Die
Bundesregierung

Second Guideline Paper

of the Federal Government

for the

Forthcoming Framework Programme

for Research and Innovation

- Thematic Positions -

17 June 2011

I. Preliminary remarks

In its First Guideline Paper of April 2010, the Federal Government proposed a simple and transparent structure. This includes *inter alia* two central national and European objectives: "Meeting societal challenges" and "Strengthening competitiveness". With the present Second Guideline Paper, the Federal Government is adding thematic positions to these two areas.

Europe is facing big societal challenges. The most important problems of the 21st century are in the areas of energy, climate, resources, health, nutrition and demographic change. Viable answers and solutions can in many cases only be found by way of European or international cooperation in science and research. At the same time, Europe is facing enormous economic challenges. The global competition for talents, technologies and markets is steadily increasing. Our aim must therefore be to strengthen the competitiveness of European industry by creating an optimum research and innovation policy framework. From a long-term perspective, this also includes strengthening basic research in Europe.

These complex challenges can only be addressed jointly in Europe. For this purpose, the Innovation Union flagship initiative of the Europe 2020 Strategy must be developed further together with the European Research Area to provide a sound basis and ensure Europe's future. The forthcoming Framework Programme for Research and Innovation, which forms part of the Common Strategic Framework and is the world's largest research and innovation programme, is of central importance in this respect. The structure and topics of the Framework Programme must be tailored to suit the specific objectives of the Innovation Union and the European Research Area and must focus in particular on the implementation of existing strategies.

The Federal Government aims to contribute the positions presented in this paper to the forthcoming debate on the topics of the Framework Programme. The proposed topics are intended to help Europe play a pioneering role in meeting global challenges while exploiting the potential for value creation and opening up new markets. Key technologies play a central role in this respect. At the same time, however, support must be given to the entire range of topics because not all markets can be assigned to a big societal challenge.

The social, economic and political developments in Europe and the world are complex and highly dynamic. European integration in the process of gobalisation needs reflection by the humanities and social sciences. That is why sufficient budgetary provision should be made in the thematically open areas of the Common Strategic Framework, particularly the European Research Council (ERC) and the Marie Curie measures, so that funding can be made available covering broad topics in the humanities and social sciences. Close coordination is therefore necessary for this programme area as well as for all other thematic areas.

II. Thematic considerations

1. Meeting societal challenges

1.1 Sustainability, Energy and a resource-conserving lifestyle

1.1.1 Energy – Energy efficiency, reduction of emissions and renewable energy

Redesigning the European energy supply is among the central challenges in Europe and the EU Member States. The new supply system will feature great energy efficiency, an increasing percentage of renewable energy, reduced greenhouse gas emissions, a high level of energy security, acceptance by the population, and the competitiveness of European companies. The technological prerequisites must be provided by research and development. European research topics are based on the priorities of the SET plan. They cover technologies ranging from conversion to transport to end users as well as horizontal activities. Efforts should be made to prevent the fragmentation of energy research topics; such topics should only be included in other areas if there are specific reasons for doing so. The following research fields are considered to be priorities:

(1) **Energy efficiency technologies**, energy efficient buildings; industrial processes; efficient, flexible and low-emission power plant technologies and CCS; alternative conversion technologies.
(2) **Renewable energy technologies**, wind energy; photovoltaics; solar thermal conversion; (deep) geothermal energy; bioenergy.
(3) **Optimised energy supply systems – combination of renewable energy and conventional energy**, intelligent linking of energy supply and energy demand, network technologies; conurbations with complex structures; energy storage technologies; demand-based feed-in of electricity from renewable sources; systems services in the future energy system with a high percentage of renewable energy.
(4) **Cross-cutting approaches**, interdisciplinary approaches *[together with the challenges "Environment", "Mobility", and "Resources"];* socioeconomic aspects, acceptance research, sustainability and strategy, international cooperation, visionary concepts, interface issues.

1.1.2 Environment – Environmental factors and risks as a driver of global economic and social change

In order to improve change management, it is not only necessary to study environmental risks and their impact on society, the economy and individuals, but also to enhance our understanding of relevant systems. The following research fields are considered to be priorities:

(1) **Adaptation to climate change**, e.g. through the development of adaptation strategies (including assessment of the impact on the health sector, resources supply, climate-adapted cities, biodiversity) and improvement of basic knowledge (e.g. improving climate

(impact) modelling); potential for reducing climate-relevant greenhouse gases in agriculture.

