EARCH FORUM

S FOR HORIZON 2020

n Copenhagen Research Forum

UNIVERSITY OF COPENHAGEN

Copenhagen 2012

Visions for Horizon 2020
- from Copenhagen Research Forum

2012

The report is made available by financial support from:
University of Copenhagen, Technical University of Denmark and the Capital Region of
Copenha-gen

Grapics and Layout: We Love People
Publisher: Copenhagen Research Forum - 2012
Editorial office: Technical University of Denmark, Anker Engelundsvej 1
DK-2800 Kgs. Lyngby

Preface

On behalf of the Copenhagen Research Forum (CRF) I would like to thank the European Commission for its strong visionary proposal for the 2014-2020 Framework Programme for Research and Innovation: Horizon 2020.

The CRF invited more than 600 researchers from across Europe to contribute their comments and expand on ideas concerning the six societal challenges that form an important part of Horizon 2020. Divided into six panels, one for each challenge, recognised experts from both old and new EU member states have made contributions. This is the first time in the history of EU framework programmes that researchers, without the involvement of other stakeholders, have worked jointly to formulate a research-based critical view of the European research agenda.

The goal of Copenhagen Research Forum is to provide advice and input to Horizon 2020 to strengthen research in Europe.

The six societal challenges are not to be seen as silos wherein experts are isolated from each other in academic disciplines. One of the CRF's major findings is realizing how intensely the themes and solutions to societal challenges are interacting and interdependent. The CRF's mission would not have turned out as successful without our positive and constructive interaction with our research colleagues from all over Europe as well as our open, valuable communication with the European Commission and the Danish Ministry of Science, Innovation and Higher Education.

Europe needs to find solutions for growth, prosperity and safety for the next decade in the areas of health, food & agriculture, energy, transport, climate change & resources and societies. The Copenhagen Research Forum represents the European research community's commitment to contributing to a better, stronger Europe, through better, stronger research.

Professor Liselotte Højgaard,
President of Copenhagen Research Forum

Copenhagen, January 2012

Content

ISBN:[978-87-985272-7-5] (electronic version) • ISBN: [978-87-985272-8-2] (printed version)

Executive summary

Solving the societal challenges of Europe demands the collaboration of the best researchers in Europe to provide sustainable solutions. The European Commission Proposal for Horizon 2020 is a strong platform and a good starting point.

Copenhagen Research Forum gathered 80 European scientists in January 2012 to discuss these societal challenges and depict how research can contribute with the best solutions. The outcome of the CRF is this report, which contains a set of recommendations to the European ministers for research and innovation, the European Parliament and the European Commission on how to solve the societal challenges through research.

For each of the social challenges the six abstracts below summarise the key issues, but one of the strongest messages coming from the CRF was that the societal challenges can only be solved in a true multi- and cross-disciplinary research context. Future research solutions need to transcend and expand our traditional view, and true cross-cutting research is the key word. The Horizon 2020 program should, therefore stimulate and encourage collaboration between the research communities associated with the 6 defined challenges. One possible organisational mechanism for achieving this goal could be that, in addition to programme elements dedicated to each of the challenges, an element could be established that cuts across all disciplines. In this manner, it could be ensured that resources were specifically dedicated to the issues that cut across the individual challenges.

The solutions to the societal challenges cannot be seen only in a European perspective, as the nature of most of the problems is global. Research collaboration with the best teams in other parts of the world will bring better solutions, faster and cheaper, through sharing and collaboration. Europe can provide the platform and framework and initiate the needed global research collaboration to secure Europe as a prosperous, sustainable region.

New challenges will arise prior to the year 2020, which is why a dynamic approach with new research solutions that also use risk-taking approaches is needed and why emerging challenges must be recognised early. An end-user, problem-solving approach should be taken in order to strengthen the impact of the Framework Programme and the utilisation and exploitation of outcomes and results.

The open, transparent and simple approach to both calls and programme administration as proposed in Horizon 2020 is highly appreciated and should be further developed to enhance the userfriendliness of Horizon 2020.

With these solutions, the money spent for Horizon 2020 can provide the optimal innovation as well as create new jobs, ideas, knowledge and education – for a wealthy, healthy Europe as an inclusive, innovative and secure society.

HEALTH

To relieve the threat to human health and welfare imposed by an expanding number of major health challenges, biomedical research and its implementation in clinical practice must be supported and accelerated. To achieve this in the next decade, a paradigm shift toward personalised medicine will be of major importance, with the overriding aim of improving every citizen's lifelong health and wellbeing. Basic, translational, and clinical research of high quality provides the foundation for European health systems, offering the opportunity to link with social, cultural, and environmental expertise to facilitate world-class multidisciplinary research. The global revolution in biomedicine is also providing access to new technologies that will require expansion and implementation to tackle the health challenges that Europe faces. A European platform engaging all key stakeholders to ensure discovery and delivery of these technologies will be crucial. Establishment of a European Strategic Action for Healthier Citizens is also recommended to assist in strategic long-term healthcare research and planning, including preventive measures, and the delivery of best practice across Europe. In most European countries, healthcare is a driving factor for investment – in industry, in education and training, and in the European knowledge base for wealth creation. The proposals in this document will enhance investment and create jobs in research and innovation, improve the healthcare status of Europeans and at the same time drive down integrated societal healthcare costs.

FOOD

The overriding challenges of increasing demand, competition for land use and other resource scarcities put massive pressure on agriculture and the food and feed industry to produce significantly more per unit of a given resource. Food, agriculture and land use must be seen in a much more complex and multi-directional value chain, where research and innovation must encompass needs and opportunities from climate, available resources, environmental sustainability, transport, energy and health perspectives, not to mention social and economic requirements. The processing of food, feed, bio-energy and bio-materials must also be seen, to a much greater extent, from a holistic perspective that includes a full life-cycle approach to the use of raw materials, either for their fresh use or their conversion into shelf-stable and refined products and their use in the associated supply chain. Here, key objectives are reductions in food waste and water consumption, valorisation of all bio-resources, including municipal bio-waste and agro- and bio-industrial side streams, as well as the recycling of sufficient amounts

of carbon and phosphor to maintain soil vitality. Valorisation from biomass must be optimised by developing and utilising smart and energy-efficient processing chains, while maintaining the chemical integrity of valuable components and exploiting the highest value from each biomass component (e.g. nutraceuticals for gut health improvement, food ingredients, proteins, optimised animal feed, biopolymers, fibres, chemical feedstocks, car fuel, and, finally, converting any remaining residues to biogas, electricity and heat. Increasing prevalence of diet-related diseases and disorders calls for a balanced health care concept more geared towards prevention. This calls for new knowledge for the development of affordable and effective dietary adjustments for better health at individual and population levels, with special emphasis on children's needs and the ageing population. There is an overall need to create an innovation culture where researchers, companies (especially SMEs), university education, NGOs and governments (including regulatory authorities) work closely together to increase the speed and volume of the exploitation of research and knowledge across this area.

ENERGY

Secure, clean, and efficient energy is rightly chosen as a key focus area in the Horizon 2020 agenda as it is essential to be able to provide the EU with clean, reliable and affordable energy midway through this century. Stronger national and transnational efforts, as well as better coherence and coordination are badly needed between national and joint European efforts, including public-private partnerships with all EU countries. This requires European-scale management and support in order to: (1) enable a decisive contribution to climate protection; (2) achieve European technology leadership; and to (3) give adequate support to European industry.

Horizon 2020 priorities should build on: (1) a revised SET-Plan based on a thorough review at the beginning of Horizon 2020, including a critical update of the road maps based on ambitious but realistic scenarios for the development and deployment of technologies, and (2) a complementary systemic approach to combine technological, economic, political, social and cultural research to facilitate the transformation of the energy system as a whole. Collaboration of social sciences and humanities with "hard sciences" must be recognised as necessary and organised and funded accordingly to meet the challenges at system level.

More efficient innovation programmes and new instruments are needed to couple educational efforts with research and innovation to ensure that enough trained talent is available to realise the ambitious roll-out scenarios for the different energy technologies, and for the transformation of the energy system as a whole. Direct mobilisation of universities in addressing systemic challenges should be given high priority. Mobility of scientists and students among research institutions and industry should be pursued through new types of flexible grants. Transfer of knowledge from universities to students and companies must be made in a more efficient way. Public technology procurement policies could be used to shorten the time from research to market.

Main criteria for selection of European projects in Horizon 2020 are scientific excellence, society needs and European competitiveness combined with more focus on outcomes and impacts. The composition of research consortia should give high priority to the quality of partners and their openness to new partners. Openness, dialogue, and competition are the proper values to ensure quality and rate of progress.

TRANSPORT

Efficient and sustainable transport for people and goods is vital for Europe's prosperity. The transport sector's overall mission to provide mobility is constrained by a complex set of multiple additional considerations which can be summarised in the comprehensive concept of "environmental and societal sustainability". The complexity of the transport (sub)-challenges urges for continuous research and development and requires closer cooperation across scientific domains and integration across universities, research institutions and industry than in the past. In addition, the multiple and to some extent conflicting aims for transport policy have to be taken into account in the research strategy for every specific research activity. The radical transformations of the transport sector required to achieve the vision of 'smart, green and integrated transport' call for cross-cutting research and research on feasible transition pathways.
The range of highly relevant transport research topics is broad. However, there are three overriding challenges facing the development of a competitive and sustainable transport system which are absolutely crucial and particularly hard to solve and where research therefore should be prioritised as an essential part of the solutions:

Smart: Congestion due to overexploitation of system capacity;
Green: Greenhouse gas emissions from transport's oil dependency;
Integrated: A modally divided and vulnerable transport system.

Meeting the political challenge of both improving mobility by smarter utilisation of a more integrated transport system and making it greener by radically reducing greenhouse gas emissions will require not only technological solutions but also better understanding of transport behaviour and the use of innovative and effective policy instruments. This calls for a more pronounced role for social sciences than in previous Framework Programmes. In many cases the efficiency of research can also be improved by strengthening the integration of scientific domains.

Technological innovation will still be of paramount importance as development of novel and more efficient technologies will be pivotal for reaching the main European transport policy goals:

- Cleaner and safer vehicles for all modes;
- Cost-effective alternative fuels, (electric) drives, propulsion technologies, battery and chemical storage of energy and new materials for vehicle construction;
- Advanced ICT for personalised real-time travel information with modal integration, metropolitan traffic management and smart payment systems;

to highlight a few exceedingly important areas which will require massive investments in R&D&I towards 2020 and beyond.

Apart from greenhouse gas (GHG) emissions the majority of the negative impacts from transport occur in and around major urban areas where the majority and an increasing share of Europe's population live. This calls for intensified research in the challenges related to urban mobility. A significant change of modal split away from cars is necessarily an essential part of the solution. This will also make cities more liveable, but it will require both sticks and carrots to achieve, e.g. urban road pricing schemes accompanied by more competitive public transport and facilities for cycling and walking.

Expectations for increasingly scarce funding for infrastructure improvements highlights the need for cross-modal integration as a means to improve overall efficient and sustainable mobility rather than effectiveness at modal level. Further development and implementation of concepts such as door-to-door mobility, seamless connectivity, and global interoperability can contribute to more customer-oriented services. In the future, transport may be more vulnerable to extreme events, and this calls for research in resilient systems.

Finally, traffic is still responsible for a death toll in the EU of about 35,000 annually and many more serious injuries. Hence, in spite of dramatic improvements in traffic safety over the last four decades, substantial research efforts are still indispensable. Reaching the 'close to zero' vision will require a paradigm shift toward a holistic system approach.

A substantial part of the chapter on transport is devoted to presenting a number of highly important yet indicative research topics organised under the following three headings: Mobility – behaviour and modelling; Balancing demand and capacity; and Governance, financing and organisation. The goal has been to also inspire the subsequent work with implementing Horizon 2020 in future work programmes and calls.

CLIMATE

With the global population currently at 7 billion and projected to be at least 9 billion by 2050, not to mention increasing per capita consumption, the human demand for the Earth's natural resources has never been larger. With this human pressure on the Earth's living ecosystems (e.g. biodiversity) and abiotic resources (e.g. rare Earth metals), the establishment of mechanisms for intra- and inter-generational sharing of essential natural resources becomes the greatest challenge to the continued development of all human societies. The primary role of research in developing these mechanisms must be to provide the knowledge necessary to underpin sound and responsible decision making. Input from all research disciplines is necessary to provide this knowledge. While the ultimate goal of research relating to this challenge is to sustain societal development, at the heart of research focusing on developing more responsible use of natural resources must also be the development of an understanding of societal transformation processes. A large global market is anticipated for technologies and processes that improve the efficiency of resource use and/or that can provide substitutes for natural resources under pressure. However, transition to sustainable resource use will also require a change in values and thinking. One important contribution Horizon 2020 can make to these processes is to provide means whereby scientists from different academic fields are brought together to address possible transitions and how to achieve them.

Climate change constitutes one of the most urgent global resource challenges facing society, where the resource in question is our common atmospheric receptacle for the greenhouse gas wastes of society. Development of actions and strategies for dealing with this challenge can, potentially, provide models for dealing with resource scarcity issues coming on line (biodiversity, ecosystem services, water, phosphorous, ores and metals etc.). A general paradigm for dealing with resource scarcity is reducing the need for – and more efficient use of – the resource, combined with the adaptation of human activities to changed conditions and/or the recognition of resource scarcity. In dealing with resource scarcity in general, and climate in particular, a major challenge is to channel the knowledge gained on the mechanisms of the Earth's system into political and societal action. This requires cross-disciplinary and interdisciplinary approaches that integrate the research conducted in many fields within the natural sciences with that conducted in other disciplines (including engineering, statistics, social science, and humanities) to provide solution-oriented results to decision makers.

