-Cluster Committee which aim is to improve the communication within the EUREKA network. The Committee spokesperson - E. Villa, CATRENE Chairman - will now be invited to the EUREKA decision bodies meetings in order to reinforce the interaction between EUREKA PA representatives and the Clusters.

During the last EUREKA Ministerial Conference (June 2010) , EUREKA organisation welcomed the Inter-Cluster Committee and acknowledged EUREKA Clusters strategic role in fulfilling the vision of EUREKA as expressed in the EUREKA Strategic Roadmap. Indeed, EUREKA encouraged the Clusters to address the so-called Grand Challenges.

CATRENE, as other Clusters, are in regular contact with its stakeholders and particularly with the Public Authority (CATRENE Directors Committee (CDC), CATRENE Public Authority (CAPA), NPCs and HLG) representatives in charge of EUREKA programmes in their respective countries. Regular meetings with these representatives are organized in order to share comments on proposals and address items in relation with the Cluster operation and strategy.

The interaction between CATRENE and Public Authorities takes place at 2 levels:

- With the CATRENE Board, the Public Authority Directors meet twice a year in order to address strategic issues related to the CATRENE programme progress and evolution.
- On average every 2 months, CATRENE and CAPA members exchange on the status of the Call proposals and projects progress. In addition CAPA members give a feedback on proposals/projects in term of eligibility for funding.

CAPA Group is composed of Public Authority representatives in charge for their respective countries of the funding strategy for the domains of CATRENE.

CAPA is a key group in order to manage good interaction and communication between industry and Public Authorities. On top of the exchanges on proposals and projects, CAPA and CATRENE Support Group analyse and prepare decisional guidelines for the decision makers of Industry and Public Authorities.

This level of exchange has created trust and has eased evolutions in the MEDEA+/CATRENE programme operation and organisation when identified necessary. The recognized flexibility of the Clusters is linked to this privileged relationship.

1.2 Guideline for the Clusters

According to the EUREKA Clusters guidelines, Clusters are long-term, strategically significant industrial initiatives. They usually have a large number of participants and aim to develop generic technologies of key importance for European competitiveness.

Clusters are initiatives proposed and led by industries. A wide industrial participation is strongly recommended by EUREKA in collaboration with universities and research institutes.

Usually and in order to manage their activities, Clusters create a legal entity (an industrial association for example) whose members cover the operating costs.

Following the EUREKA bottom-up approach, the Clusters organize themselves differently to reflect their individual scope, members, goals and objectives.

To get the EUREKA label, a Cluster should present the Cluster project form with 2 strategic documents:
- A White Paper defining the Cluster programme in which the rationale, vision, strategies are described with competitive and technological challenges,
- completed with a Technology Roadmap developing the technological direction with, in particular, identification of end users' needs and enabling technologies that have to be mastered in order to satisfy these needs.

Clusters are responsible for the generation of R&D projects according to their specific goals and objectives as stated in their White Paper and Technology Roadmap as well as for the technical evaluation and endorsement of the projects.

EUREKA requests that Clusters provide to EUREKA organisation regular project updates and other relevant information.

Clusters can stimulate the generation of R&D projects using the means they consider most suitable for their own goals and objectives, including periodic and thematic Calls.

Clusters evaluate all projects proposals according to a set of predefined technical criteria. Positively assessed proposals receive a Cluster label. A funding application still needs to be done individually by each project partner with the funding body of its country.

In that respect CATRENE organizes one Call for proposals per year, and during all the proposals evaluation process, regular meetings take place with Pubic Authorities in order to collect their comments and to prepare funding decision.

In term of project monitoring, CATRENE requests for each project, and on a bi-annual basis, technical reports completed by a yearly on site review. In addition CATRENE prepares every 6 months a Programme Review Report which summarizes the status of all projects completed with a market analysis and a domain roadmap synthesis.

Each year CATRENE receives 15 to 20 new proposals and monitors around 25 projects.

1.3 CATRENE Interaction with Other EUREKA Clusters and JTIs

CATRENE belongs to the first EUREKA cluster line approved by EUREKA (JESSI started in 1989, followed by the MEDEA, MEDEA+ and CATRENE programmes) and remains one of the most important clusters of EUREKA. This line initiated a European vision and strategy for the European R&D players. And also new clusters, when created, benefited from this pioneer cluster line experience.

This created a tight connection with other clusters particularly when activity had connection with the MEDEA/CATRENE one. As an example with ITEA2 and EURIPIDES, CATRENE is cooperating to use and implement the same management tools and operational process.

In electronic and information systems, complexity of system is continuously increasing and, at the same time, more and more of the complexity is integrated in nanoelectronics components. This trend was observed in the contents of MEDEA+ projects and more in CATRENE projects. In this way it is noticed an increased demand for both More Moore and More than Moore technologies with more and more embedded software and packaging becoming part of the system solution.

The merge of multiple technologies within a nanoelectronic solution requires enlarging system knowhow in nanoelectronic design house but also pushes to more cooperation. Complex system solutions will require in the near future an enlarge co-operation between the other ICT clusters. At the level of Eureka, it has initiated CATRENE common projects with ITEA2 and EURIPIDES. THOR for example was co-label and the two organisations agreed project handling/management/monitoring in common without the introduction of new tool and procedure.

With the new challenges faced by Europe and the new societal needs, EUREKA with its Clusters is quite organized to manage new project organizations addressing large scope of technical domains and the Grand Challenges emerging from the new societal needs.

In this will of cooperation, CATRENE supported the launch of the ENIAC JTI.
CATRENE provided help for the set up of AENEAS Association (Industry organization member of the ENIAC JU) with logistic support.

The start of ENIAC programme created some confusion. So CATRENE with AENEAS made proposals with Public Authorities so that the co-existence of the 2 programmes would be the most efficient.

This resulted in the finalisation of a co-existence scheme between the 2 programmes, with the definition of a delineation scheme which implementation started from 2010.

And for the preparation of their respective Calls, AENEAS and CATRENE decided to manage a yearly common Brokerage Event. During this event R&D actors are invited to propose project subjects in order to prepare the set up of consortia.

New areas of cooperation between the clusters have been identified in the European Technology Roadmap. Clusters with the other Eureka structures have initiated actions to address issues like:

- improving the level of commitment to the clusters of the supporting Eureka members(industry, national funding authorities, synchronization of funding decisions etc.-Other issues to be considered include the increased participation from SMEs and additional Network members;
- Ensuring the participation and commitment from industry to the clusters
- looking at ways of simplifying procedures and shortening the "project endorsement life style".