(2) **Natural hazards and hazard management**, including the identification of natural hazards and their impact (e.g. climate change-induced phenomena); improvement of forecasting methods and early warning systems; analysis of socioeconomic impact and vulnerability and resilience of societies.

(3) **Societal developments relevant to the environment** *[together with the challenge "Society"],* including innovations for sustainable consumption and sustainable production; governance – new structures and solutions for sustainability; environmentally induced crises and conflicts (e.g. causes and impact of the scarcity of resources).

(4) **Building, housing, urban development** *[together with the challenge "Energy]*, including sustainability (networking of vehicles and buildings (electromobility); closed cycle management; climate-adapted/ resource-efficient building; climate-adapted cities; sustainable buildings e.g. full recyclability, convertibility, reduction of land consumption; impact of climate change on buildings and infrastructures (materials, stability, safety); innovative efficient refurbishment of buildings; development of control technologies for buildings.

(5) **Environment and health** *[together with the challenge "Health"]*, including the identification of the environment-related disease burden and of required action (e.g. quantification of morbidity and mortality); implementation of long-term surveys (e.g. environmental survey as epidemiological cross-sectional study); source and impact research e.g. on fine and ultra-fine dust, allergies, noise; epigenetic studies of environmental impact; improvement of diagnosis and control of climate change-induced animal diseases and zoonoses; risk assessment of environmental contaminants.

(6) **Preservation of the cultural heritage** *[together with the challenge "Society"]*, including the development of technologies and methods for preserving the cultural heritage.

(7) **Global monitoring for environment and security (GMES)**, including the expansion of existing and/or development of new innovative GMES core services and development of automatic techniques; integration of satellite communication and satellite navigation via GMES (e.g. techniques for EO data transfer directly to the disaster location); climate, environment and crisis information systems (e.g. Tsunami Early Warning System).

1.1.3 Resources – Sustainable use of resources and area-related resources management

The different quality and quantity of the available natural resources is a special challenge for sustainable management. The ecosystems services concept is a model approach for dealing with this situation. The following research fields are considered to be priorities:

(1) **Securing ecosystems services to cover all natural resources**, including groundwork to enhance our understanding of processes (e.g. biodiversity modelling); protection, sustainable use and restoration of biodiversity and ecosystems, e.g. forests; climate protection, adaptation to the impact of climate change, and sustainable land management; sustainable water management; degradation of pollutants in ecosystems (e.g. prospective chemical safety research), sustainable soil management, sustainable raw materials management; sustainable food production.

(2) **Protection and sustainable use of the seas and of marine resources**, including the improvement of our understanding of the system (e.g. impact of human action on biotic/abiotic compartments); improvement of our knowledge of the interaction between

sea and climate (e.g. prediction and management of coastal erosion); low-impact development and use of marine resources (e.g. mineral resources and gas hydrates) and study of possible impact; marine technologies.

(3) **Sustainable management of resources**, including resource efficiency and substitution (e.g. substitution of polluting resources in product design, production processes, product use and services, and saving resources through reuse); a global view of the quality and quantity of resources; sustainable infrastructures for the future; recycling and life cycle management (e.g. reduction of resources in value added chains), scarce resources in agricultural production.

1.1.4 Mobility – Sustainable, affordable and efficient transport systems

Mobility by road, water and air is an important prerequisite for functioning modern societies and their economies. The main goal of European transport policy is to improve the overall quality of transport. Europe is facing big challenges due to the enormous speed of globalisation with a further growth of traffic and increasing system interdependence, and the need for a sustainable, safe, user-friendly and affordable transport system. Transport-related emissions and increasing land consumption by transport are further challenges for people and the environment, while geological and climatic changes are a challenge for the transport infrastructure. Research must place a greater focus on identifying and removing the (often hidden and not directly visible) causes instead of merely remedying symptoms. The maritime industry is a key sector which is of outstanding importance for Europe's competitiveness; approximately 90% of European foreign trade and 30% of domestic trade is by sea. This sector mainly depends on innovations through research and development if it is to maintain its technological leadership on a global level. The following research fields are considered to be priorities:

(1) Reducing the dependence on fossil fuels, including the optimisation of conventional engine concepts and the development of alternatives not favouring a specific technology (e.g. enhancement of energy efficiency and of currently prevailing fleet structures and combustion engines, new energy storage options, tailor-made materials); innovation-friendly standards (e.g. for infrastructures such as energy supply and interfaces like plug connections); pilot schemes and demonstration (e.g. zero-emission urban transport with electric and hybrid engines), development of biofuels; networking/use of emerging technologies in the building sector for transport purposes (e.g. electromobility).