Resource scarcity is a global issue, although it is not experienced to the same extent everywhere and not all regions enjoy the research infrastructure necessary to support good decision-making. Therefore, regions such as the EU that rely strongly on resources from all parts of the world and have well-developed research capacities, should not limit their research activities to their own geographical regions. Existing knowledge on the causes of climate change, for example, provides a sufficient basis for society to act immediately on reducing potential human interference with the climate system. Such knowledge is also being further developed for other aspects of the declining resource base. Therefore, the focus in Horizon 2020 should be to underpin decisions designed to increase the efficiency and impact of the societal response. This will, however, include research on the climate and other resource systems in order to better understand systemic interactions, the collection of baseline information, and the establishment of monitoring activities to assess the efficacy of different mitigation and adaptation approaches.

SOCIETIES

The focus on 'inclusive, innovative and secure societies' provides a highly welcome challenge to the social sciences and humanities (SSH). This societal challenge is well justified not only because these qualities are particularly vital for future European society, but as importantly, because the *relationship* between these three characteristics is crucial and hitherto understudied. Inclusion, innovation and security are frequently studied by separate research communities (and similarly politically addressed independent of one another), but already existing research in these various fields support the premise that they are closely linked. Some links are based on synergies, where, say, inclusion and security are important conditions for innovation, or growth through innovation can enable further inclusion and security. At other points, tensions can be identified, e.g. when some forms of innovation or security potentially marginalise certain groups and thus reduce inclusion.

In response to the existing proposal of the Commission, the present report aims to show how it is possible to pursue a focused strategy more consistently and ambitiously. As currently presented, a considerable risk remains that this challenge of 'inclusive, innovative and secure societies' will become at best the three sub-challenges of 'inclusion', 'innovation' plus 'security', with the potential for further disintegrating into separate topics (calls). Integrating them demands carefully attending to the cross-cutting themes within this broad challenge (which de facto covers most of the social sciences and a good deal of the humanities, plus some informatics, etc.) as well as formulating some currently still absent linkages to other challenges.

The Horizon2020 proposal tries to achieve coherence and integration on the research agenda by narrowing the focus towards "hard" technologies, especially statistics, assessments and measures of efficiency (evidence-based lessons). It shows a corresponding tendency towards a somewhat technocratic definition of the nature of challenges (e.g. in the security part, critical infrastructure protection is prioritized over international politics). Indeed, inclusion-innovation-security *can* be viewed from a technocratic angle and the relevant form of knowledge be generated around data and efficiency assessments, but this represents a limited political and social vision that underestimates the power of citizens and communities to contribute to the realisation of inclusion, innovation and security.

Corresponding to a vision comprising a broader mobilisation of societal energies are forms of research that employ a wider selection of methodologies and theories to study the dynamics of society as productive and generative, rather than as the site of problems to be solved. Society must become the solution. Europe faces dramatic challenges that cut across established fields: creating cultures and mentalities of openness and innovation, reinventing the welfare-state, recreating politics and handling new lines of inequality and diversity within Europe. Research needs to go beyond technical questions to more controversial areas like global power shifts, sources of the economic crises and malaises affecting political participation, legitimation and self-steering. In such times of deep change, not all statistical relationships will remain stable, and European social knowledge therefore needs both improved databases and theoretical work. The social sciences and humanities can play key roles in relation to both the other five grand challenges and the significant ones, they have identified themselves. It is particularly important that researchers in the SSH engage scholars in the hard sciences in a joint effort to cultivate research-based innovation regarding the way expertise and democracy interact.

Acknowledgements

Copenhagen Research Forum was established by the University of Copenhagen, Technical University of Denmark and the Capital Region of Denmark in autumn 2011. The aim was to create a forum where researchers in Europe, independently and without any other agenda, could discuss and contribute to the European Commission's proposal for the next Framework Programme for Research and Innovation: Horizon 2020.

In the autumn of 2011 more than 600 researchers were invited to participate in a virtual discussion forum. I would like to thank everyone who contributed with ideas and suggestions.

I would also like to take the opportunity to thank those who have committed time and effort to making the Copenhagen Research Forum successful. The chairs of the six panels deserve special thanks for their dedicated effort: Professor Deborah Smith, Professor Peter Olesen, Director Kees de Gooijer, Professor Katherine Richardson, Professor Johan Rockström, Professor Ole Wæver, Professor Loet Leydesdorff, Head of Department Niels Buus Kristensen, Programme Director Dr Christian Piehler, Dr Jørgen Kjems and Professor Kjell Hugo Bendiksen. Sincere thanks are also due the rapporteurs for supporting the writing of this report: Tine Willum Hansen, Anna Munck Laybourn, Mai Winstrup, Nicolaj Tofte Brenneche, Kristoffer Kropp and Claus Hedegaard Sørensen.

Acknowledgement is due the European Commission for lending an ear to the conference and for providing positive feedback on the process and outcome. With CRF being an associated conference to the Danish EU presidency programme, I would also like to thank, on behalf of the organisers, the Danish Ministry of Science, Innovation and Higher Education for its support and collaboration.

Without the steering committee of the University of Copenhagen, Technical University of Denmark, and the Capital Region of Denmark, not to mention Anna Haldrup, Claus Henrik Andersen and Kristian Johnsen, together with CreoDK and Birgitte Wederking, the Copenhagen Research Forum would not have taken off.

I would also like to give a special thanks to Anne Line Mikkelsen, Torben Høøck Hansen and Jan Andersen for handling the practicalities of the CRF-process in a highly professional and dedicated manner.

Finally, I am grateful to the organisers for having given me the honour of chairing the Copenhagen Research Forum.

Professor Liselotte Højgaard,
President of Copenhagen Research Forum.

Copenhagen Research Forum

European research can contribute to solving the challenges facing society today and tomorrow in the best way possible by finding solutions, working across disciplines and involving stakeholders. European researchers are willing to participate by doing the necessary research and setting the research agenda. CRF is one of many responses to Horizon 2020, but this report is special as it was written independently by researchers from all over Europe and from many disciplines. CRF has provided an opportunity with room for creativity and cross-disciplinary dialogue. One of the main messages is that cross-disciplinary research will be of utmost importance for research in Europe and the rest of the world in the future. Tomorrow's research issues are complex and the societal challenges vast. Only by collaboration, both in planning and doing research, will we succeed. We need collaboration and real dialogue between all areas of science, technology, life science, biomedicine, social science and humanities. The outcome of CRF is a report advising European politicians and leaders on how to prioritise and how to utilise the research being carried out now and over the next eight years. The six societal challenges form a framework, but research across those challenges as well as combining and cross-fostering new ideas and solutions are vital to the success of Horizon 2020.

PROCESS BEHIND COPENHAGEN RESEARCH FORUM

The main idea behind CRF was to involve a broad spectrum of Europe's top-level researchers in the making of Horizon 2020, as part of its preparation would take place during the Danish EU presidency in the first half of 2012.

The University of Copenhagen, Technical University of Denmark and the Capital Region of Denmark wanted the scientific community's input to Horizon 2020, unbiased and with the aim of making Horizon 2020 as attractive as possible to researches working in the areas covered by the six societal challenges. In spring and early summer of 2011 the concept was finalised. The key issue was that CRF should convey ideas, visions and comments from active, outstanding researchers, all of whom were invited personally to join CRF.

The tools of CRF were designed to be as simple as possible and to take as little time as possible. Moreover, the idea was to put the scientific community in charge of the process and for the three organisations behind the project to only provide funding and manpower for the:

• Chairship – This involved contacting researchers for the six groups and establishing a chairship comprised of one Dane and one European researcher for each challenge. They were then asked to invite up to 100 researchers to offer their views in a virtual discussion forum. Out of the invitees, 15 researchers from each group were also asked to meet at a workshop conference in Copenhagen on 16 January 2012 shortly after the Danish EU presidency began.

• Virtual discussion forum – Divided equally between the six societal challenges, the 600 researchers were invited to comment on the draft text of Horizon 2020. The researchers were asked to contribute personal visions for the future as well as point out needs and possible solutions. They were also asked to suggest and comment on the technologies and the priorities within the given challenge, as well as to consider the instruments and implementation needed to ensure success as seen from a scientific perspective. Lastly, they were asked to contribute their ideas on how to secure the link between research and the innovation perspective stressed in Horizon 2020. All of the input was collected in a draft report that formed the basis of the aforementioned conference in Copenhagen.

• Conference - On 16 January 2012 the six panels met and discussed the draft report, offering comments and adding new ideas inspired by the input collected in the virtual discussion forum. The aim was to reach agreement on: 1) the views and recommendations in each of the six panels; 2) a joint statement during plenary sessions expressing the view on scientific issues cutting across all six challenges; and 3) recommendations for the implementation of the challenges so they become a basis for excellent research and far-reaching solutions.

• Outcome – A condensed report offering ideas and solutions that could help form Horizon 2020 from a scientific point of view; presentation of the conclusions to the European community in an open dialogue.

Horizon 2020 at a glance

Horizon 2020 is the financial instrument implementing the Innovation Union, a Europe 2020 flagship initiative aimed at securing Europe's global competitiveness. Running from 2014 to 2020 with an € 80 billion budget, the EU's new programme for research and innovation is part of the drive to create new growth and jobs in Europe.

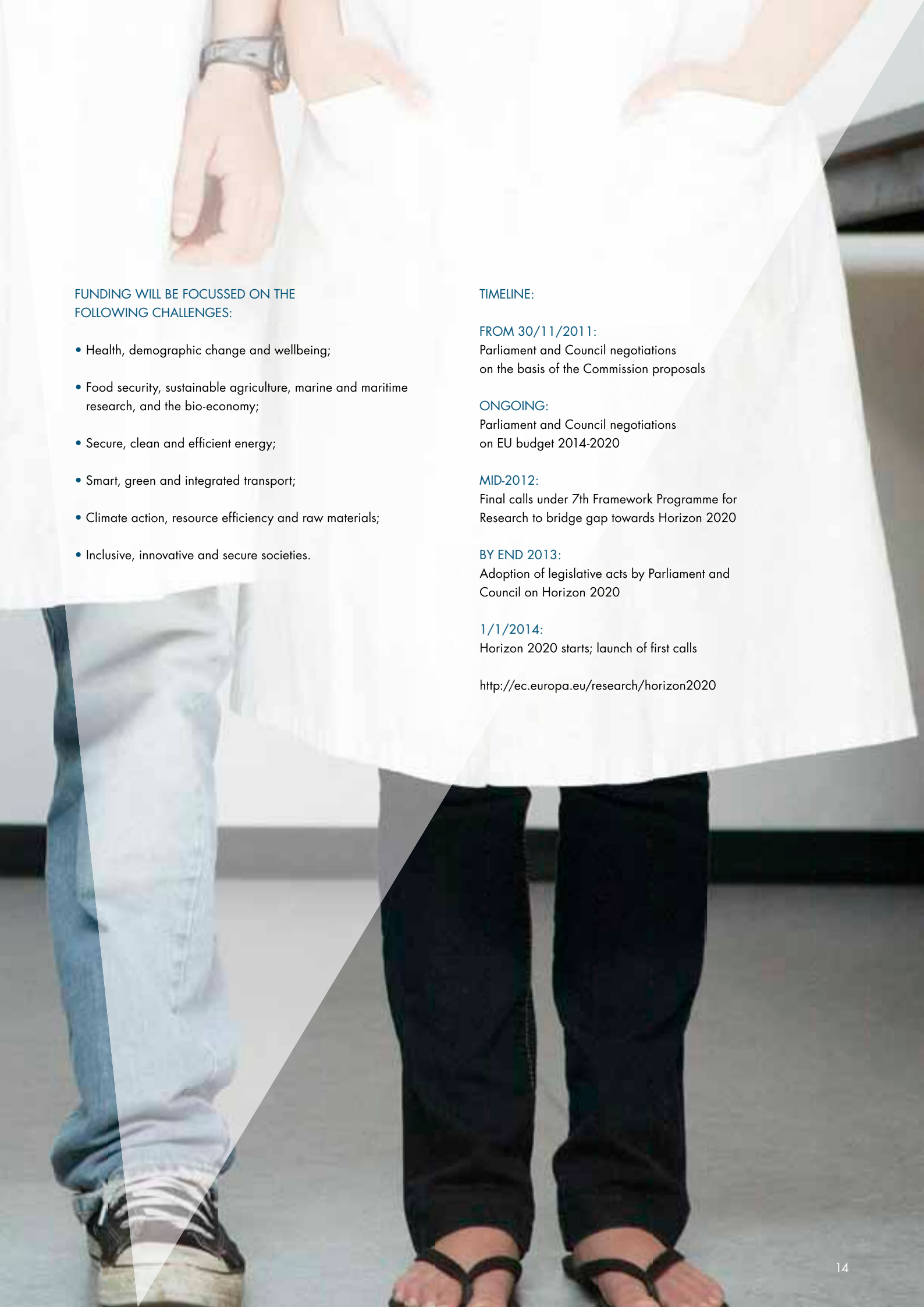
Horizon 2020 provides major simplification through a single set of rules. It will combine all research and innovation funding currently provided through the Framework Programmes for Research and Technical Development, the innovation related activities of the Competitiveness and Innovation Framework Programme (CIP) and the European Institute of Innovation and Technology (EIT).
The proposed support for research and innovation under Horizon 2020 will:

- Strengthen the EU's position in science with a dedicated budget of € 24 598 million. This will provide a boost to top-level research in Europe, including an increase in funding of 77% for the very successful European Research Council (ERC).