1.4 Multidisciplinary approach with Clusters and ETP

The new Eureka Strategic Road Map indicated that "the willingness of members countries to provide funds to Eureka clusters is connected to the expectation in term of economic impact or contribution to resolving the "grand challenges" for their country in the short and long term", "grand challenges" being defined as "long-term societal challenges, such as climate changes, ageing society etc."

ICT is the driving for all those sectors. ICT technology are indeed considered more and more as priority to help other sectors involved into a sustainable environment. To "move toward more sustainable and efficient economy, to ensure harmonize use of nature and resources, to mitigate effect the effects of climate and to preserve our environment", the European Commission suggests to "make extensive use of connectivity and distributed information processing to redesign their business and operational processes and make them 'smart'.

The concept of disciplinary approach is that R&D thematic areas related to these grand challenges are cross sectors (multi-disciplinary)and requires the joint effort of different actors. The Eureka cluster would be the main implementation instrument to a multi-disciplinary approach related to the cross sectors grand challenges. Indeed their flexible structure allows them to be immediately operational for cross-sector co-operation. They already involve all main stakeholders of the ICT, energy, water and manufacturing industry, whether large companies, SMEs and academic institutions, thus allowing for a quick mobilization.

Multidisciplinary projects can be launched without any major change in the current clusters performing and transparent management and procedures which are a combination of the standard CATRENE, and more in general Eureka clusters, bottom up approach with some strategic orientations.

With the increasing variety of instruments of the ERA (Framework programmes, ETPs, JTIs, EUREKA programmes…) and thanks to their successful results, Clusters are identified as playing a leading role in the new ERA landscape, looking for cooperation and complementarities.

2. Structure and operation of CATRENE

2.1 Organisation

The scope and purpose of the CATRENE organisation is to stimulate, organise and co-ordinate research and development work within the goals of the CATRENE programme executed by CATRENE partners. The CATRENE organisation is a non-profit organisation.

The CATRENE organisation has a high degree of self-organisation in which the industrial partners are the main pillars.

The programme works in a bottom up mode. Within the frame of a White Book, the programme relies on the initiatives of individual R&D actors to decide in which areas proposals are put forward and implemented. In this way projects are therefore close to industrial needs and are market-oriented.

The CATRENE organisation is based on decision bodies (Board and Support Group), and Experts group (Steering Groups and Scientific Committee), with a dedicated team (CATRENE Office) in order to manage the day to day operations.

An important asset of the organisation is the involvement of high level representatives (CEOs or CTOs) of the leading European nanoelectronics and electronic equipment companies who are members of the CATRENE Board.

These high level representatives are not involved in the day to day management; they have delegated major parts of the decisions to the Support Group which is set up to act on behalf of their companies.

In this way, the Support Group gives guidelines for projects priorities and selection, makes decision for labelling and decides on major project Change Requests. In addition the Support Group is the contact point with CAPA. The Support Group is also a managing body for roadmap documents (Strategic document, market orientation and guidelines, White book…). Finally, the Support Group reports to the Board and prepares with CATRENE Office proposals to be approved by CATRENE Board.

The main activities of CATRENE are related to the management of Calls for proposals and the monitoring of projects. In order to assess the wide scope of techniques which are now addressed by CATRENE Projects, two Expert Groups - Steering Groups - are in operation. The first one is managing proposals and projects which are Technologies oriented and the other one, proposals and projects which are more Applications oriented.

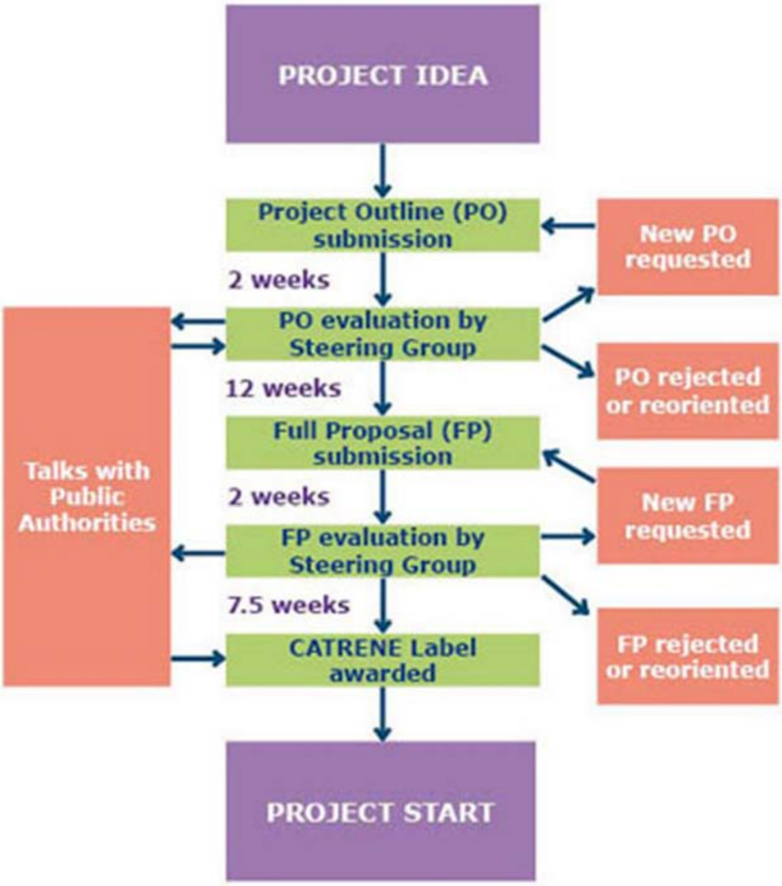
Each Steering Group has around 15 experts lead by a dedicated member of the CATRENE staff. The main activities are technical evaluation on proposals, labelling proposals, monitoring of project progress with decision on project reports. Steering Groups are also involved in the completion of roadmap documents (i.e. EDA roadmap, market orientation, White Book….).

Via its projects, CATRENE is preparing the European industry to the market needs. But CATRENE is also concerned by the medium to long term aspects.