(2) Sustainable, transborder goods transport, intelligent logistics concepts, organisation, management, infrastructure, data management; facilitating transborder demonstration projects; sustainable urban goods distribution, innovative transport infrastructure construction technologies (e.g. road of the future, innovative tracks in the railroad sector).

(3) Modern, resource-conserving maritime industry, including new production technologies (new materials and processing techniques, shorter production periods, reduction of production costs); safety and reliability of the systems (reliability of ship structures, safety concepts, accident prevention with intelligent systems, emergency concepts); resources conservation (new clean engines, reduction of emissions, optimised hydrodynamics, prevention of the transport of organisms, particularly germs, by ballast water, opening up the Northern Sea Route).

(4) **Intelligent transport systems and their networking**, including ICT-based transport management; standards in transport management; satellite-based services for transport;

transborder control and safety technology (e.g. ETCS); system-in-system considerations; reducing the vulnerability of IT systems in the transport sector; reduction of costs (construction, operation, refurbishment) and simplification of systems; innovative forms of mobility; delinking of traffic growth and economic growth; development of intermodal information systems.

(5) **Transport**, including more efficient vehicle technology and sustainable transport systems (e.g. innovations in engine technology, structure and aero-/hydrodynamics); innovative vehicle construction.

(6) **Intermodal transport**, including networking of different modes of transport, uninterrupted information from start to finish.

1.2 Public welfare

1.2.1 Health – Efficient health systems between demographic change and individualisation

Demographic change and the increase of multimorbidity and of diseases with a high disease burden are a considerable challenge for patients and their relatives, society and the health systems in Europe. These developments necessitate the establishment of a knowledge base of a more multidisciplinary nature and the pooling of critical masses of expertise, resources and structures at European level. New findings must be subjected to more systematic testing and validation procedures. Only in this way can enhanced approaches and new methods be generated for their broader and more intensive use in products, processes and services. Medical biotechnology is a major driver in this field. Efforts will include the optimisation of concepts for transfer between academic and privately funded R&D. The following research fields are considered to be priorities and should take gender-specific aspects into account:

(1) **Research into widespread diseases** such as cancer, cardiovascular diseases, metabolic diseases, musculoskeletal disorders, neurological/neurodegenerative and mental illnesses, for example identification of basic biological mechanisms and linkages and related factors and their interaction; development of new treatments and new diagnostic agents for early diagnosis of diseases, supervision of the success of treatment and prognostic analyses; development of new methods in medical technology such as nanotechnology-based methods of molecular imaging and for the effective transport of active substances in the body, materials development and production technology (e.g. biocompatible implants, innovative biomaterials, artificial tissues and tissue structures); telemedicine or e-health including the development of new processes and techniques for indirect application; improvement of drug treatment safety.

(2) **Individualised medicine**, including individualised diagnosis (e.g. molecular biology and "omics technologies", imaging) and treatment (e.g. pharmacological applications tailored to small groups of patients which can be clearly described in diagnostic terms, and individual biomaterials); development of treatment strategies that combine diagnostic procedures and therapeutic decisions (theranostics); research for safe and efficient medicines and treatments for specific population groups; study of rare diseases – ranging from basic research to translational research; general conditions for health innovations such as licensing, standardisation and patent law aspects, stronger focus on patients' perspective and consideration of different forms of inequality; ELSI research.

(3) **Prevention and nutrition research**, including protection against infections (e.g. research on multiresistant or climate sensitive pathogens, zoonosis research, research on the direct and indirect transmission of antibiotic resistance and related properties from

animals to people, development of new or improved vaccines and anti-infectives, improvement of vaccination strategies, rational antibiotic treatments and sanitary measures); strengthening epidemiological research as a basis for prevention research (improvement of general conditions and European coordination; understanding the pathogenesis of diseases by studying the interaction of genetic, physiological, social and other processes and factors such as working conditions); evidence-based approach of prevention measures; prevention through sufficient exercise, stress management and a healthy diet including research into the structure and composition of foodstuffs and their metabolic response, validation research on public health measures in the field of nutrition, improving the quality and safety of food.