- Strengthen industrial leadership in innovation with a budget of € 17 938 million. This includes major investment in key technologies, greater access to capital and support for SMEs.

- Provide € 31 748 million to help address major concerns and societal challenges shared by all Europeans, such as climate change, developing sustainable transport and mobility, making renewable energy more affordable, ensuring food safety and security, and coping with the challenge of an ageing population.

SOCIETAL CHALLENGES:
Horizon 2020 will tackle societal challenges by helping to bridge the gap between research and the market by, for example, helping innovative enterprises to develop their technological breakthroughs into viable products with real commercial potential. This market-driven approach will include creating partnerships with the private sector and member states to bring together the resources needed.



FUNDING WILL BE FOCUSSED ON THE FOLLOWING CHALLENGES:

- Health, demographic change and wellbeing;
- Food security, sustainable agriculture, marine and maritime research, and the bio-economy;
- Secure, clean and efficient energy;
- Smart, green and integrated transport;
- Climate action, resource efficiency and raw materials;
- Inclusive, innovative and secure societies.

TIMELINE:

FROM 30/11/2011:
Parliament and Council negotiations on the basis of the Commission proposals

ONGOING:
Parliament and Council negotiations on EU budget 2014-2020

MID-2012:
Final calls under 7th Framework Programme for Research to bridge gap towards Horizon 2020

BY END 2013:
Adoption of legislative acts by Parliament and Council on Horizon 2020

1/1/2014:
Horizon 2020 starts; launch of first calls

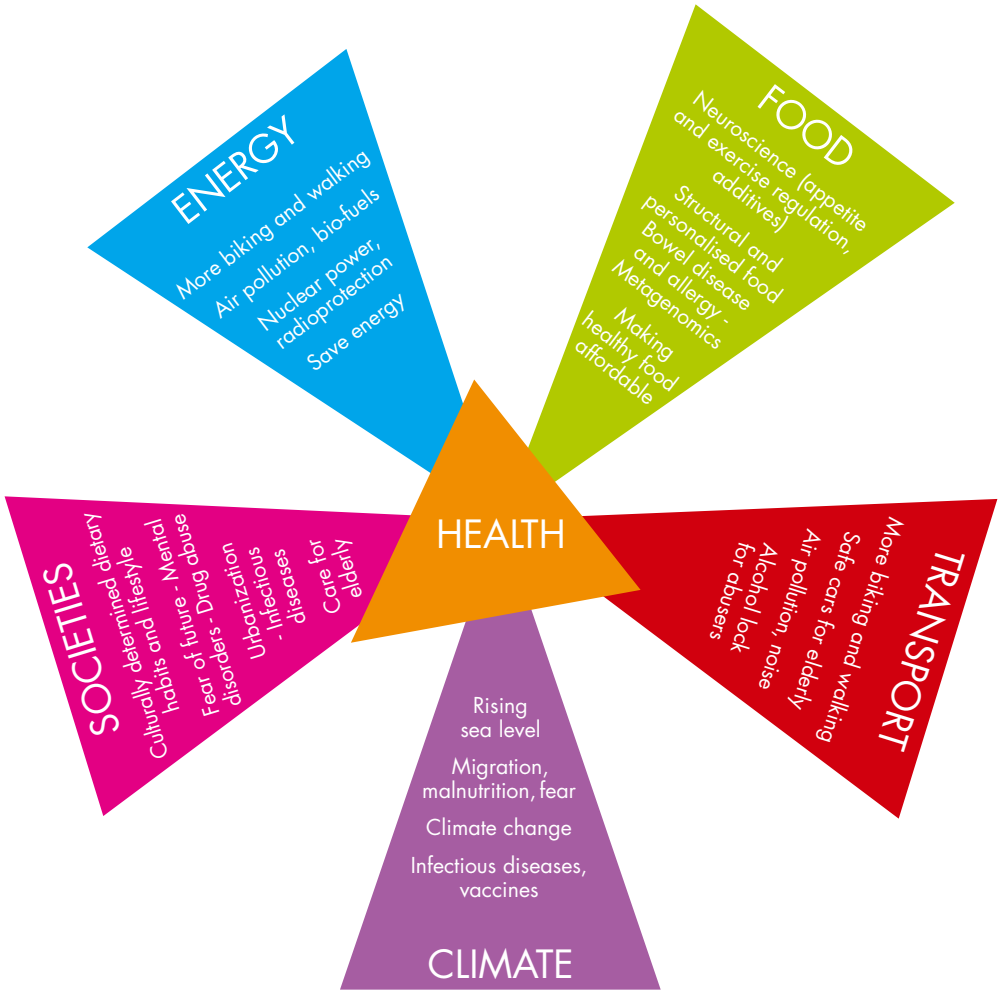
http://ec.europa.eu/research/horizon2020

Cross-cutting research issues

Cross-disciplinary research is the prerequisite for success. This was a strong message from the Copenhagen Research Forum. Future European Research should be planned and performed in a context with a genuinely holistic approach with inter- and multidisciplinary research groups working in Europe jointly with the rest of the world. This will require structuring the programme to stimulate and encourage research cooperation between the research communities contributing to each of the individual societal challenges. One mechanism for doing so could be the establishment of a programme element with the specific purpose of pursuing research on the interconnections between the challenges. The researchers must be the very best, and they must work together across research areas and across boundaries. The transition to a sustainable, healthy and wealthy European society demands research between the identified six challenges and bridging across the different areas. A new concept including viewing the whole area on a holistic basis must be developed and the programmes should be designed to meet these needs.

HEALTH, DEMOGRAPHIC CHANGE AND WELLBEING

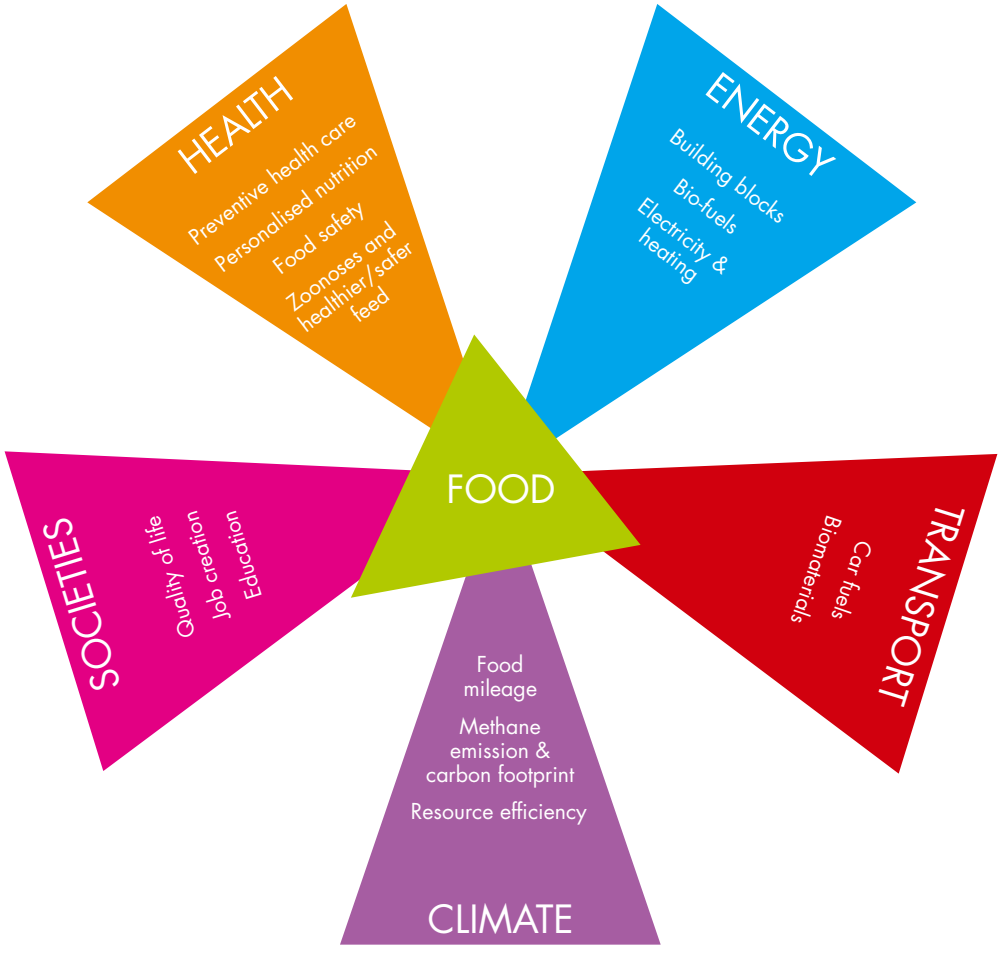
Basic, translational, and clinical research are the foundation of European health systems and services, and the social, cultural, and environmental factors that affect health need to be linked in a multidisciplinary approach. An important solution for the health challenges Europe faces involves rethinking conventional biomedical practices and converting to personalised medicine. This paradigm shift is dependent upon obtaining a detailed description of individual biological variation in connection with the environmental, societal, and lifestyle factors that influence the development of disease. One specific goal involves dealing with the huge health problems related to overweight and obesity. Prevention is of obvious importance and there is an urgent need for further research into how physical activity and training, in addition to nutrition, can prevent the steadily increasing average body mass index of Europeans. This proposal includes a vision that integrates a lifestyle of healthy habits with an environment that promotes healthy living by encouraging exercise and making healthy food affordable. This requires cross-disciplinary work not only with architects and designers but also with the food and beverage industry. Many of our current health problems stem from lifestyle factors greatly influenced by marketing and industry. More work must be done with the food industry to help persuade them to make healthier food by reducing the amount of saturated fat, trans fat, sugar, and salt. The escalating incidence of chronic inflammatory conditions and allergy observed in industrialised countries is clearly linked to environmental and lifestyle factors, though somewhat mediated through gene-environment interactions. Research in infectious diseases and vaccines are central due to the changes in climate and the structure of society.



Created in an interdisciplinary, enthusiastic, creative and positive atmosphere, the CRF workshop poster shown here depicts the interdiciplinarity necessary in the modern research landscape.

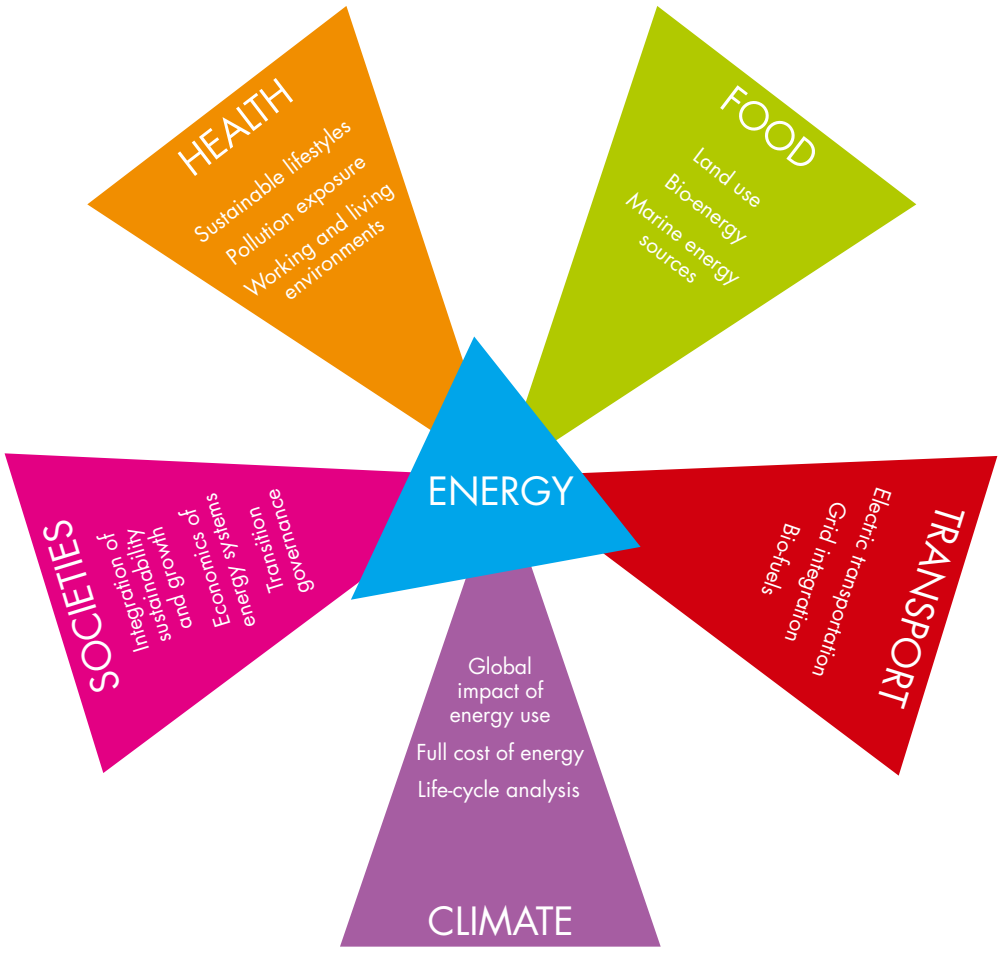
FOOD SECURITY, SUSTAINABLE AGRICULTURE, MARINE AND MARITIME RESEARCH AND THE BIO-ECONOMY

The complexity of the challenges related to food, feed and biomass production and the associated multi-directional value chain from primary production to the needs and opportunities from climate change and its mitigation, available resources, environment, new biomaterials, energy, food, feed, health, transport, and new biomaterials perspectives calls for an interactive and multidisciplinary cross-cutting research and innovation approach that embraces the other five defined societal challenges. It is critical that research and innovation in this area are addressed in a fully integrated manner, including social science and humanities perspectives at all points along the food value chain in order to realise the huge potential of challenge-driven and interactive innovations. Increases in the prevalence of diet-related diseases and disorders and the associated steep growth in public health costs and the deterioration of individual quality of life emphasises the need to develop a more balanced health care concept geared towards prevention. This must focus on a more personalised health and nutrition principle (knowledge, products, and behaviour) that is closely associated with culturally determined dietary habits and lifestyle, clearly calling for cross-cutting approaches between the challenges of food, health and social science. Research from a broader food and bio-economy perspective must be strengthened by applying cutting-edge research results and technology platforms from other areas, such as molecular biology, nanotechnology and information and communications technology (ICT). This should be combined with the application of mathematical and computer modelling in order to meet the global challenge to produce significantly more per unit of a given resource. Processing of food, feed, and the biomass in cascade must involve to a much greater extent multidisciplinary approaches to fully integrate requirements for minimal energy consumption, optimal process design and operation, the engineering of desired product attributes, and consumers' preference, acceptance, and needs – not to mention include the latest results from research in transport and logistics (food mileage), ICT and mathematical modelling, and the implementation of advanced management practices all the way from consumer to farm.