In this way the CATRENE Scientific Committee (CSC) is a council group whose main mission is to report on the latest advances and technological trends, and to highlight potential subjects which could become of key importance for the nanoelectronics industry in the future. The CSC also manages tasks defined by CATRENE Board, which leads to the elaboration of a specific study on average every 2 years. The Committee reports to the Board, and presents on a regular basis its activity’s status to the Board and Support Group.

2.2 Call Management

CATRENE organises one Call for proposals per year. And the selection process is summarized by the following picture:



Before labelling, a proposal has to follow a two phase process, i.e first a Project Outline phase followed by a Full Proposal phase.

The answer to the Call is done via the submission of a Project Outline. At the end of the PO submission phase, this document (around 20 pages) is reviewed by 2 experts of the CATRENE Steering Groups. The Steering Group team consolidates the experts' reviews and declares the PO either rejected or to be amended or eligible for preparation of a Full Proposal. Comments resulting from the Steering Group consolidation are provided to the CAPA members.

The Full Proposal is an update of the PO document in which particularly the project organisation, schedule and tasks with list of deliveries are detailed. In addition this document must answer to comments and recommendations delivered both by CATRENE and Public authorities during the PO phase.

Similar to the PO phase, the FP must be delivered before the end of the FP submission phase and after review and consolidation the FP is declared either rejected or to be amended or eligible for labelling.

The main criteria for project selection are the following ones:

- Commitment to CATRENE vision and objectives
- Innovation in basic and industrial research
- Existing European R&D capacity
- Competences of the partners
- Strengths of the consortium ("team effect")
- World market potential
- Leverage effect on employment
- Meeting societal needs

A labelling is proposed by the Steering Groups and accepted by the Support Group.

The main rules in Steering Group operations is to keep as much as possible the same experts (on average 2 per proposal/project) from the proposal selection phase till the end of the project. In addition, the potential conflict of interest is controlled by the selection of experts who are not in companies involved in the proposals under evaluation and all experts' reviews are shared within the Group first in order to consolidate expert evaluations and second to detect potential biased evaluations.

The experience accumulated by JESSI, MEDEA and MEDEA+ has resulted in the set up a of multiple interaction process in order to allow updates on Project Outlines and on Full Proposals taking into account the comments fed by Public Authorities and CATRENE experts. This process leads to quality improvement proposals while taking into account Public Authorities guidance on funding issues and eligibility criteria.

2.3 Project Management

Once the project has started, after funding decision by Public Authorities, then the CATRENE Office monitors the project progress.

A technical report is requested twice a year and an on-site review is managed every year. The reports are reviewed by the Steering Groups. Such a review may generate requests for more information or corrective actions. These reports are mandatory to follow the project progress and detect any deviation from the original plan.

The life of a project may face various unexpected phases. Technical issues, consortium reorganisation following a partner participation reduction or withdrawal (funding issue or reorientation of partner R&D strategy priorities…) are among the most common source of project re-orientations.

In order to update the project plan, such re-orientations are described via Change Requests, which are amendments on the original Full Proposal.

The Change Requests are also reviewed by the Steering Group who judges if an amended project remains of interest according to the main criteria used for proposal selection. The result may lead to the Change Request approval, a request for modification (usually more information are requested before approval) and worse the CATRENE label is withdrawn because after amendment the project is no longer in line with CATRENE programme principles (innovation, technical and economical results...).

As a matter of fact, the management of Change Requests is a rather important activity for the CATRENE Office, it leads to secure a high quality level on project results.

During the meeting with CAPA, project status are addressed, because some Change Request approvals also need an agreement by Public Authorities (change in funding allocation for example).

3. CATRENE 0bjectives, Goals and Work programme

3.1 Objectives and goals

CATRENE will address mostly Technologies and challenges involving a smaller number of Members States and/or partners. In line with the ITRS, the CATRENE objectives will guarantee the access to the most advanced More Moore and More than Moore technologies with manufacturing capacity in Europe.

The access to most advanced technologies manufacturing capacity is deeply linked with the use of most advanced equipments and materials.
Europeans equipment and materials suppliers will maintain close connections with market leaders in order to develop their technological leadership. CATRENE will consolidate and build their world leadership positions .The reference in these domains is made to lithography, metrology equipment and materials as advanced substrate, SOI and gaz precursors. The existing world leading position of European E&M companies generate economic growth in Europe thanks to their world market share.

In order to answer to the market and societal needs, CATRENE will help to master both More Moore technologies and More than Moore technologies in Europe. R&D actors insist on the fact that Europe has to be careful not to lose contact with More Moore technologies in order to maintain the long term competiveness and innovation leadership in More than Moore. CATRENE will work in tight connection with existing Clusters in order to enhance the existing eco-system. In top of this will support manufacturing sciences and manufacturing capability in order to be in a position to further improve.

It is well recognized that Eureka frame is a dynamic and flexible tool, market oriented, and the limited number of partners is key to guarantee the protection of intellectual property rights. CATRENE offers the needed processes which ensure the high quality of programme/project by continuous improvement taking into account through the change requests the necessary adaptation to a changing landscape. CATRENE is therefore the recommended tool for multi-disciplinary and multi-clusters projects. In that respect CATRENE is well adapted to fit all new activities/innovations issued from various scientific domains to be embedded in nanoelectronic devices or to be adapted to any semiconductor activities.

CATRENE is bottom up organised and close to the market. CATRENE will concentrate its R&D activities in order to discover innovative solutions for key building blocks or sub-systems, specific appliances, tool and technology, equipment and material, like (non-exhaustive):

- Devices and products for automotive, transport, industry, automation and energy efficiency
- Devices for health care and medical application
- Devices for communication systems (One chip phone, high speed optical transceivers…)
- Sensors and actuators, MEMS
- Design Technology (Architectures, Design Methods and Tools, EDA, TCAD, DfM, DfR, DfT …)
- More Moore and More than Moore technology development
- Specific equipment and material development (lithography tools, SOI, SiC, etc)
- 3D technologies and associated CAD tools
- 450mm equipments and materials
- Manufacturing sciences

MEDEA+ generated value to Europe and CATRENE will continue to improve the economical return by capitalizing in the following and non-exhaustive list of major MEDEA+/CATRENE already programmes successes[29] .

- Europe is on a par with global competition in advanced basic CMOS process developments (100 nm to 45 nm). One European company has been amongst the first manufacturers in the world to offer a 45 nm Low Power technology.
- Fully integrated technology platforms for embedded Non Volatile Memory. In these markets European companies are recognised leaders.
- European leadership in Lithography with worldwide market-share >70%.