When developing and planning the next Framework Programme, attention should from the outset focus on establishing joint basic principles for ethically sensitive research projects in the life sciences, particularly in human biology research. In this context, Germany assumes that the next Framework Programme too will include sufficient arrangements to ensure that funding is neither provided for embryo-consuming research projects, including the production of human embryonic stem cells, nor for activities aimed at reproductive cloning, germ-line intervention or stem cell extraction for research purposes, including therapeutic cloning. This is expected to safeguard the high protection standards of the German Embryo Protection Act at European level.

1.2.2 Bioeconomy – Development of a bio-based economy and securing the world food supply

Securing global food security, a sustainable supply of raw materials and energy from biomass, the preservation of biological diversity, and climate and environmental protection while increasing Europe's competitiveness is a big challenge. The bioeconomy covers all sectors that develop, produce, process or use biological resources (plants, animals and microorganisms). Biotechnology provides the basis for bioeconomic innovations. The following research fields are considered to be priorities:

(1) **Increasing food production to secure the world food supply**, including the identification and breeding of high-yield plants and animals; control of and adaptation to biotic and abiotic stress factors; security and efficient processing of foodstuffs, strategies to reduce the destruction of foodstuffs before and after marketing, strategies to control food-related diseases; strategies to strengthen consumer protection and nutritional skills.
(2) **Development and use of bio-based processes and products** *[together with the area of "Energy"],* including the development of industrial biotechnology; development of integrated biorefineries.
(3) **Securing the economic and societal sustainability of the bioeconomy**, including the improvement of agricultural and forestry production systems; establishment of a scientific and technical basis for knowledge-based political and regulatory decision-making; enhancement of skills and capacities; supporting research to improve societal development and acceptance, consumer behaviour, risk/benefit analysis.

1.2.3 Demographic change

Demographic change in Europe requires not only that health issues be addressed (see 1.2.1 above) but also that efforts be made regarding the quality of life for older people, social cohesion and the performance of European industry on a global scale. Tomorrow's working

worlds must therefore improve the general conditions for work and private life and address the demographic challenge right from the start. The following research fields are considered to be priorities:

(1) **Housing and safety**, including the development of functional, reliable and individual support services for everyday life such as ambient assisted living systems, intelligent homes, innovative services concepts.
(2) **Mobility and participation**, including maintenance of the quality of life by means of accessible mobility chains and driver assistance systems for older drivers, intermodal passenger transport that meets the needs of the elderly, further development of infrastructures (including administrative infrastructures) *inter alia* through ICT-based solutions or urban design innovations; innovative forms of mobility organisation.
(3) **Work and productivity**, including maintaining, promoting and using people's working ability/performance and employability over their entire active life by designing attractive and modern workplaces, development of personnel management concepts and innovative work organisation, suitable ergonomics (design for all), design of workplaces and assistance systems in production processes that meet the needs related to age and ageing, development of new ways of imparting skills and new vocational training and continuing training programmes.
(4) **Health and care for the elderly** *[together with the area of "Health"],* including maintaining physical and mental performance well into old age through research on ageing (study of molecular ageing processes and of multimorbidity and related treatment strategies), development of individualised medicine, further development of geriatric medicine, development of new ICT for telemonitoring, further development of biomedical technology and nutrition research, dietetics and prevention, development of new care concepts and innovative assistance systems to support people in need of long-term care as well as professional and family carers.

1.2.4 Society – Innovation, participation and integration

Rapid and complex social, economic and political developments can be observed throughout Europe and the world. Challenges like climate change, an ageing population, migration flows and society's capacity for integration require the development of new forms of global solutions for economic, political, and socio-cultural problems. These are specific societal challenges that must be addressed primarily by the humanities and social sciences. The humanities and social sciences study processes of societal change produce robust empirical data and provide forecasts and scenarios to support political decision-making. These research activities must go beyond national borders and have a stronger international focus as they are a major prerequisite for reaching the goals of the EU 2020 Strategy. Following an anticipatory approach, the potential of research must be exploited to provide solutions for future challenges in European societies and beyond. The following research fields are considered to be priorities:

(1) **Scenarios for innovative societies in the context of global developments**, including topics such as intergenerational and gender equity and sustainable action in an integrating society; a participatory society; ways towards knowledgeable societies; experiencing social cohesion; security in societies that are able to handle conflict situations.
(2) **Diversity and inequality**, including the development of a better understanding of their causes and consequences by comparing models for diversity management in Europe;

the relationship between diversity and inequality; normative pluralism and social integration; evidence-based intervention models (individual, society, organisation); transnationalisation trends; political and social participation, poverty and difficult situations in life; education systems.