SECURE, CLEAN AND EFFICIENT ENERGY

The transition towards carbon-free energy solutions calls for a more integrated approach combining technological, economic, social and cultural aspects, and for better cooperation between policy and research. Sustainable energy solutions need two types of approaches: Highly innovative technology research plus a new approach to systemic research and innovation challenges. The first type is already being pursued adequately as a result of SET plan efforts to organise energy research on a European scale. However concerning the second type, the SET plan lacks the systemic approach and does not sufficiently mobilise universities. Universities represent a major opportunity for expanding the knowledge base and for addressing problems at system level through new instruments using problem-oriented, cross-disciplinary collaboration. The systemic approach should involve expertise from a variety of scientific areas depending on the problem to be solved. Many of the key transition challenges in energy transcend the scope of individual technologies (wind, solar etc.) and individual disciplines. Combining advanced energy technology with innovative approaches to systemic problem solving constitutes a major challenge in Horizon 2020, but also a major opportunity for European research and industry. The combination of energy expertise with food and agriculture, transportation, health, climate and societal expertise can further ensure the development of lasting solutions and balanced transformations of energy systems.



SMART, GREEN AND INTEGRATED TRANSPORT

Passenger and freight transport is derived from the spatial dispersion of people's activities and production of goods and as such an essential and integral element in our lifestyle and consumption pattern. Transport research therefore should be (and have been) using multidisciplinary approaches ranging from several branches of engineering to various disciplines in social sciences, such as economics, sociology, psychology, geography and political science. The major transport (sub-)challenges also relates closely to the themes of the five other societal challenges, and the relationship goes both ways, clearly calling for cross-cutting research cooperation:

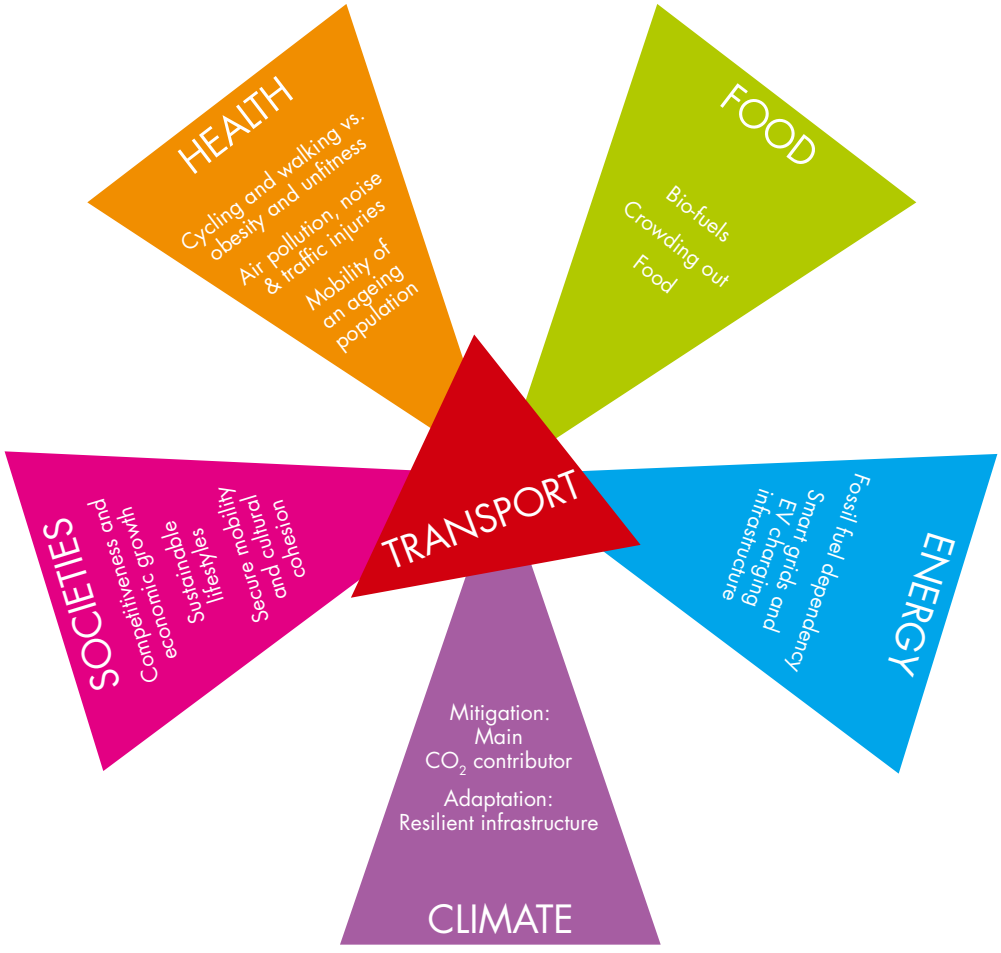
Health: Biking and walking helps prevent many conditions, such as obesity, type 2 diabetes, heart disease, hypertension, some cancers, depression, and osteoporosis. On the other hand, tail pipe emissions of air pollutants, traffic noise and accidents all takes heavy death tolls every year and causes severe impacts on human health and well-being, which also entail substantial economic costs to society. The ageing population makes new mobility demands which are also strongly related to physical conditions of elder people.

Food: Widespread use of first generation biofuels for transport can crowd out food production on arable land and drive up food prices with significant global impacts on living conditions of poor people.

Energy: The transport sectors' significant share of total consumption makes the link with energy obvious. Further, transport's almost sole dependency on oil places it at the core of energy security. Transition to alternative energy sources, e.g. via electric vehicles will set new requirements to the power distribution net but also potentials in terms of smart grids.

Climate: Transport is one of the main contributors to global GHG emissions and the share is rising. Hence, transport should be at the centre of mitigation efforts, yet transport CO_2 emissions have shown very difficult reduce. Adaption to climate change is also calls for heavy investment to make transport infrastructure resilient to extreme weather events.

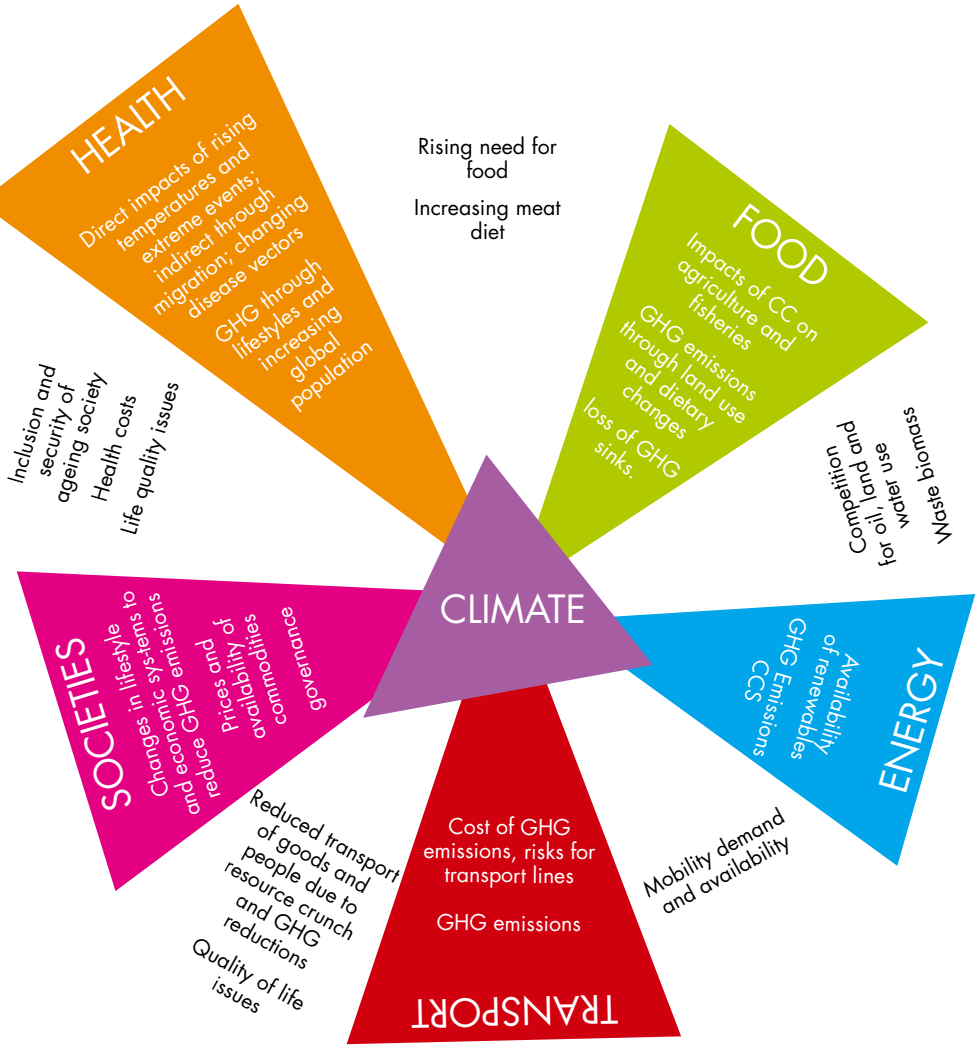
Societies: An efficient transport system is an essential framework condition for a competitive industry and the functioning of the internal market. Hence, further research in how direct effects of improving the transport system transform into industrial competitiveness and economic growth is crucial and of topical interest with a view to the current economic crisis and the need to revitalize Europe's competitiveness. Secure mobility is essential for a secure society as terrorist actions has often focused on transport. Finally, cultural cohesion is fostered by high mobility and sustainable lifestyles are closely linked to environmental impacts of our transport pattern.



CLIMATE ACTION, RESOURCE EFFICIENCY AND RAW MATERIALS

Climate-related research, climate action and increasing resource-use efficiency are cross-cutting challenges which cannot be considered on their own but need to be addressed as a part of the overall challenge of developing a sustainable path for society. They must, therefore, be embedded in the remaining challenges, and cannot be carried out independently from, for example, the energy challenge, food security or the development of inclusive and equal societies. Ideally, all six challenges should be incorporated into the overarching challenge of achieving sustainable development. With the global population at 7 billion and growing, a paradigm shift in the way human societies approach the extensive use of natural resources is inevitable. Such a shift will lead to changes in all six societal challenges.

Climate and resource-related research does not solely concern an understanding of the climate and Earth system. Research on the best social models to be employed for sharing global natural resources and research on how to use scarce resources most efficiently are also needed. Interdisciplinary research, including natural sciences as well as the humanities and social sciences, must therefore be encouraged.