[29] For the time being comparison with ENIAC is not possible due to the fact that ENIAC is a recent initiative with only running projects

- Innovations at material and substrate levels boosting device performance and strengthening European competitiveness. European leadership in SOI with world-wide market share >70%
- Breakthroughs in wireless broadband (low-cost version, convergence fixed/wireless) and multimedia systems and terminals, consolidating the European leadership in Mobile Communication.
- In automotive electronics, essential contributions to platform development, substantial achievements in reliability, safety and intelligent features for vehicles.
- European smart card and security activities have created standards and technologies as enablers for new applications, dominating the global smart card market.
- Mature 3D integration technology platforms and innovative packaging SiP.
- Europe is one of the most innovative regions for EDA and design technology. The well recognized CATRENE EDA roadmap demonstrates this European innovative position. On top of the update of this roadmap, CATRENE will work with its partners on how to develop more business in Europe.

3.2 Work Programme and Implementation of delineation

The implementation is based on the delineation agreement from January 19, 2010 applied on the work packages defined in the "Vision Mission Strategy" paper.

The delineation will be applied to the main objective/goal of the project. This does not prevent to embed in the project specific objectives not attributed by the delineation paper to the main objective/goal.

3.3 Technology domain

Technology programme will support the following work areas mentioned in the VMS: micro- and nanoelectronics:
1. Semiconductor process and integration
2. Equipment, Materials and Manufacturing

3.3.1 Semiconductor process and integration

For the coming years, CMOS will remain the basic technology for integrated circuit, even if research on alternative devices has led promising results. The International Technology Roadmap for Semiconductors (ITRS) provides global long trends, which drive the continuous evolution and will pave the way of the technological breakthroughs. These alternative devices coming from the diversity will bring new ideas/options to the CMOS process and will contribute to the integration of new materials, equipment/techniques and will provide new sources of technological breakthroughs.

The related technologies are:

- More Moore Technologies: Technologies platform for the next generation core CMOS processes and advanced nodes development.
- More than Moore technologies: Technologies platform for CMOS process options and Non-CMOS technologies, e.g. for RF, Sensors and actuators.
- Heterogeneous integration technologies: Silicon in Package, System on Chip, Bio technologies integration, photonic devices...

3.3.2 Equipment, Materials and Manufacturing

This work area is an indispensable enabler in the supply chain of future semiconductor applications. The rapid evolution of the semiconductor industry is supported by the timely development of equipment, materials and processes.

This work area leads (list not exhaustive):

- the 450mm supply chain : tools and materials.
- the innovations for the advanced node for 22 nm and below.
- the innovations for more than Moore options and heterogeneous integration
- The manufacturing science and the cross cutting technologies.

3.4 Applications domain

The CATRENE Applications domain will support all the application work areas mentioned in the VMS: CATRENE will address innovation research with well-focused efforts with projects requesting some key partners with dedicated national support.

Applications in CATRENE projects can be:

1. A new technology which is demonstrated by an application to demonstrate the performance of a new process some sub-systems or building blocks can be developed to compare performances with existing state of the art. Example is the new MEMS technology which offers denser solution for RF. Here IP protection is key, players are limited.
2. Or, the definition and development of new subsystems/building blocks for a given/existing application, for example is a new processor core or another example is an innovative wireless modem solution for 3.5G mobiles. IP protection is key, the number of players is most probably limited.
3. Or, a new platform or solution for an existing application or system: e.g. innovative device/product. In this case IP handling is key with a limited number of partners.

3.4.1 Communication and digital lifestyle

Devices, improvement of existing solutions and stand-alone complex products (e.g. LTE solutions, parallel antennas use, MIMO, RF technologies for sensor network, high speed optical communication systems,…). This list of examples is not exhaustive.

3.4.2 Safety and Security

The emphasis will be placed on improvement of existing solutions and stand-alone complex products (e.g. trusted platforms, smart-card security issues). This list of examples is not exhaustive.

3.4.3 Automotive and transportation

This work area deals with devices and stand-alone complex products for automotive, transport and industrial applications. Special attention will be given to introduction of multi-core technology, advanced reliability research (e.g. EMC), reliability and safety from components (e.g. sensors) and subsystems, reliability and safety in operation and control and communication, appropriate multi-access / multi standard communication gateways, intelligent electronics for security and privacy protection. This list of examples is not exhaustive.

3.4.4 Health and the aging society

The focus will lie on devices for healthcare and medical appliances. Examples are e-inhalers, MEMS actuators coupled with low power logic and energy scavenging, improved and combined image detectors for more precise and earlier detection, bio-sensors. This list of examples is not exhaustive.

3.4.5 Energy efficiency

In this area CATRENE will focus on new materials, devices and stand-alone complex products. Especially power efficient designs in devices will have the attention in the context of reduction of energy consumption of electronic components. This list of examples is not exhaustive.

3.4.6 Design Technology

One of the main focuses of the application programme is Design Technology. Design Technology is split into application driven (EDA, Electronic Design Automation) and physical and manufacturing driven Design Methodologies and Tools (TCAD, Technology Computer Aided Design).

The programme will be led by the (internationally recognized) European Design Automation Roadmap. The CATRENE association will continue to play an important role in maintaining the roadmap. CATRENE is organising a Design Technology conference every year since 1998 in order to disseminate the programme results.

ANNEX 2: ENIAC

1. ENIAC JTI

The ENIAC Joint Technology Initiative (JTI) is an ambitious approach to large-scale public-private partnerships in nanoelectronics - a field of major interest for European competitiveness.

It aims at combining national and Community funding within a clear legal structure in a harmonised and synchronous manner. It also fosters collaboration between stakeholders including industry, small and medium-sized enterprises (SMEs), national and community authorities, and academic and research centres with the aim to pull together and to focus the research and development efforts.

Through a research agenda commonly agreed upon by the stakeholders, the ENAC JTI identifies and regularly reviews research priorities for the development and adoption of key competences for nanoelectronics across different application areas in order to strengthen European leadership and to stimulate the emergence of new markets and societal applications.

As such, the ENIAC JTI addresses the following objectives:

- enhancing the further integration and miniaturisation of devices, and increasing their functionalities;
- delivering new materials, equipment and processes, new architectures, innovative manufacturing processes, disruptive design methodologies and new packaging and ‘systemising’ methods;
- driving and being driven by innovative high-tech applications in the area of communication and computing, transport, health care and wellness, energy and environmental management, security and safety, and entertainment.