(3) **Governance and modern government**, including the study of institutional and process-oriented aspects of governance; normative aspects of governance; reflective governance.

(4) **Culture, society and innovation**, including the study of cultural and historical prerequisites and resources for innovation; cultural and religious diversity as a source of social renewal and development; innovation processes: relativity and reflectivity; stakeholders in social innovation in politics, the economy and civil society; local and transnational innovation spaces.

(5) **Sustainability of society** *[together with the challenge "Environment"]* including the sustainability of work, production and consumption in Europe; a sustainable model for prosperity and economic activity; sustainability as a challenge for governance (including innovation-friendly public procurement) and management; environmentally induced crises and conflicts: origin, social implications and solutions, strengthening consumer skills/ consumer protection.

1.2.5 Security – Protecting the freedom and security of the people in Europe

The increasing global threats posed by terrorism, organised crime, natural disasters, and large-scale technical accidents are a new challenge for Europe. We need innovative solutions that provide for public security in combination with measures at Member State level and at the same time strengthen Europe's culture of freedom. In order to meet this challenge we must ensure that research for civil security continues to focus on the sustainable protection of the open civil society while strengthening the competitive position of European industry. We must maintain the clear division of responsibilities with defence research and the separation from space activities. The feature of end user involvement must be strengthened by the greater representativeness of end users and transborder networking. Research activities must be accompanied by consistent standardisation. We do not agree to support for precompetitive procurement. In order to ensure the effective commercialisation of research results, it is essential that we enhance coordination with relevant EU budgets that are available outside FP8. The means of EU competition policy should be used to reduce existing market fragmentation. The following research fields are considered to be priorities:

(1) **Security and protection of the population**, including improving transborder communication and cooperation and the interoperability of security authorities and organisations such as fire brigades, police forces, and civil protection and disaster control organisations.

(2) **Protection of critical European infrastructures**, including the prevention or reduction of cascade effects in the case of transborder infrastructures (e.g. Trans-European Networks or TEN); protection of commodity chains (e.g. hazard detection) and transport routes, energy supply.

(3) **External dimensions of security**, including the development and enhancement of civil solutions for a common foreign and security policy (e.g. protection of European citizens outside the EU); border protection.

(4) **Cyber security**, including scenario-related consideration of IT infrastructures as part of critical infrastructures with a special focus on the economic and societal dimensions (sharing responsibility with ICT research areas).

(5) **Societal dimensions** *[together with challenge 1.2.4 "Society"]*, including issues related to civil security in the context of the Area of Freedom, Security and Justice (e.g. culture and architecture of security in Europe; ethics, law and economics of security; freedom and security).

2. Strengthening competitiveness – Key technologies

Key technologies are of great systemic importance. Europe's competitiveness can only be strengthened and the big social challenges met if Europe is among the world leaders in key technologies. New products and services in the automobile sector, in medical technology or mechanical engineering are based on innovations in key technologies such as information and communication technologies (ICT), nanotechnology, innovative materials, photonics, production technology, biotechnology or aerospace technology. Cross-cutting themes such as standardisation and metrology are also important here. For example, highly effective modern medicines can only be developed or CO_2 emissions in road traffic reduced if research results are translated into key technology innovations. Energy- and resource-efficient technologies, e.g. "Green IT", play an important role in sustainable development in view of climate change, urbanisation, and the increasing global demand for raw materials and mobility and transport services. The aim is to increase energy and resource efficiency in the IT sector itself and in other sectors of the economy using ICT.

2.1 Advanced Materials

The adequate and early availability of innovative materials is of central importance for realising industrial applications. In many cases, product innovations can only be achieved if new tailor-made high-performance materials are available in time. Innovative materials enhance the performance of power plants, engines and turbines. At the same time, they open up new technological horizons, for example in organic photovoltaics or the development of new high-performance energy storage technologies. Against this background, we need materials research that is organised and funded at European level and geared to the requirements of potential economic applications. The following research fields are considered to be priorities:

(1) **Materials classes** *[together with the area of "Energy"]*, including lightweight construction materials (e.g. aviation/space activities, car industry, shipping); functional ceramics (e.g. gas separation in zero-CO_2 emission power plants, medical technology); intelligent materials such as piezoelectric materials and shape memory alloys.
(2) **Availability of resources and resource efficiency** *[together with the challenge "Resources"],* including resources efficiency, recycling, the development of substitutes (e.g. due to rising extraction costs of platinum metals); catalysis research (e.g. for process intensification in the chemical sector); product life and reliability.
(3) **Consideration of the entire value chain**, including reliability and safety of product application; method development for materials innovations (design engineering); bionics (e.g. impetus for the development of completely new materials systems); process innovations.
(4) **Modelling and simulation to shorten material and product development times**, including the development of the "From atom to component" vision; new measuring/

testing techniques (e.g. calibration of model parameters of materials behaviour in simulation models).