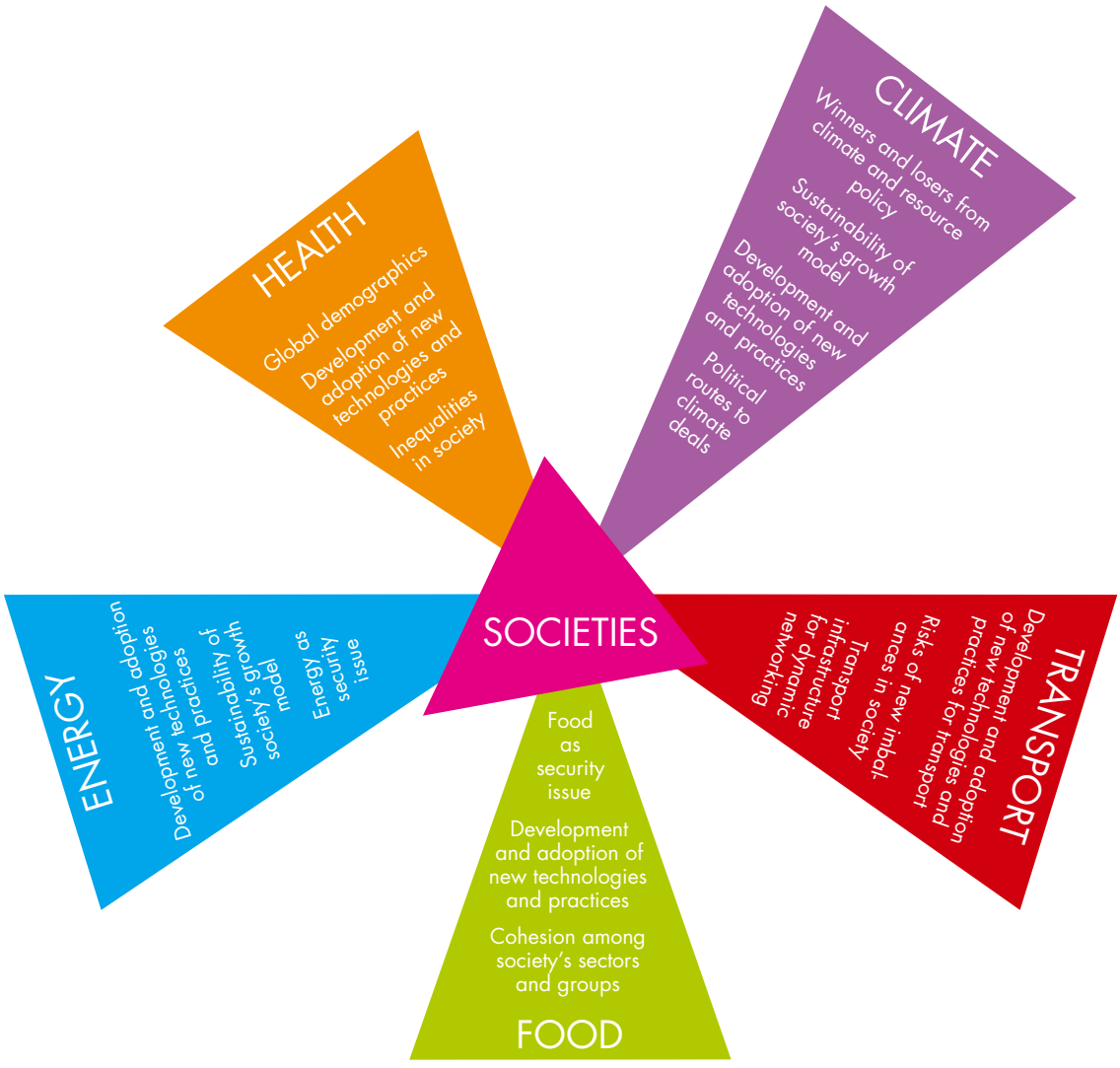


INCLUSIVE, INNOVATIVE AND SECURE SOCIETIES

The focus on inclusive, innovative and secure societies is an original construction of a cross-cutting problématique for many social sciences and the humanities. These three attributes are frequently studied (and addressed politically) by separate communities, but strong links exist between them. This triad is therefore a visionary call for original inter-disciplinary research, and many of the comments by this panel aim at ensuring that the theme actually fulfills the promise of this call and avoids disintegrating into 'inclusion', 'innovation' plus 'security'. The nexus must actually be explored in relation to the urgent challenges in European economics, politics and social life.

Some of the many important cross-linkages to the five other societal challenges are: how health both supports and is furthered by inclusion and innovation (and by security, in the wide sense of the word); the centrality of transport and energy as infrastructures that condition the achievement of inclusive, innovative and secure societies; and the importance of thoroughly thinking climate sustainability into all technological developments in society. Furthermore, the five other challenges contain potential contributions to economic growth that will be important in achieving these three aims for societies. Yet some formats for growth can have negative effects, especially regarding inclusion, if particular groups are marginalised.

This sixth challenge is strongly linked to the other five, because the whole innovation theme is a meta-issue that reappears numerous times in the other challenges, as innovation in research, technologies and usage are first discussed specifically, sector by sector, for the other challenges, and then generally as an undertaking of societal evolution in the present challenge. It will be crucial to connect and contrast knowledge about innovation that emerges 'bottom up' from specific fields with more generic innovation research in order to both optimise specific procedures in research and development and to adjust society in ways that generally foster innovation. Ultimately, the challenge is how to be innovative about innovation.



ABSTRACT

To relieve the threat to human health and welfare imposed by an expanding number of major health challenges, biomedical research and its implementation in clinical practice must be supported and accelerated. To achieve this in the next decade, a paradigm shift toward personalised medicine will be of major importance, with the overriding aim of improving every citizen's lifelong health and well-being. Basic, translational, and clinical research of high quality provides the foundation for European health systems, offering the opportunity to link with social, cultural, and environmental expertise to facilitate world-class multidisciplinary research. The global revolution in biomedicine is also providing access to new technologies that will require expansion and implementation to tackle the health challenges that Europe faces. A European platform engaging all key stakeholders to ensure discovery and delivery of these technologies will be crucial. Establishment of a European Strategic Action for Healthier Citizens is also recommended, to assist in strategic long-term healthcare research, planning, including preventive measures, and delivery of best practice across Europe. In most European countries, healthcare is a driving factor for investment – in industry, in education and training, and in the European knowledge base for wealth creation. The proposals in this document will enhance investment and create jobs in research and innovation, improve healthcare status of Europeans and at the same time drive down integrated societal costs of healthcare.

HEALTH

DEMOGRAPHIC CHANGE AND WELLBEING

VISION

Europe faces an increasing number of major health challenges. A positive message is that, thanks to improved health care, a drop in smoking rates and safer jobs, we live longer. In the coming decade, European health issues will focus on confronting an ageing population with an increasing number of people beyond retirement age. This change in demographics will result in complex disease patterns, with multimorbidity, which necessitate a change in therapeutic approaches from treatment through isolated (and often organ specific) specialities and subspecialities towards more comprehensive and holistic approaches. Furthermore, we will face a growth in the incidence of physical disability, cardiovascular and neurological diseases, including dementia, and cancer. Moreover, emerging sensory impairments, and especially hearing deficiency will reduce not only quality of life but also how individuals can interact with society.

Poor dietary habits and a lack of physical activity also mean coping with associated serious public health issues such as obesity. With about half of the population in Europe now considered overweight or obese, the occurrence of diabetes and metabolic syndrome is on the rise. Reproductive health problems contribute to increasing need of artificial reproduction techniques and despite advanced technology, infertility is an increasing problem.

Another challenge is the emergence or reemergence of infectious diseases and antimicrobial resistance in Europe and the rest of the world. The role of environmental factors on disease, and more generally the role of lifestyle, is also increasingly recognised for its major impact on health. The escalating incidence of chronic inflammatory conditions and allergy observed in industrialised countries is clearly linked to environmental and lifestyle factors, though somewhat mediated through gene-environment interactions. Our ability to treat more conditions combined with people's rising expectations toward the health care system means that health care expenditures will continue to be under pressure, thus increasing the gap between cost and economy. Consequently, these challenges require an even more efficient and equitable healthcare system.

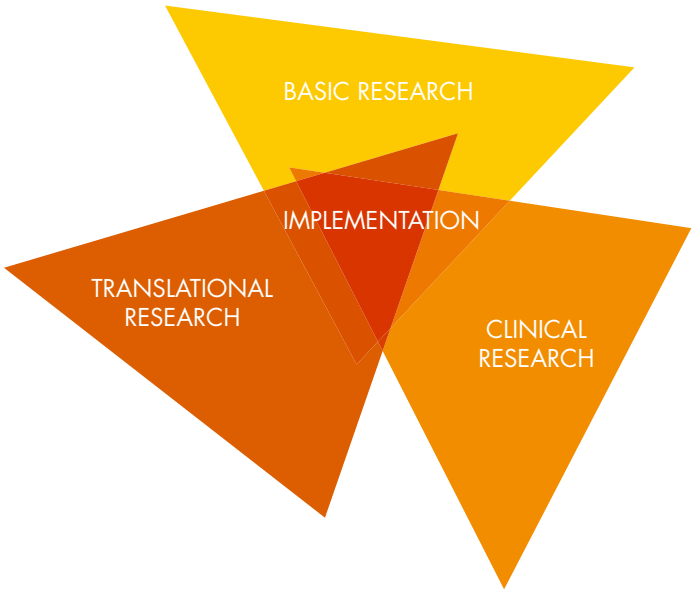
The evidence is overwhelming that investment in biomedical research yields economic returns both through improved health gains, e.g. a healthy workforce and healthy aging, and through commercial exploitation of research outputs. Investment in medical research has been shown to continually yield an annual financial return of 39%. This means that appropriate funding and best practice for medical research are not only essential to securing health and welfare in Europe and the rest of the world, but also make sound economic sense. Correspondingly, health economics is a central instrument to link costs and health gain and to prove that research costs should be viewed as an investment.

The major goals for health in Europe are to improve the lifelong health and wellbeing of all Europeans. The idea is not just "to add years to your life", but "life to your years". Improvements of this nature will also reduce overall healthcare costs. Consistent with this is a more holistic approach in evaluating the true cost of disease for society, including costs from the workplace (i.e. lost productivity) and thus also the true value of investment in good and efficient treatments.

To relieve the future burden on European society we need to strengthen bio-medical research and its implementation in clinical practice. We have to rethink healthcare in ways that make it possible, for example, for the elderly and other patients to maintain their quality of life and to stay in their own homes longer and hence out of hospitals and nursing homes.

NEEDS AND SOLUTIONS

Horizon 2020 will provide a positive and crucial instrument for strengthening biomedical research in Europe. Biomedical research is basic research in the laboratory. It is clinical patient oriented research using the results from basic research in patient studies. Translational research is the bridge or link taking basic research results from the bench to the bedside and back. When clinical research has been established as new treatment, implementation of this new treatment in clinical every day practice is needed.



Basic, translational, and clinical research are the foundation of European health systems and services, and the social, cultural, and environmental factors that affect health need to be linked in a multidisciplinary approach.

An important solution for the health challenges Europe faces involves rethinking conventional biomedical practices and converting to personalised medicine. Stratified Medicine, the first step towards personalised medicine is where an existing disease is classified into subsets of patients that respond to different therapies. These groups are defined either through different response to therapy or new diagnostic methods. Personalised Medicine is where, through the use of advanced diagnostics, novel combinations of therapies are identified where the combination is specific for an individual patient. Each specific combination of two or more agents may appropriate for only one in a thousand or one in ten thousand patients. This is an emerging concept in investigator sponsored studies that will become more and more common in cancer as the number of agents with companion diagnostics become available. Because our understanding of the molecular pathology of disease grows, this principle will be applied to many other disease using existing and new medicines.

One specific goal involves dealing with the huge health problems related to overweight and obesity. Prevention is of obvious importance and there is an urgent need for further research into how physical activity and training, in addition to nutrition, can prevent the steadily increasing average body mass index of Europeans. This proposal includes a vision that integrates a lifestyle of healthy habits with an environment that promotes healthy living by encouraging exercise and making healthy food affordable. This requires cross-disciplinary work not only with architects and designers but also with the food and beverage industry. Many of our current health problems stem from lifestyle factors greatly influenced by marketing and industry. More work must be done with the food industry to help persuade them to make healthier food by reducing the amount of saturated fat, trans fat, sugar, and salt.

Empowerment and education of people with knowledge and skills to make informed choices about their health and wellbeing and motivate them to become better selfmanagers is a further key topic.

TECHNOLOGIES AND PRIORITIES

There are technologies available to meet the above challenges and the development of new technologies will be a key factor in meeting the goals. A multi-disciplinary approach is necessary now more than ever.

The European Research Council (ERC) meets the requirements of research excellence, but the field of biomedicine in the hitherto given ERC grants has not been prominent. The ERC should be strengthened as proposed and biomedicine should have a more prominent role. Also, the spend should be more commensurate with the scale of the disorders – currently brain disorders account for one third of European health disability yet only receive one 6th the research spend. Europe needs a strong new generation of medical researchers who are trained to deal with the various aspects of basic, translational, and clinical research. Critical to this training programme is a cross-disciplinary approach and international mobility. In this respect, the Marie Curie Actions are highly important and should be continued and extended into the clinical arena.

Research excellence needs excellent research infrastructures that not only underpin research but also lead its development and create an attractive climate for world-class researchers. There is encouraging progress in the area of research infrastructure in Europe and the European Strategy Forum on Research Infrastructures (ESFRI) should be implemented in biomedical research. The ESFRI Roadmap 2010 contains the following nine research infrastructures for the biomedical sciences: BBMRI (for biobanking and biomolecular resources); EATRIS (for translational research); ECRIN (for clinical research); ELIXIR (underpins biological information and data storage for biomedical research); EUOPEN SCREEN (for screening platforms for chemical biology); EuroBiolmaging (for biomedical imaging infrastructure); MIRRI (for microbiological services); Infrafrontier (for phenotyping and archiving of model mammalian genomes); and ERINHA (for high-safety laboratories). Securing further founding for the ESFRI-project could be effectively linked to the Structural Funds.

Data collection and input need to be harmonised and more advanced integrative IT tools are essential for connecting databases. Furthermore, novel research methodology, including new mathematical models and statistical tools, will be needed and relevant facilities for biostatistics and bioinformatics must be established. Mathematicians have developed extremely powerful models with a wide spectrum of applications. Modelling can lead to groundbreaking innovations in many areas of utmost interest, for example from pharmacokinetics to cancer treatment; the interpretation of medical imaging to data mining in statistics; and from the design of prostheses to the use of electronic aids. The ESFRI proposals are relevant for this.

Promoting self-care and patient empowerment is a critical challenge to be addressed in the near future if we are to succeed in relieving pressure on the healthcare sector. An increasing amount of research activity focuses on mobile health (mHealth) solutions. An emerging technology, mHealth (wireless healthcare) can change how a person's health may be monitored. Some examples are wireless Band-Aids, wireless sensors, remote health monitoring, pill containers that remind patients to take prescribed medicine, and devices that measure fitness. Smartphone's with medical apps are useful new tools that empower patients, physicians, and health care employees to become more efficient in their daily activities and communication. Further effort toward "digitizing" as much of the health care process as possible is warranted. This issue also calls for the increased use of Information and Communication Technology (ICT) in people's/patients' homes, in clinical workplaces, in the management of institutions, and among healthcare professionals across disciplines and sectors. Insilico medicine is the modelling, simulation, and visualisation of biological and medical processes on computers and is the result of the advance of medical computer science over the last 20 years. The largest impact of insilico medicine may come not just from simulation, but also from a broader range of computational efforts to improve disease management and prediction.