In order to implement the ENIAC JTI and all of its objectives, the ENIAC Joint Undertaking was set up as a legal entity for a period up to 31 December 2017 under Article 171 of the Treaty of the European Community.

2. ENIAC JU

2.1 Organisation

Set up in February 2008, the ENIAC Joint Undertaking (JU) is the legal entity responsible for the implementation of the JTI on nanoelectronics.

The founding members of the Joint Undertaking for nanoelectronics include the Community, a list of participating Member States and AENEAS, an association representing companies and other R & D organisations active in the field of nanoelectronics in Europe.

2.2 Objectives and goals

According to the Council Regulation setting up the ENIAC Joint Undertaking, the objectives of this public-private partnership are to:

(a) define and implement a Research Agenda for the development of key competences for nanoelectronics across different application areas in order to strengthen European competitiveness and sustainability and to stimulate the emergence of new markets and societal applications;
(b) support the activities required for the implementation of the Research Agenda, notably by awarding funding to participants in selected projects following calls for competitive proposals;
(c) promote a public-private partnership aiming at mobilising and pooling Community, national and private efforts, increasing overall R & D investments in the field of nanoelectronics, and fostering collaboration between the public and private sectors;
(d) achieve synergy and coordination of European R & D efforts in the field of nanoelectronics including, when added value can be created, the progressive integration into the ENIAC Joint Undertaking of the related activities in this field currently implemented through intergovernmental R & D schemes (Eureka);
(e) promote the involvement of SMEs in its activities.

2.3 Bodies of the ENIAC Joint Undertaking

To ensure the achievements of defined targets as well as of daily operations, the management of the ENIAC JU is taken care of by several bodies including:

(a) The Governing Board;
The ENIAC Governing Board (GB) consists of representatives of the members of the ENIAC Joint Undertaking and is chaired by the chairperson of the Industry and Research Committee. It has the overall responsibility for the operations of the ENIAC Joint Undertaking and oversees the implementation of its activities.

(b) The Executive Director;
The Executive Director is the Chief Executive responsible for the day-to-day management of the ENIAC Joint Undertaking in accordance with the decisions of the Governing Board.

(c) The Public Authorities Board;
The Public Authorities Board (PAB) consists of representatives from ENIAC Member States. Amongst other responsibilities, it establishes the amount of funding available for each Call, approves the research priorities as set in the Annual Work Programme and approves the selection of project proposals to receive funding following a Call.

(d) The Industry and Research Committee.
The Industry and Research Committee (I&RC) is made up of representatives of Europe's nanoelectronic R&D community appointed by AENEAS. In consultation with Public Authorities, the I&RC drafts strategic roadmaps for the ENIAC JU and helps define the content of each Call for project proposals. The committee can also submit other propositions to the Governing Board on subjects like fostering partnerships and promoting SME participation in projects.

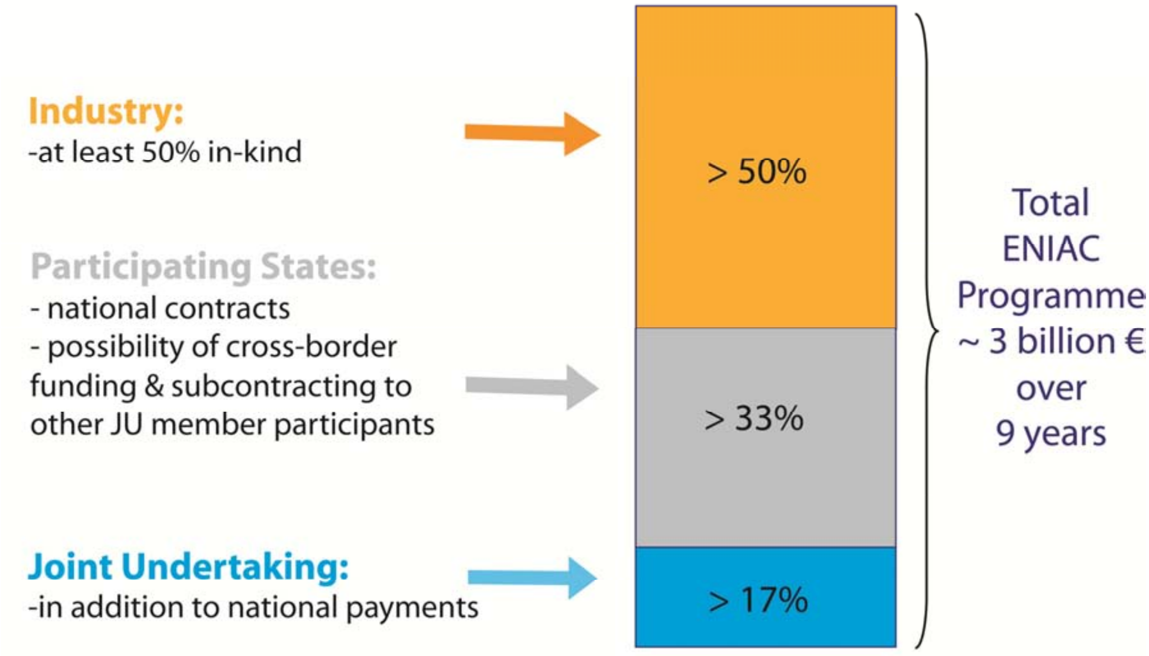
2.4 Call and project management

By pooling resources from the public and private sectors, the ENIAC JU supports R & D activities in the form of R&D projects. To this end, the ENIAC JU organises calls for competitive proposals for projects based on the goals defined in the research agenda.

Selected projects are supported both by financial contributions from the Community and ENIAC Member States as well as by contributions in kind from the R & D organisations participating in the projects of the ENIAC Joint Undertaking.

For each Call for proposals launched and published by the ENIAC Joint Undertaking, the overall budget available is specified. This budget indicates the amounts committed at national level by each ENIAC Member State and the estimated amount of the ENIAC Joint Undertaking's financial contribution. The content of the Calls also states the evaluation criteria in relation to the objectives of the Call and any national or Joint Undertaking eligibility criteria.

The ENIAC Joint Undertaking's funding scheme is based on the following:



The eligible costs for this programme are estimated at 3 billion euro, committed over 6 years.