2.2 Nanotechnology

Nanotechnology is of great strategic importance for many industrial branches. It currently provides the basis for numerous practical applications and has potential for further improving the quality of people's lives and the protection of the environment. For example, the use of nanostructured materials enables considerable progress in the field of modern building services or energy-efficient lighting. Using nanotechnologies in medicine can contribute substantially to new diagnostic and therapeutic approaches. The broad technological basis and our good understanding of nanoscale processes will make it possible to use nanomaterials effectively to meet the big societal challenges. The following research fields are considered to be priorities:

(1) **Nanomaterials and nanoparticles**, including the development of nanomaterials and nanoparticles (e.g. production and functionalisation of nanoscale materials).
(2) **Nanotools, nanoanalytics and methods**, including the development of equipment and methods for the production of nanosystems and their routine detection and characterisation; medium-term development of reliable high throughput analytics for simultaneous real-time measuring and modelling of different parameters (e.g. spatial and chemical structure).
(3) Impact of nanomaterials on environment and health (EHS) *[together with the challenges "Environment" and "Health"],* including horizontal activity to study the opportunities and risks (e.g. life cycle of nanomaterials, toxicological/ epidemiological issues, risk assessment and management strategies).
(4) Standardisation, including activities that supplement international activities, e.g. the work of ISO, as well as relevant national activities.

2.3 Production technology

Europe must remain an important location in global goods production. This is a basic prerequisite for employment and prosperity. Production technology is of central importance for efficiently placing new products and technologies on the market. New production technologies and systems offer potential for making significant progress with regard to production rate, cost reduction, energy and materials efficiency, production/ product quality, and waste/pollutant management. The following research fields are considered to be priorities:

(1) **Integrative production**, including all operations along the product chain (from the selection of raw materials to recycling at the end of the life cycle); this enables other technologies like materials technology, nanotechnology, biotechnology and ICT to be applied in new goods in a competitive manner.
(2) **Flexible, adaptive production systems and companies**, including modular construction of production facilities and successful management of interfaces (e.g. reconfigurable systems, devices and installations).
(3) **Consistent use of ICT and networked production** *[together with the key technology "IT systems"],* including the use of ICT for production and product development, networking of logistics operations across companies and sectors.

(4) **Green production technologies, products and factories** *[together with the challenges "Energy" and "Resources"],* including the reduction of energy and resources consumption in production (e.g. by using new materials); conversion into self-powered, water-saving and low-waste production facilities.
(5) **Human-machine cooperation**, including the development of suitable systems for smooth and intuitive interaction between people and technical components of the production system; development of cooperative machines and "cobots"; development of systems for production and work that meet the needs of older workers; development of new forms of learning for production know-how (e.g. learning factories).
(6) **High-tech production equipment for low-cost products**, including the use of high technologies for manufacturing low-cost products e.g. OLEDs.
(7) **Development of new metrological techniques**, *inter alia* under the EMRP; e.g. precise measuring of nanostructured materials for optics and electronics or enabling the exact shaping of mechanical and optical precision components, using high-quality data to contribute to an efficient and environmentally compatible production that meets consumer needs.

2.4 Photonics

Photonics, the field of science that deals with light in its many forms, covers all technical applications of light and uses its outstanding properties. It focuses on the generation, control and measurement of light and in particular its use in almost all important areas that are of societal and economic relevance. Building on a common technological basis, photonics combines different disciplines such as laser technology, mechanical engineering, energy and lighting, medical technology, environmental technology, high-performance optics, optoelectronics, image processing, and communication. The following research fields are considered to be priorities:

(1) **Photonics components and systems**, including the development of new elements for optical data communication such as optical interconnects, integration of optics and electronics.
(2) **Solid state lighting (SSL)**, including the development of semiconductor-based lighting components (highly efficient, using less material).
(3) **Organic electronics**, including the development of organic photovoltaics (clean energy generation), organic light-emitting diodes (sparing use of energy), resource-conserving production of electronic circuits, storage devices and sensors.
(4) **Biophotonics**, including the development of applications using the properties of light in areas such as biotechnology, medical technology, pharmaceuticals and food production (e.g. for medical diagnosis or detection of resistance to antibiotics).