Nanomedicine and synthetic biology are emerging technologies, which are quickly establishing themselves as key enabling technologies. These are promising approaches to realise the vision of a bio-based European economy through research and innovation as well as to delivering competitive and sustainable growth in Europe. Development and optimization of artificial, bioartificial and tissue-engineered organs are related to this.

TASKS FOR CONSIDERATION IN HORIZON 2020:

Europe should lead the establishment of a fundamental reinterpretation of how to approach healthcare by pursuing **personalised medicine.** This approach, when appropriately implemented will give much better outcomes for a given health care spend. The transition from the long established one-size-fits-all approach to a new healthcare strategy based on individual biological phenotypes (genomic, proteomic and metabolomic profiles, including epigenetics), will provide an opportunity and a framework in which the current structure of healthcare will be transformed based on advances in molecular understanding and redefinition of diseases. This paradigm shift is dependent upon obtaining a detailed description of individual biological variation in connection with the environmental, societal, and lifestyle factors that influence the development of disease. To achieve this, enormous wide range of biological samples and patient-relevant data must be collected, catalogued, and stored in biobanks. The data must then be interpreted and linked with new approaches for interpretation, such as the application of mathematical models and statistics. Integrity of these biobanks and ethics approval by relevant bodies is of outmost importance. As a result of earlier significant investments, Europe currently boasts some of the most valuable population and patient cohorts available, as well as some of the most extensive biobanks in existence worldwide. The value of these tools, however, is rapidly lost if they are not adequately maintained, updated, and expanded. There is an urgent need to integrate these advances in order to work toward development of a new molecular redefinition of diseases **(taxonomy)** by 2020. Part of this topic is enhanced use of patient stratification. Although a considerable number of novel biomarkers, including lab tests, imaging, genetic testing etc. are currently available, our understanding of them is incomplete at present and we have yet to exploit their true potential for better prevention and patient treatment. Animal models are important with appropriate quality and relevant research questions as prerequisite. These models can refine design to secure relevance to health and have the opportunity to back translate questions from clinical practice.

Preventive medicine is of obvious importance. Knowledge to help the population to live a healthy life through education and behavioural science by influencing the remedies will reduce the harm of chronic diseases in all age and assure a healthier population and influence economy in a significant positive way. This also entails putting greater emphasis on applying do-it-yourself (DIY) medical monitoring and services recognising that they are an essential part of preventing and predicting personal health risks before they evolve into real health problems in need of treatment. Scientifically responsible medical community aiming to pave the way for promotion of public health is central.

Multidisciplinary research is essential for a **healthy aging** from conception to old age, including focus on developmental disorders. This face the challenge of improving access to active aging in order for senior citizens to live healthy and independent lives. Self-care and empowerment using mHealth are essential issues. Furthermore it is important to translate the knowledge into sustainable community-based programmes to minimize physical disability and reduce the burden of **musculoskeletal conditions.**

Neuroscience will be of vital importance for the development of more effective treatments for age-related cognitive changes and neurological diseases, e.g. Alzheimer's and Parkinson's disease plus improving the woeful impact we currently have on life-long disorders such as schizophrenia and depression. With the rising number of elderly in Europe, neurological diseases and **sensory impairment** represent important challenges when it comes to reaching the overall vision for health laid out here.

Cancers affect one in three Europeans at some stage in their lives. Rapid advances in the molecular understanding of these diseases are already leading to a major shift in diagnosis and therapy. The opportunities for creating technologies for earlier diagnosis and much more focused targeting of therapies are enormous. These new approaches will bring much more efficacious use of the resources currently devoted to cancer and will lead to increasing likelihood of long term remission

Cardiovascular disease continues to be a leading cause of death in Europe. More research is needed in areas ranging from genetic and molecular studies of the mechanisms of cardiovascular disease to studies of vascular properties, lifestyle interventions, and responsiveness to preventive pharmacotherapy.

The rising incidence of overweight and **obesity** means there is a need for even more research into how physical activity and training, in addition to nutrition, can prevent the steadily increasing average body mass index in Europe, not to mention the major health problems e.g. **diabetes** associated with overweight.

Research of **host defence mechanisms** in disease – the innate and adaptive immune systems – are of importance, as well as **immunotherapy. Stem cell research** is a related issue. Research in **infection diseases** and vaccines are central due to the changes in climate and society structure.

Research to improve the prevention, diagnosis and management of **reproductive health** disorders, including infertility in areas of long standing low fertility rates below replacement level. There is a strong need to focus on fetal origin of adult reproductive diseases in both sexes.

It is important to develop the understanding of **rare diseases** and to optimise diagnosis, care, and treatment, including the clinical evaluation of the long-term effects of new treatments. Patients suffering from rare diseases are scattered all over Europe, but some countries could take charge of certain given diseases. Establishment of centres of expertise within specific diseases. The role that whole genome sequencing is starting to play in finding therapies will certainly accelerate.

Medical imaging is central to improving diagnosis and treatment in a non-invasive or minimally invasive setting. Molecular imaging might enable the characterisation of patients based on the behaviour of certain tracer molecules or tissue characteristics using imaging modalities. Specific actions towards mapping molecular imaging technologies and other biomarkers would help foster the development of personalised medicine and

patient stratification approaches to obtain clinically applicable strategies. Radioprotection of patients and the environment will also be an issue of great importance.

Related to several of the areas above is research in palliative medicine directed to improve care for seriously ill patients and their families.

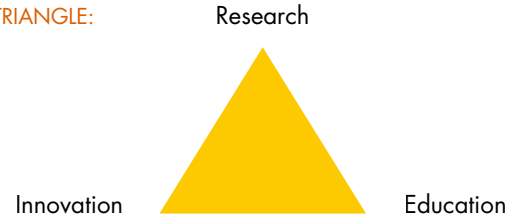
INSTRUMENTS AND IMPLEMENTATION

In the research area the most important focus is to implement in clinical practice, we must however be careful when pushing for implementation and demand evidence and usefulness. When clinical research has been successfully implemented in clinical practice it will answer important questions relevant to clinicians and practitioners and provide the evidence necessary to underpin practice.

An important tool will be European cooperation schemes and the enhancement of student and researcher mobility. Among others, a widely understood taxonomy for research careers across Europe will improve scientific cooperation. Ideally there should be no restrictions preventing researchers in the 27 member states from collaborating, so that the most excellent minds will have the possibility of working together. Based on an understanding of the value of working in partnership with research communities around the world, this collaboration should also be set in a global context.

The benefits of a common approach for classifying research portfolios applied across research organisations are clear. Classification helps research organisations keep track and evaluate investments or programmes and, more generally, research policies. The benefits of successful classification approaches also include improved communication, the identification of opportunities, the ability to compare activity with other research organisations, support for partnership work, and the increased efficiency of operational processes. The proposal for the Horizon 2020 includes application of exante research classification of funding schemes and expost classification of the outcome of research programmes. This is an exceedingly positive and important initiative.

THE TRIANGLE:



is more important in the future than at present and interdisciplinarity and collaboration with other research areas and disciplines is of outmost importance for all three sides of the triangle.

A major threat to European leadership in research resides in the decreasing attractiveness of this field for students in several European countries. Europe should improve its attractiveness by taking proactive decisions and promote the training of students to experimental approaches and to data-based decisions very early at school, initiate a strong effort to propose attractive careers not only at the researcher positions, but also to create a career path in bio-engineering, and elaborate an intense communication program for researchers to present their results to the widest audience in all media. Training in the development of research policy and agendas is further important.

The Innovative Medicines Initiative (IMI) to remove bottlenecks hampering the efficiency of the development of new medicines through public-private partnerships (PPP) is increasingly relevant. Early involvement of the private sector can bring creativity, efficiency, and capital to address complex research questions.

The biomedical companies' often face severe difficulties in commercialising their research, with the proliferation of excessively onerous and poorly conceived regulation acting as a major inhibitor to innovation. Only few companies have the scale, resources, and competences to bring new treatments to market, and this lack of diversity leaves Europe vulnerable. More and more companies are finding drug development in Europe economically challenging and are moving their operations from the region. This is an issue that requires a new dynamic between academia, clinical practitioners, industry, and the regulatory agencies and this has recently been addressed successfully via the IMI.

Biomedical research of high quality should be conducted in an open, honest, and transparent way and people and patients should be more greatly involved at all stages. For a more inclusive research we need further patient involvement. One way to achieve this is to include and educate members of organizations as research project partners. In NIHs prioritizing and evaluations it is now common practice to include patient advocates. Patient empowerment and advocacy will also be important for translation of new relevant research into clinical practice.

Furthermore, healthcare professionals should be well equipped to communicate about biomedical research and funding agencies should require researchers to report their plans for involving patients and the public in their research projects. This also involves a system of scientific publications and information retrieval in which free access to all (published) information is guaranteed. Open access could be provided through institutional repositories by the authors or by directly publishing in open access journals with publishing costs paid by the authors' institutions, grants, or philanthropic support.

Another important issue is the creation and maintenance of an open trial registry for trial protocols and results which can in turn be linked to approval by relevant ethics committees, while also working towards allowing conditional public access to full clinical trial data sets. Furthermore, investigator-led clinical trials have the potential to contribute widely to the body of research but need to be easier to undertake, much more widespread, and less burdened by bureaucracy such as introduced by the European Clinical Trials Directive, 2001.

The proposal for Horizon 2020 will simplify the rules for participation including abolition of time sheets for staff that work full-time. This is an important issue; however it should be extended to part-time workers. In health research a high proportion of researchers work part time, as they are physicians and researchers at the same time. The bureaucratic burden of the time sheets makes this funding less attractive, and "best practice" for NIH, MRC, and Wellcome Trust should be consulted.

Regulators and directives etc. at both EU and national levels must keep up with the rapidly developing technological advances in medicine to facilitate research and optimize patients access to new treatments. Moreover, the regulatory issues and the directive of clinical and other types of research need to facilitate researcher and not the opposite.

INNOVATION IMPACT

Healthcare is a driving factor for different industries in most European countries, which means investments in research and innovation will pay off for Europe as new concepts in therapy can be exported worldwide. Biomedical research is necessary for providing jobs and growth in the European pharmaceutical industry, in biotech, and in the medical technology device industry. However, innovation in Europe faces important structural impediments. Europe's system of capital provision is not well adapted to high-tech research, both in terms of its appetite for speculative investment and its ability to operate across borders. Attempts to fill this gap with centralised funding programs, such as the IMI, while highly welcomed, can only go so far.

To facilitate this coordination of European health research activities, funding should include the entire chain of innovation, from basic research to the technical and organisational implementation of a new innovation. Programmes such as EUROHORCs' Money Follows Researcher scheme, the development of Money Follows Cooperation schemes, as well as further work on common administrative procedures would also greatly improve coordination.

At present there is no European platform between stakeholders that covers a variety of fields, from bench to bedside, from clinic to community, and no common overview on health and biomedicine research implementation in clinical practice and health-related industry. Establishing a "European Strategic Action for Healthier Europeans" designed to aid strategic long-term planning driven by healthcare and optimising healthcare delivery across Europe through high level treatment guidelines and a shared understanding of how health technology assessments can deliver value for money will be an important instrument. An additional goal will be establishing a virtual infrastructure that can provide "a one-stop shop" where front-line research groups and laboratories can find information and people with the expertise they need.

FOOD
SECURITY, SUSTAINABLE AGRICULTURE, MARINE AND MARITIME RESEARCH AND THE BIO-ECONOMY

ABSTRACT

The overriding challenges of increasing demand, competition for land use and other resource scarcities put massive pressure on agriculture and the food and feed industry to produce significantly more per unit of resource. Food, agriculture and land use must be seen in a much more complex and multi-directional value chain, where research and innovation must encompass needs and opportunities from climate, available resources, environmental sustainability, transport, energy and health perspectives, not to mention social and economic requirements. The processing of food, feed, bio-energy and bio-materials must also be seen to a much greater extent in a holistic perspective including a full life-cycle approach to the use of raw materials, either for their fresh use or their conversion into shelf-stable and refined products and the associated supply chain. Here, key objectives are reductions in food waste and water consumption, valorisation of all bio-resources, including municipal bio-waste and agro- and bioindustrial side streams, as well as the recycling of sufficient amounts of carbon and phosphor to maintain soil vitality. Valorisation from biomass must be optimised by developing and utilising smart and energy-efficient processing chains, while maintaining the chemical integrity of valuable components and exploiting the highest value from each biomass component (e.g. nutraceuticals for gut health improvement, food ingredients, proteins, optimised animal feed, biopolymers, fibres, chemical feedstocks, car fuel, and, finally, converting any remaining residues to biogas, electricity and heat. Increasing prevalence of diet-related diseases and disorders calls for a balanced healthcare concept more geared towards prevention. This calls for new knowledge for the development of affordable and effective dietary adjustments for better health at individual and population levels, with special emphasis on children's needs and the ageing population. There is an overall need to create an innovation culture where researchers, companies (especially SMEs), university education, NGOs and governments (including regulatory authorities) work closely together to increase the speed and volume of the exploitation of research and knowledge across this area.

VISION

The overall challenge to Europe in this area is to develop a new and much stronger knowledge and innovation platform to meet the demand for high-quality affordable nutrition to a growing global population under the conditions of climate change, increasing scarcity of land, water and other resources, sustainable production and protection of the environment. In Europe's transition from an oil economy to a future bioeconomy, there will be increasing competition between crop production for food, animal feed and chemical feedstock, thus increasing the demand for agricultural outputs - Europe has to produce twice as much with half the inputs.