The Statutes of the ENIAC Joint Undertaking state that the Calls, evaluations and selection of proposals shall respect the following rules:

(a) calls for proposals launched by the ENIAC Joint Undertaking shall be open to participants established in ENIAC Member States and in any other Member State or associated country. They shall be made public;

(b) consortia of participants in project proposals submitted in response to these calls shall include at least three non-affiliated entities established in at least three ENIAC Member States. The prospective participants and their contribution to the project proposals shall be verified by the Joint Undertaking, on the basis of verifications provided by the respective public authorities, against the pre-defined national and Joint Undertaking eligibility criteria for funding. They shall be informed on their compliance, where possible before they submit a full project proposal. These checks shall not result in significant delays in the proposal evaluation and the selection process;

(c) the evaluation and selection process carried out with the assistance of independent experts shall ensure that allocation of the ENIAC Joint Undertaking's public funding follows the principles of equal treatment, excellence and competition;

(d) following the evaluation of proposals, the public authorities board shall establish a ranked list of proposals on the basis of clear evaluation criteria and their collective contribution towards achieving the objectives of the call;

(e) the public authorities board shall decide on the selection of proposals and the allocation of public funding to selected proposals up to the limit of the budgets available, taking into account any national eligibility criteria and the verifications carried out in accordance with point (b). This decision shall also be binding for ENIAC Member States without any further evaluation or selection processes.

The Multiannual Strategic Plan specifies the strategy and plans for achieving the objectives of the ENIAC Joint Undertaking, including the Research Agenda.

The Annual Work Programme describes the scope and budget of calls for proposals needed to implement the Research Agenda for a particular year.

The ENIAC Joint Undertaking Calls 1 (2008) and 2 (2009) resulted in 18 funded projects with more than 450 M€ in eligible costs and included 239 companies from 21 different countries.

3. AENEAS

At the end of 2004, the ENIAC Technology Platform on nanoelectronics was launched to enhance the competitiveness of the European nanoelectronics industry. It brought together the key players in the field to develop a common roadmap with the aim of optimising the effectiveness of investments in R&D. The roadmap was successfully defined and presented in the Strategic Research Agenda (SRA).

Part of the implementation of the SRA involved the creation of two legal entities:
- the ENIAC Joint Undertaking, a public-private partnership to carry out R&D projects,
- the Association of European NanoElectronics ActivitieS (AENEAS).

Established as a non-profit association in November 2006, AENEAS federates the R&D organisations to continue the activities of the ENIAC Technology Platform and to represent its members in the ENIAC Joint Undertaking. With a constant growth in membership, AENEAS has become the meeting place for the European Nanoelectronics community. The strength of the association is due to a diverse representation with large industrial companies, SMEs, research organisations, universities and other associations working together towards a shared goal – ensuring a cost-efficient environment for research and development in nanoelectronics throughout Europe.

The Director General of AENEAS coordinates activities for Europe's Nanoelectronics R&D performers and ensures the representation of AENEAS stakeholders in the ENIAC Joint Undertaking.

AENEAS serves the entire European nanoelectronics community - from its suppliers, to its producers to its users. Members of the Association, from all fields of this technological sector, benefit from ideal networking opportunities. In the framework of AENEAS, organisations can discuss the building of project consortia in order to share the costs of pre-competitive research and development as well as the common results. Furthermore, AENEAS works on behalf of SMEs to advocate for their participation in strategic discussions and partnerships.

Not only do AENEAS members participate and lead projects in the ENIAC JU, they also represent the driving force behind the research strategy which outlines the basis of future project calls. Through a methodical consultation of all its members and partners, the Association pro-actively defines the key objectives of the industry and the measures which need to be taken to ensure competitiveness. To accomplish tasks such as the updating of the Strategic Research Agenda or the Multi-Annual Strategic Plan, AENEAS relies on several working groups. All members of the Association are encouraged to join these different teams.

AENEAS also enjoys a close link to an important organisation in which research scientists and academia are represented, the Scientific Community Council. Its mission is to establish, strengthen and optimise interactions and co-operation between Europe's scientific community and industry involved in nanoelectronics. The Scientific Community Council is considered an essential stakeholder in pursuing AENEAS' objectives and a major building block for the Association. Positions in the presidium of the SCC are exclusively reserved for members of AENEAS chamber B (see below)

3.1 Structure of the AENEAS Association

The Association is organised in 3 chambers: one for SMEs, one for scientific institutes and one for large companies. The 3 chambers are represented in the AENEAS Steering Board which oversees the association's administration and management. The 15 members of the Steering Board are appointed by the General Assembly. From its members, the Steering Board names a Presidium: the President and 2 Vice Presidents of the Association as well as a Secretary and Treasurer who are not necessarily members of the Board.

To technically advise the Board, a Support Group meets frequently throughout the year to propose solutions and closely follow each development. On a daily basis, AENEAS is managed by a small office, led by the Director General, who reports to the president of the Association.

3.2 Connection to the ENIAC JU, other JTIs and Eureka clusters

As an association representing European R&D actors in the field of nanoelectronics, AENEAS cooperates with a number of similar organisations in specialized in the sector.
AENEAS is a co-founder of the **ENIAC Joint Technology Initiative** (JTI) that represents a joint financing mechanism, levering public and private investments, for the implementation of large collaborative transnational R&D projects. The ENIAC JTI is implemented by a Joint Undertaking, a partnership between the European Commission, Member and Associated States as well as European R&D organisations.

Each of the above-mentioned parties is represented in the ENIAC Governing Board to make common decisions which ensure the overall functions and administration of the Undertaking. On this board, European R&D actors are represented by the Industry & Research Committee. This committee is nominated by AENEAS from its members

As a founding member of this partnership, AENEAS pays about 2/3 of the operational costs of the ENIAC Joint Undertaking.

The research and industrial community within AENEAS has also defined, in the Multi-Annual Strategic Plan (MASP), a research strategy on behalf of the ENIAC Joint Undertaking.

By inciting European actors to come together around a project, AENEAS and the ENIAC Joint Undertaking will help avoid the duplication and dispersion of efforts and ensure a critical mass of coherent investments. Thus, they will contribute to the creation of a strong and competitive nanoelectronics industry in Europe which includes the entire value chain.

At the same time, AENEAS shares an office with and benefits of a close working relationship with CATRENE – the Eureka Cluster for Application and Technology Research in Europe on Nanoelectronics.