2.5 Micro- and nanoelectronics

Together with microsystems engineering and photonics, micro- and nanoelectronics provides the material basis for ICT as these key technologies supply the components and systems on which ICT is based and which are very important to industry. These technologies aim to promote better system integration and functionality (smart systems), enhanced energy efficiency and performance as well as greater reliability and robustness. The following research fields are considered to be priorities:

(1) **Electronic components**, new micro- and nanoelectronic components suitable for integration such as high-performance semiconductor components, including developments in the area of materials, equipment and design ("More than Moore" technologies).
(2) **Electronic systems**, including the development of new integration technologies such as silicon 3D integration, smart power technologies, intelligent systems (systems on chip), mainly in the analog/mixed signal area.

2.6 Microsystems engineering

Microsystems are the centrepiece of smart systems. They can perceive, describe and analyse specific situations, identify other microsystems and interact with the environment. They must be able to operate under extreme conditions. The following research fields are considered to be priorities:

(1) **Further miniaturisation**, including the integration of nanostructures.
(2) **Enhanced system integration**, including micro-nano integration, functional enclosure, networked microsystems, printed microsystems.
(3) **New principles and effects**, including research into new principles and effects; making new materials and structures accessible (e.g. via bio-coupling).
(4) **Enlarged functions and applications** *[together with the challenge "Energy"]*, including self-sufficiency (e.g. energy management or repair), cognition (e.g. learning capacity) and communication; assistance systems for people, in climate protection, and in food production and distribution.
(5) **Sustainability** *[together with the challenges "Energy", "Environment", and "Resources"],* including the development of microsystems for energy efficiency, waste avoidance, recycling, reuse and labelling of materials.

2.7 IT systems

IT systems are indispensable for the smooth functioning of our technical environment in many different ways. Various components are involved such as embedded or robotic systems. Supercomputers and grid computing provide extensive computing capacity, e.g. for simulations. The safety aspect is gaining increasing importance, particularly in software architectures and applications and in the emerging areas of grid and cloud computing. The following research fields are considered to be priorities:

(1) **Embedded systems**, including the development of new methods and technological approaches for the design of complex cooperating systems, construction of relevant software architectures, development of technology platforms covering different applications.
(2) **Robotics**, including the enhancement of adaptation and learning capacity to increase self-sufficiency, efficiency and user-friendliness.
(3) **Software development**, including the development of software architectures and front ends (high degree of user-friendliness, safety and reliability), dynamic and adaptive networks.
(4) **Supercomputing**, including further support of the PRACE network.
(5) **Cloud/grid computing**, including issues concerning further virtualisation of infrastructures (interoperability of clouds, support of mobile applications, energy efficiency, security), support for the European Grid Initiative (EGI).

2.8 Communication systems

The Internet will become increasingly important, not least owing to the emergence of cloud computing and the increasing virtualisation of infrastructures. We must aim to lead this development, and in particular to identify future trends following on from the developing Internet of things and services. In addition, basic aspects must be addressed. The following research fields are considered to be priorities:

(1) **Fundamentals of communications technologies**, including the definition of future user requirements; specifications for the network platform of the Internet of the Future (e.g. design, development, implementation, IT security).
(2) **Future networks**, including issues relating to the interoperability and convergence of different network technologies; management of the increasing data flow (e.g. scalability, connectivity, addresses, names); flexible and efficient use of the frequency spectrum in mobile broadband and radio networks.
(3) **Internet of things and services**, including the development of an open architecture for different objects that are connected with the Internet; development of suitable platforms and technologies for further integration of the real and virtual worlds; new methods for the development of service applications; provision of more sophisticated forms of media for users.
(4) **Digital content and languages**, including the development of advanced language technologies (e.g. compilation, management, translation and publication of multilingual content); future management of digital content (e.g. inventory maintenance, restoration and repair of lost and damaged content, long-term availability of new content).