REMARK ON TITLE

Since the overall vision is to support research and innovation in order to increase and make best use of all available bio-resources, the inclusion of specific research areas like 'marine and maritime research' in the title of the chal-lenge is misleading. The panel recommends: "Food security, sustainable agriculture, the marine environment, and the bio-economy".

RESOURCE USE EFFICIENCY THROUGHOUT THE ENTIRE BIOMASS PRODUCTION AND PROCESSING CHAINS

One challenge of the European bioeconomy will be to build secure and sustainable agricultural, horticultural and aquaculture supply and product processing chains to meet the increasing demand for food, feed, fibre, chemical feedstock and biomass for energy. Biological materials (from agriculture, forestry, fisheries, and aquaculture as well as side products from agro-industrial production chains and municipality biowaste) must be brought into use for food, feed and biomass valorisation in bioindustries. Land use must be optimised while paying special attention to maintaining biodiversity and improving agricultural practices, e.g. by using crop rotation methods (including catch crops, aftercrops etc.), mixed cropping systems, perennials, reduced tillage etc. At the same time crop and forest production must increase resource-use efficiency and reduce chemical (fertilizer, pesticides, herbicides) and water input. Sea- and land-based animal production must similarly reduce the use of antibiotics for disease control and reduce phosphate in animal waste products. This requires all available (including genetic modification) and new technologies for breeding and germplasm utilisation, and also a systems-level understanding of plant and animal metabolism under changing environmental conditions. Harvested plant products and residues not used for food and feed must be developed into higher value products while recycling sufficient amounts of carbon and phosphor to maintain soil vitality. Valorisation from biomass must be optimised by developing and utilising smart and energy-efficient processing chains, while maintaining the chemical integrity of valuable components and exploiting the highest value from each biomass component (e.g. nutraceuticals for gut health improvement, food ingredients, proteins, optimised animal feed, biopolymers, fibre, chemical feed-stocks, car fuel), and, finally, while converting any remaining residues to biogas, electricity and heat.

The rapidly increasing global demand for food of animal origin (meat, fish, milk proteins etc.) resulting in a huge growth in the need for feed protein is another important aspect which will be difficult to meet in an eco-sustainable way. Europe must find an alternative solution to the current practice of feed imports. Oceans and other aquatic environments constitute a large and yet underutilised potential for growing and harvesting food and feed, but it is essential that they are not seen as more renewable than terrestrial resources – and aquatic production is facing similar environmental issues (e.g. antibiotics) as plant-based production.

PREVENTIVE ROLE OF FOOD AND DIET IN HEALTH AND WELLBEING

Demographic changes (ageing population and urbanisation) and expected increases in the prevalence of diet-related diseases and disorders will accelerate the steep growth in public health costs in all European countries. This calls for a more balanced healthcare concept further geared towards prevention, since the current curative concept is socially and financially unsustainable. Preventive healthcare should focus more on personalised health, nutrition, and wellbeing supported by improved understanding of the link between genetic make-up and food and nutrition impacts on health at both individual and group level. Such understanding requires research into interactions between gut components, gut flora and food components at a molecular level. This will be instrumental in order to meet several of the challenges specified in the priorities under the health challenges, among others diabetes, obesity, ageing, cancers, and cardiovascular diseases. Therefore, food and diet should be seen as a more interactive component of the overall healthcare system which may help realise great potentials for value creation for European industry to produce foods that meet these perspectives and to develop technologies for export. An important overall objective is to develop inexpensive and effective dietary adjustments for better health at individual and population levels with special emphasis on early effects within the pre- and postnatal window, child nutrition and maintaining the quality of life of the ageing population.

HOLISTIC PERSPECTIVE AND USE OF CROSS-CUTTING APPROACHES AND TECHNOLOGIES

A pivotal issue for food- and agri-research in Europe is to address the complex matrix of both challenges and the huge opportunities with strong multidisciplinary and cross-cutting research and innovation programmes to support the development of excellent solutions for food security, health, climate change and sustainable agricultural production (locally and globally), embracing the five other societal

challenges identified and defined in Horizon 2020. This should incorporate technologies from other areas, like micro- and nanotechnologies, biotechnology, genomics and systems biology, including the full potential of social science and humanities' perspectives, rather than relegating social science to consumer issues as so often happens in these kinds of multi- and inter-disciplinary programmes. The latter can contribute both to the development of consumer demand-driven sustainability and behavioural changes necessary for healthy eating.

RESEARCH COORDINATION AND ENHANCEMENT OF INNOVATION

Traditionally, Europe has been strong in the development of a bio-based and more sustainable economy but must be prepared to meet increased global competition. By 2020, Europe must be in the forefront of biosciences, and – well before 2020 – Europe must have created an innovation culture where companies, especially SMEs, researchers, NGOs and governments work closely together to increase the speed and volume of the exploitation of Europe's vast and growing knowledge capital. Education strategies and programmes must include a focus on improved entrepreneurial skills and the development thereof at both undergraduate and graduate levels. An acceleration of the public-private-partnering (PPP) principle is seen as a prerequisite for the development of new prod-ucts, processes and services at all levels and sectors. This is also true for industry and startups, including the regulatory system and processes available to the authorities. The acceptance of existing technologies (such as irradiation and the use of genetically modified organisms (GMO) in conventional and organic agriculture) and the adoption of rapidly developing new technologies (such as systems and synthetic biology) must be approached in a more pragmatic way, where identification and understanding of needs versus challenges will require the choice of optimal technologies to be used, including ethical considerations.

Due to the complexity of the topic combined with the need for accelerated innovation, new approaches to conducting research and innovation have to be envisioned, not the least from a societal value creation point of view. A shift from the classical linear approach to a more interactive learning loop is needed to get new knowledge implemented at more practical levels (from farm management to industrial food production), and to feed more practice-based knowledge inputs into research objectives and planning.

NEEDS AND SOLUTIONS

A fundamental principle of research in this area ought to be a focus on the development of a completely new knowledge and innovation platform that supports a long-overdue paradigm shift in the agriculture and food industry value chain.

BUILDING INNOVATIVE VALUE CHAINS

The classical view of an agriculture-food value chain (farm-to-fork) is largely asset-driven and often characterised by a low degree of innovation and the development of added-value products. The global challenge ahead is to start with consumer needs, and subsequently align food production, agriculture and land use in a much more complex and multi-directional value chain. Such an approach should encompass needs and opportunities from climate, available resources, environment, energy and health perspectives. This requires a complexity of interactive and multidisciplinary cross-cutting research and innovation approaches to realise the huge potential for challenge-driven and interactive innovations, meeting consumer needs, and thus creating jobs.

SUSTAINABILITY, RESOURCE UTILISATION AND INCREASED OUTPUT

The pressure on agriculture, forestry, aquaculture and the food and bio-industries to produce significantly more per unit of resource and the associated strong need for increased utilisation and valorisation of all bio-resources will probably be the most prominent driver for introduction of new technologies across the entire challenge area. This requires relevant research and innovation investments into new technologies, methods, processes and management practises along the entire value chain. And this must be done with due consideration of all sustainability dimensions, i.e. meeting environmental, social, and economic requirements (sustainability and economic competitiveness must go hand in hand).

Important mitigating options are to reduce competition among animals and humans for land exploitation, improve plant and animal health, improve plant water and fertilizer-use efficiency and reduce pesticide inputs, optimise animal protein production with respect to environmental impact and ethics, develop plant-based alternatives to conventional animal protein containing products, and create a change in the eating habits (from both health and sustainability perspectives) of populations.

Another urgent topic for integrated research is the interaction between the soil microbial flora and plant materials (crops, processed raw materials and leftovers from food and biorefinery production processes). Apart from addressing the biomass resource efficiency (yield and quality) and waste issues, this is important for biological production of e.g. single-cell protein and added-value biomaterials by microorganisms utilising such bio-substrates. Linking green and white biotech systems (with or without GMOs) would be an interesting approach to exploit more synergies between food and biomass production and industrial biotechnology.

The consideration of sustainable production chains from plants and animals to the final product that reaches the consumer should also focus on increased production of high-quality protein, oils and added-value ingredients in the aquatic environment relative to production on land. This will reduce the pressure on terrestrial production today and unlock the potential for aquatic living resources. Further, as less than 1% of the microorganisms in the aquatic environment can be cultured today, the vision must be to understand the biological principles for life in the oceans with the purpose of exploiting "blue growth" through bio-prospecting to increase the competitiveness of the European bio-economy. However, the production systems from land-based operations and those from the aquatic environments should not be considered separate or in parallel, but combined, such that principles hitherto undiscovered in the oceans can be applied in land-based production and vice versa. In order to decrease the volume of by-products and waste from one production system, by-products could be considered raw material in the other production system, which could include feed as well as food.

Unravelling the life principles in extreme oceanic environments should be a particular research target as life forms under high pressure, low temperatures or combinations thereof would be of particular interest for application in processing technology (microbial systems and novel enzymes) for food, feed and ingredients.

In relation to the developing scarcity of water there is a strong need for research and innovation in more efficient use and recirculation of water, e.g. in irrigation and production processes including cooling and heating, growth and culture habitats/enclosures, sanitation and decontamination. The development and implementation of a new generation of equipment sanitation and food product decontamination technologies which are environment-friendly seen in a systems perspective will help to avoid sub-optimisation along the supply chain, including a reduction in the use of water and chemicals. All the individual factors that contribute to microbial contamination and persistence must be addressed in order to propose new alternatives for sanitation and decontamination strategies while proposing a new generation of food products, including organic foods and minimally processed foods.

Emerging food processing technologies such as the use of high hydrostatic pressure, pulsed electric fields, low temperature plasma, ultrasound, subcritical water and smart/intelligent packaging need to be developed further and integrated into the food value chain.

HEALTHY AND SAFE FOODS, DIET AND FEEDS FOR ALL PARTS

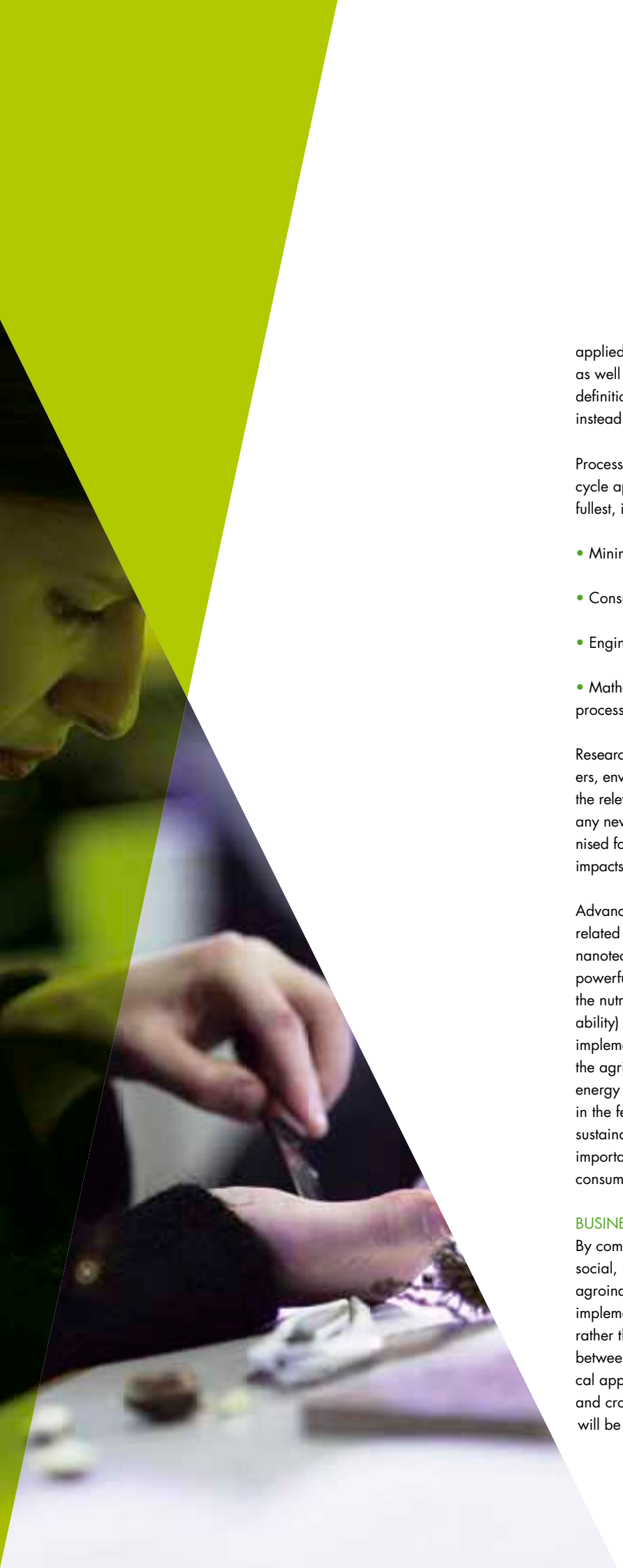
Within this scenario, research and innovation should not focus only on ageing and the development of chronic diseases, but, as importantly, on the consequences of early nutrition (pre- and post-natal and during infancy). We need to identify main determinants for the mother-to-foetus and mother-to-child imprinting on development of the gut flora and the immune system, including epigenetic changes during development. In addition, understanding how dietary health and nutrition needs vary between individuals and population groups, not only across the whole lifespan but also as a consequence of their genetic make-up, is very important for the development of more healthy products and diets tailored to specific health and nutrition needs. Further research into nutrigenomics and epigenetics and the identification and documentation of nutritypes will guide the individual towards improved eating habits through informed food choices and help the food industry to develop a wider variety of added-value products contributing not only to health and public budgets but also to individual quality of life experiences. Therefore, food and diet should be integrated into the Commission draft as one clear determinant for health and wellbeing under the health challenge.