Together, the Associations have been able to promote European leadership in the field of nanoelectronics through several different mechanisms. AENEAS and CATRENE have co-hosted a variety of different events including brokerage events that help R&D actors form strong and efficient consortia and summits that encourage participation in the elaboration of strategic documents. They have also worked together on numerous occasions to further synchronise the co-existence of CATRENE and the ENIAC JU.

Further cooperation exists between AENEAS and **ARTEMISIA**, the Association for R&D actors in embedded systems. In fact, both organizations have been established along the guidelines of European Technology Platform and therefore share similar structures. And while the organizations focus on different technologies, both have successfully assisted in the establishment of JTIs in their specific domains (ENIAC JTI for nanoelectronics and ARTEMIS JTI for embedded systems). With cross cutting technologies, the organisations represented in both AENEAS and ARTEMISIA are often one in the same. As such, the Associations are brought to work together during conferences to host workshops for example or coordinate their presence at an exhibition together.

4. ENIAC Multi Annual Strategic Plan (MASP)

ENIAC is designed to set up long term relationships between all involved in the European nano-electronics industry. By strengthening and coordinating innovation and investment in nanoelectronics R&D, Europe will contribute to the intense R&D effort that is required for the industrial and research organisations to take part in the global race, while overcoming the current fragmented R&D landscape.[30] The ENIAC programme, from a "top-down" perspective, must address mostly applications and socio-economic challenges of pan-European interest.[31] Annex 2 and in particular the ENIAC work programme of this annex, together with parts A, B and C and annex 3 of this document constitute the MASP, the Multi Annual Strategic Plan of the ENIAC Joint Undertaking, that will be submitted for approval to the ENIAC Governing Board of November 2010.

ENIAC is top down organized. It focuses on socio-economic challenges, which require pan-European solutions with a high participation and acceptance of many European states. Complex systems with a combination of hard- and embedded software solutions of several industry sectors, combined with new standards, like (non exhaustive):

- Electronics for hybrid or electrical cars
- Smart power grid
- Patient surveillance, remote diagnostics
- E-passport and other smart cards
- European GPS (Galileo)
- 3DTV_2G
- Advanced LTE
- Advanced Optical Communication Systems
- Smart integrated sensor and actuator systems
- 3D solutions and standardisation
- 450mm initiative
- Advanced Process Control and Overall Equipment Efficiency

[30] COMMISSION STAFF WORKING DOCUMENT, *Accompanying document to the* Proposal for a COUNCIL REGULATION, Setting up the "ENIAC Joint Undertaking", IMPACT ASSESSMENT, [COM(2007) 356 final, SEC(2007) 852]
[31] See point 22 of annex 3

4.1 Implementation of delineation

The implementation is based on the delineation agreement from January 19, 2010 applied on the work packages defined in the "Vision Mission Strategy" paper.

The delineation will be applied to the main objective/goal of the project. This does not prevent to embed in the project specific objectives not attributed by the delineation paper to the main objective/goal.

4.2 Technology domain

Technologies topics in ENIAC projects being either:

- The technology development is not the R&D core of the project and refer to specific applications where new subsystems/buiding blocks are innovative e.g. applications project oriented(Health Care, Energy efficiency,...)
- The pan-European interest seeks a large number of countries and partners
- The standardization/regulation aspects of the project is put in priority involving large participation of partners
- The technology development has a medium to long term vision.

Technology programme will support the following work areas mentioned in the VMS: micro- and nanoelectronics:

- Semiconductor process and integration
- Equipment, Materials and Manufacturing

4.2.1 Semiconductor process and integration

The Technologies platform for process options (More than Moore) and heterogeneous system integration for differentiated processes involving a large number of European countries and when these technologies are strongly linked to a given application which drives their development.

4.2.2 Equipment, materials and manufacturing

Standardization and infrastructure projects for future technologies and standards exhibiting a medium long term vision and/or involving a large number of actors in Europe as e.g. the 450mm initiative.

The domains of manufacturing science (OEE, APC,yield engineering) with large partnership or dealing with regulation (footprint optimization, materials replacement...) who interest a large number of actors to reinforce manufacturing capabilities in Europe.

4.3 Applications domain

Applications in ENIAC projects being either:

- Global new system. Example Advanced LTE, with a major effort on system definition for a European leadership.
- A new subsystem, for example is a new processor core or another example is an innovative wireless modem solution for 3.5G mobiles, if the standardization aspect is important and the number of partners is large.
- New Platform for an existing system in case of a large number of players / countries with a European scope: Example smartcard. Some companies may propose a platform project (i.e new architecture with new services in order to achieve a competitive breakthrough).

The Applications programme will support all the application work areas mentioned in the VMS: micro- and nanoelectronics for :

1. Communication and digital lifestyle
2. Safety and security
3. Automotive and transport
4. Health and aging society
5. Energy efficiency

And

6. Design technology (DT)

Design Technology aspects are addressed in ENIAC system projects where Design Technology is not the main goal of the project or Design Technology projects of pan-European interest.

ANNEX 3: Enhancing the competitive advantage of Europe in Nanoelectronics

The purpose of this paper is to present the policy guidelines underlying the collaborative European R&D programs CATRENE and ENIAC

Why is action needed at European level?

1. Finding paths to a sustainable development is a global challenge. Innovation and knowledge are the pivotal requirements of the next decade to deal with the complex problems of today such as global warming, protection of the environment, energy conservation, healthcare, security and mobility.

2. Given Europe's high innovation potential and excellent R&D-clusters it is capable of making important contributions to successfully address these topics. Europe's unique strength lies in the wide diversity of its expertise, in new business concepts, innovative and established companies, institutions and academia.

3. At the same time opportunities are emerging to create a competitive advantage and new employment. Many of these challenges require development and implementation of innovative technologies.

4. Against this background nanoelectronics offer an unprecedented potential, particularly to Europe. It is the key enabling technology in domains of high strategic, societal and economic importance: transportation, information and communication, energy, security, health care. Indeed, this highly innovative technology offers the unique capability of changing the product and the value chain in virtually every industry.

5. In itself the nanoelectronic industry is a source of innovation, knowledge, competitiveness, high level employment and the basis of economic prosperity in many European countries.