2.9 Biotechnology

Biotechnology is a central driver of numerous applications in the pharmaceuticals and chemical industries and in the food and feed industry. The applications range from drug manufacture and new diagnosis and treatment concepts to the production of fine chemicals and methods for waste water treatment and energy generation from biomass. Biotechnology research thus provides new basic findings and solution concepts for existing and emerging societal challenges in the areas of health/nutrition and climate/energy and is the most important enabling technology for establishing the bio-economy. The following research fields are considered to be priorities:

(1) **Medical biotechnology**: Biotechnological processes, such as genome, post-genome, epigenome analysis, metabolome research and bioinformatics as well as their systems biology integration, for decoding life processes, ageing, pathogenesis; applications in diagnostics and drug development, regenerative medicine, medical technology.
(2) **Industrial biotechnology** *[together with the area of "Energy"]*: Methods, services and products such as basic and fine chemicals, pharmaceuticals, food additives, detergents and cleaners, bio-based plastics, textile products and cosmetics as alternatives to oil-based raw materials and energy sources; development of detection methods to improve product quality and safety.
(3) **Plant biotechnology**: Biotechnological research methods (including genetic engineering, smart breeding) for breeding crop plants with optimised yield; plants that are tolerant to biotic (e.g. predators, fungal infections) and abiotic (e.g. dry spells, salty soils) stress

factors; plants with new/improved properties suitable for industrial use or beneficial to human health.

2.10 Space technology

The space sector can contribute directly to the implementation of various political objectives described in the Europe 2020 Strategy. For example, earth observation and navigation satellites provide major direct contributions to climate research and enhanced efficiency in the transport sector. Communication satellites not only enable us to use mobile phones, which are an integral part of modern life, but also provide fast Internet access even in remote regions. Europe started establishing its GMES (Global Monitoring for Environment and Security) initiative in recent years. This major earth observation initiative supports in particular the European administrative organs with improved, sustainable data (quick mapping). This applies to a wide variety of areas including urban planning, border security, land use, shipping safety, disaster prevention, and rescue operations. In addition to these applications, space research also makes an important contribution to scientific knowledge gain. The following research fields are considered to be priorities:

(1) **Space technology**, including critical space technologies; rocket stages and propulsion systems (e.g. greener propulsion system technologies); orbital propulsion; Power Harvesting (conversion of hitherto unused energy); space-based Data Relay Centre; terabit satellite networks; mobile Internet via satellite.
(2) **New generations of technologies and technologies for different missions**, including exploration missions (e.g. swarm intelligence for deep space missions); communication and navigation technologies for interplanetary missions; technologies for observation missions and astronomical applications; ultra low-noise components.
(3) **Space research**, including the use of data from past and ongoing missions; instrument development for future missions; ground support for space missions; scientific experiments on the ISS; study of space parameters.
(4) **Small satellites**, including the use of small satellites for testing components; use of small satellites for training young researchers.
(5) **Research to reduce the susceptibility to damage of the space infrastructure**, including space debris, space weather, jammers, on-orbit servicing.
(6) **Studies accompanying space policy and addressing new concepts for space activities**, including Blue Sky projects, legislation governing space debris.

2.11 Aeronautical engineering

The airborne transport of people and goods plays a major role for mobility within the EU and for Europe's export-oriented economic sector. The aeronautical industry must ensure the future availability of relevant technology, e.g. in the most up-to-date and eco-efficient aircraft. This is the only way for us to achieve the objective of a sustainable air transport system because resources consumption and emissions will mainly be reduced through aircraft development. With its special requirements in terms of service life, reliability, size and weight, aviation technology is a driver of innovation and a key technology for the economy. The following research fields are considered to be priorities in the areas of basic research and technology integration:

(1) **Green aircraft:** Lightweight aircraft and helicopter construction (e.g. CFK and innovative metal design), flight physics (e.g. laminar wing), overall aircraft design, systems (all-electric aircraft, fuel cell), flight control, recycling, (secondary) energy generation and use.
(2) **Manufacture, service and maintenance:** e.g. innovative, cost-efficient and automated manufacturing processes, methods and facilities, environmentally friendly service and maintenance concepts, ecological materials systems, service life prediction, sensor and diagnosing systems, modification and retrofitting.
(3) **Engines:** New engine concepts (e.g. geared turbofan, open rotor, CROR engines), new materials (different metal alloys), lean-burn principle, innovative engine technologies to reduce soot, NOx, CO2 and noise in accordance with the Flightpath 2050 vision.
(4) **Safety and comfort:** Passenger-friendly and energy-optimised cabin concepts, e.g. modular design, broadband communication, air space capacity, flight guidance.
(5) **Helicopters:** Pilot assistant (e.g. to improve all-weather reliability), rotor systems (active and passive) to reduce noise and vibration, increase of payload and range.