6. Major interests are at stake. The semiconductor industry constitutes a vast global market, its size being about $265bn. Next to it, the market for equipments and materials can be estimated on the average at $35bn for equipments and $32bn for materials. On top of this, the sector is directly stimulating a much larger electronics applications industry ($1,500bn). Competition is very strong. Today the continent is a net importer of electronics, so a big challenge is facing us. An example illustrates this: only 13% of the global semiconductor production capacity is located in Europe, while 20% of the worldwide semiconductor products are consumed in Europe. The European governments are committed to improve this situation.

7. Mass-production of nanoelectronics basic elements for applications in consumer electronics and high performance computing is mainly located in Asia and the USA. Europe's strength is in R&D and manufacturing of complex electronic systems. These systems, although produced in smaller quantities, represent substantial added value in numerous end products. Strengthening these

European skills using a smart innovation policy will facilitate the development and manufacturing of innovative products and services while at the same time the position of European industry at the global playing field is improved.

What is the outlook for Europe?

8. Research and innovation are key to regain Europe's competitiveness in nanoelectronics. Sustainable, European based, innovation ecosystems of large companies, small and medium sized enterprises and academia should create products and systems that are globally competitive.

9. Potential for European industry lies in:
   - developing the high end part of the value chain (from product idea to design) for high-volume, low cost products with mass production being outsourced;
   - providing the entire value chain, including manufacturing for products with high added value.

10. European industry is able to excel in specific application fields by designing products featuring and exploiting nanoelectronics technologies and components. The increased focus, as mentioned above, offers opportunities for leadership in existing as well as emerging application areas. The bridge between technology and applications is provided by the design capabilities, which also needs to be strengthened in order to guarantee leading-edge nanoelectronics technologies to penetrate diversified application domains and market sectors. Strengthening the relationship between nanoelectronics competencies and application fields is essential for covering the entire value chain, including production.

11. Europe's equipment and materials industry is "state of the art" and should maintain this position. Europe has also a long tradition as supplier of advanced manufacturing equipment. It is in the clear European interest that its high end manufacturing equipment companies maintain and possibly expand their world leading position in this area.

12. Europe must keep strategic manufacturing capabilities, as well as technology knowledge, both in advanced CMOS and in other advanced or diversified (More than Moore) technologies, such as MEMS, SoC, SiP etc. The focus must be on complex systems.

13. Europe should take advantage of the strengths and local conditions the individual countries and companies have to offer, but at the same time it should be realised that using these capabilities in close and coordinated collaboration only will be beneficial to Europe as a whole.

What is the role of the public authorities? Strategy and action lines

14. Since the strength of Europe lies in the variety of its industrial landscape and the broad spectrum of advanced knowledge a collaborative effort by national public authorities, European Union and the R&D-actors is vital.

15. The public authorities' role is to stimulate, challenge and facilitate innovations in do-mains where industry in Europe is willing to create a competitive advantage for Europe. Since such an approach cannot succeed without a strong scientific basis public-private technology eco-systems capable of effective knowledge- and technology transfer have to be facilitated.

16. However, since public budgets are limited, the right strategy, prioritization and concentration are of the essence.

17. For public authorities three major strategy lines are required:

    I Focus on European competencies
    The development of innovative products based upon European competencies in the field of nanoelectronics and application oriented know how should be supported.

    II Make a joint effort to support European "leading edge technologies"
    The European countries with a highly developed nanoelectronic research and production infrastructure should make a joint effort to keep and further expand their competencies in those "leading-edge-technologies" that bear a high relevance for the development of future innovative products and services.

    III Align dedicated national innovation policies
    National public authorities should endeavour to align their dedicated national innovation policies, where possible. By acting this way the vast European resources in terms of knowledge, innovative power and industrial capabilities can be exploited successfully. Moreover this alignment should create a substantial synergetic effect.

18. Consequently the mission of the common R&D initiative is to:
    - provide innovative and sustainable solutions to societal challenges in areas like energy, mobility, health, communication and safety;
    - strengthen those sections of the value chain where Europe can gain global competitiveness and new market shares through differentiation;
    - enable an adequate level of advanced CMOS manufacturing capability in Europe;
    - foster the advancement of European "More than Moore" production sites and European foundries in the most advanced market areas;
    - put in place and support mechanisms to integrate the strengths and capabilities of SMEs and research institutes;
    -endorse the creation of R&D platforms for design, equipment, materials, manufacturing and silicon processes.

European funding instruments [32]

19. To reach these objectives, the role of the two European industrial R&D tools needs to be clarified. This will allow a more efficient support of industry by public authorities. The relevant instruments are the EUREKA cluster program CATRENE and the Joint Technology Initiative (JTI) ENIAC.

20. Looking at the way both programmes are running in parallel it is obvious that there is room for improvement. However since the interests of the participants in both instruments differ to some extent such a process needs careful consideration. Given the complicated nature this topic needs to be addressed separately. Some first guidelines are presented below.

21. A well-defined role for the European industrial R&D tools needs to be clarified. The present alignment between the EUREKA initiatives (CATRENE, ITEA2, EURIPIDES) and the JTIs (ENIAC, ARTEMIS) does not facilitate the optimal exploitation of research competencies and budgets and leaves room for improvement. Today, systems of high complexity combine questions of electronic systems, software and microsystem-technologies. This has to be taken into account when developing new programme structures by adequate cooperations and coordinated joint actions.

22. The "delineation" process has been a first effort to improve the effectiveness of both initiatives, by defining boundary conditions for each instrument.

    * The EUREKA CATRENE programme, using a "bottom-up" approach, must address mostly key technological breakthroughs, where dedicated national support is needed. This programme is funded by each European country;
    * The ENIAC programme, from a "top-down" perspective, must address mostly applications and socio-economic challenges of pan-European interest. This programme is funded both by the European countries and the European Commission.

23. Both instruments must cooperate more closely aiming at efficient exploitation of European strengths.

24. Consequently, the CATRENE White Book and ENIAC MASP have to be adapted accordingly. The objective must be to launch CATRENE and ENIAC calls well balanced in content and timing and corresponding to their respective roadmaps.

Final comment

25. Given the paramount importance of nanoelectronics for the competitiveness of all economically important branches of industry in Europe we have to act now.

[32] To address some of the issues raised in this document, policy measures – be it national, intergovernmental or European – may be envisaged, that go beyond the said R&D initiatives. Since the main objective of this paper is to provide guidelines for drafting the ENIAC MASP and the CATRENE Whitebook, both aimed at collaborative R&D, this strategy paper does not elaborate on other policy options. One should be aware of this limitation.

www.aeneas-office.eu

www.catrene.org