Economic and marketing research in this area should also devise solutions for such products and services to be made available according to "affordable choice", "informed choice", "climate-friendly choice" and "healthy choice" principles for the public that take wide variation in individual and household incomes into account.

And the consumption side of the equation should not be relegated only to the provision of secure sustainable supplies of healthy foods. In terms of the promotion of healthy diet, there should be emphasis on the informed consumer choice. But this way of thinking is typically individualistic in its approach and neglects the understanding and critical analysis of the social context of food choice. In many cases it has been demonstrated that simply providing information does not lead to change, thus new (practice-based) ways of addressing these issues are needed.

MORE HOLISTIC LIFE CYCLE APPROACHES.

The different challenges in the context of food are related to each other, and therefore solving too many in small, focused projects will lead to sub-optimisation. Hence, a full chain approach should be taken, ensuring overall optimisation and providing solutions that truly link raw materials, the conversion processes and the needs of consumers and other actors in the food chain. It is important that true interdisciplinary work is promoted by problem challenge or benefit-oriented call texts that encourage researchers to find new collaboration partners, especially SMEs. Priorities should reflect those of the European food industry as formulated, for example by the European Technology Platforms "Food for Life" and "Plants for the Future". The instruments



applied must facilitate and promote the active participation of SMEs as well as larger companies in research projects. Also, the SME definition for the agrifood sector should be adapted to 500 FTE instead of 250.

Processing of food and agricultural products should take a full life cycle approach into use, integrating and utilising resources to the fullest, including:

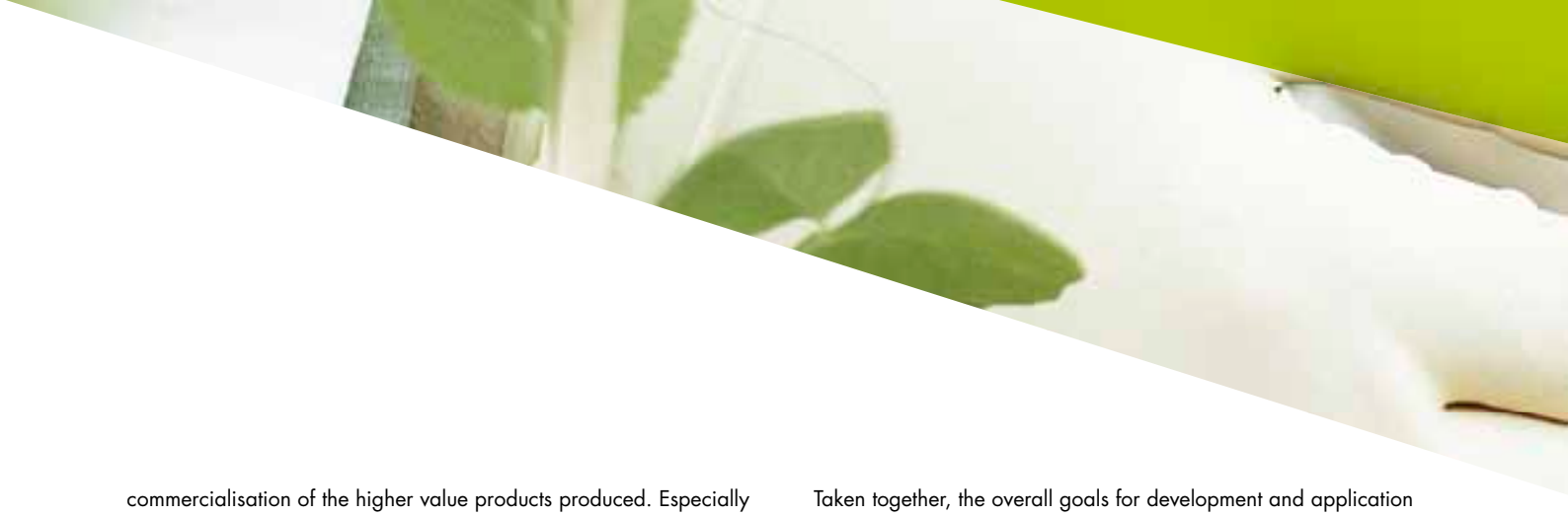
- Minimal energy consumption
- Consumer preference, acceptance, and needs
- Engineering of desired product attributes
- Mathematical models for process design, selection of proper process parameters and optimal operation of processes

Researchers of this field should work closely with technology developers, environmentalists, industry, policymakers and growers to evaluate the relevance and estimated impact of the proposed projects – and any new technologies and machineries developed should be scrutinised for efficacy, cost-efficiency and environmental performance and impacts, including effects on up- or downstream activities.

Advances in consumer research, biotechnology, genomics and related fields of research, bioinformatics, systems biology and nanotechnology will provide the agricultural and food industry with powerful information and tools to increase food security, improve the nutritional value of foods (e.g. increase nutrients and bioavailability) and mitigate risks. It is important that Europe adopts and implements these emerging technologies for suitable applications in the agricultural and food industry, including the production of bioenergy and chemical feedstock. The same applies to applications in the feed industry, where the supply of more, healthier, safer and sustainable feed and animal nutrition products will be of increasing importance – not only for yield and output purposes, but also for consumer health and animal welfare.

BUSINESS MODELS

By combining food and bioscience research disciplines with social, marketing, and economic sciences, the European food and agroindustry sector would also benefit from the understanding and implementation of a more vertical stratification (business model) rather than the prevailing horizontal model with minimal interaction between primary production and food processing actors. In a vertical approach, primary production using new agricultural systems and crops, animals and microbes tailor-made for new value chains will be integrated parts of the business structure, supporting the



commercialisation of the higher value products produced. Especially for the realisation of the wider bio-economy strategy, there is a need for developing economical and social feasibility concepts addressing both single value streams and overall resource utilisation and output, including job creation aspects.

TECHNOLOGIES AND PRIORITIES

The complexity within the challenge, as well as complex interactions with the other five challenges, opens a plethora of opportunities and huge potentials, but also problems and needs. The necessary multidisciplinary, cross-cutting approach to research and innovation requires the development, acceptance, and application of new technologies where strategies and priorities from both natural and social sciences should be combined – at programme and project levels.

The adoption of well-established biotechnological methods (such as food irradiation and the use of GMO crops in conventional and organic agriculture) and the rapidly developing systems and synthetic biology tools must be approached in a pragmatic way where identification and understanding of needs versus challenges requires the choice of optimal technologies to be used, including ethical considerations. Apart from their important future role as key enabling technologies, they must also be considered as key research topics enabling new fundamental discoveries. Within the comprehensive bio-economy perspective, much focus should be on new processes that integrate both existing and new operations in terms of converting raw materials into more flexible output streams. Examples would be new microbial production strains, novel enzyme activities, further development and application of multivariate statistics and mathematical models (such as chemo-metrics and principle component analysis) and the bio-refinery concept for integrated production of food, feed, energy and new biomaterials.

Systems biology is the overall term for the scientific field in which a holistic understanding of biological systems is being built by utilising quantitative functional genomics and metagenomic technologies in combination with mathematics, statistics, physics and modelling approaches. Bioinformatics methods based on solid experimental data are essential for modelling the dynamics of cellular processes and metabolism in biological systems, including the human body. Design-oriented systems biology, utilising synergies between nano-science, advanced bioinformatics (in silico biology) and biotechnological production machineries (also named synthetic biology or technical systems biology) must be further developed. It is one of the most promising approaches to realising the vision of a bio-based European economy, offering promising approaches to enable a sustainable scale-up of the development of future crop plants, cell-based chemical production, bio-fuels as well as novel nano-diagnostics and medicinal compounds to an industrially viable level.

Taken together, the overall goals for development and application of new or improved technologies for microbial, plant and animal production systems must be:

- The right system used under best conditions (soil type, geography)

- Producing the optimal raw materials and ingredients with highest yield for specific needs and applications

- In the most sustainable way (environment, climate, renewable resources)

Since neither organic farming nor the use of GMOs will provide solutions to all needs, research should also seriously address potential synergies between such diverse technologies in order to utilise optimal flexibility for combining key parameters in optimal production systems. One important example would be to design more robust and less resource-demanding agricultural crops and cultivating them under practises allowing for much improved recycling and preservation of minerals (phosphorous, nitrogen) and carbon content in the soil. In this context priority setting should be derived from scenario analyses targeted to identify societal payoffs from proposed major research investments. This approach should be evidence-based and be seen as a research task itself, not just a matter for good debate.

With the exception of traditional fisheries and aquaculture, the oceanic production environment for food and feed is largely untapped and increased consumption of seafood is expected to bring about health benefits. Exploiting marine bio-prospecting could lead to discoveries that may find applications in multiple profitable market segments. In order to strengthen the supply of European marine foods, there is a need to sustainably harvest current resources, investigate and utilise new marine resources, especially organisms lower in the food chain, and to optimise both food production systems and feed availability in aquaculture. A more coherent approach such as integrated multitrophic aquaculture (IMTA) needs to be introduced for a sustainable use of the aquatic environment for bio-production. The technologies for farming any species of finfish, crustaceans, bivalves and algae may be present, but the technology for combining these individual production technologies has not been sufficiently developed yet. By considering the principles of IMTA, the surplus feed and excretion products, from e.g. finfish aquaculture, are taken up and used by other organisms such as crustaceans, algae and bivalves in a controlled and balanced ecological system.

The strong need for a sustainable production of significantly more biomass and a much improved utilisation of all bio-resources also addresses important challenges and huge potentials within forestry,

not the least in the climate change and competition for land use perspectives. Here, the development and choice of optimal technologies and exploitation strategies should be targeted towards capture of the highest value from each biomass component. Further development and implementation of advanced bio-refinery strategies would help to secure all economically viable value streams from forestry biomass.

INSTRUMENTS AND IMPLEMENTATION

Three types of research and innovation work exist: basic science, applied science, and valorisation. All three should work around the great challenges ahead. For basic science, this should simply translate into the definition of areas. For applied science (the trans-formation of knowledge into new lead technologies), it should be critically assessed by multi-criteria decision methods, including both economic feasibility and technical practicability. For valorisation (aimed at the development of first-of-a-series), a new set of instruments should be devised with special emphasis on SMEs. In the interface between scientific risk assessment and research and innovation management better tools and processes should be developed to connect risk assessments with risk/benefit analyses in order to improve communication, transparency and intervention strategies with and towards concerned stakeholders.

The complexity of this challenge and the associated multi-directional value chain from primary production to the needs and opportunities from climate, environment, energy and food/feed/health perspectives calls for a multidisciplinary and cross-cutting research and innovation approach. This would address and support the multidirectional value chain potentials from the interactions between agriculture sensu lato and health, climate, environment, energy and transport perspectives. Such an approach would have the potential to solve holistic problems much faster than is observed today – and would require larger projects with more partners, more stakeholder involvement, and longer funding periods. Parallel to the holistic approach, clusters of projects grouped around one societal need with more modest numbers of partners and funding volume need to be defined. This is especially true for valorisation, where projects with large numbers of participants are impossible. The applied research area can be a mix of both project types.

Thus, this model combines longer-term projects including a large proportion of fundamental research (and large stakeholders), with projects aimed at translating knowledge and technology platforms into innovation activities (including concept implementation and application development) with shorter time-to-market profiles. Such projects could help accelerate innovation activities in general and more specifically through higher participation of smaller stakeholders (SMEs, or better: companies up to 500 FTE). Here the possibility of developing clusters of companies having complementary (noncompeting) business models for utilisation of a common knowledge/innovation platforms might be a socio-economically valuable example of open innovation. One example could be the complementary utilisation of the different value streams from bio-refinery platforms.

In order to balance the increased complexity (including management issues) in multidisciplinary approaches with the need to focus the research and innovation activities to have timely outputs, a two-tier strategy might be useful. Here, the interface between the two tiers should be at the transition from mode-of-action (delivered primarily from basic and applied research) and proof-of-concept (development via innovation and demonstration activities). If implemented via two different instruments they should be closely coordinated and allow for both parallel and sequential projects while maintaining the connectivity between the two instruments.

In the overall picture, the three dimensions of the Horizon 2020 proposal (excellent science, industrial leadership, and societal challenges) provide a relevant approach which, however, requires different instruments to secure optimal societal value creation from research and innovation investments in each dimension. Especially for the societal challenge, the pronounced need for multidisciplinary and cross-cutting approaches emphasises the necessity for development of new and appropriate instruments without increasing the administrative burden. For this purpose the Commission may find useful models and concepts already implemented in member states, such as instruments for academia-industry collaboration including both research and innovation. Here, examples could be the Top Institute model (the Netherlands), the CTI model (Switzerland) and the recent SPIR model (Denmark) – and also concepts in the EIT/KIC initiative would be relevant.

Efficiency requires reduced bureaucracy both in the calls and in the administration of projects. For basic research, larger and more long-term programmes (e.g. centres of excellence) involving multiple partners could be a more efficient option – which however has not been realised until now. Regardless, there is a strong need to reform the system in a way that would ease the funding process and at the same time maintain sufficient quality control of granted projects. Procedures should be simplified and diversified over fundamental and applied sciences, and valorisation. The ERC is known for much slimmer administration processes and it is recommended that the Horizon 2020 challenges programme strive to adopt a similar practice.

Stakeholders need to be involved not only in terms of dissemination and impact but at all stages of the research. Stakeholders should include NGOs and the voluntary sector as well as representatives of government and food and agroindustry who could be involved

through participation to advisory boards. Industry involvement should be mandatory but should not be a hindrance, from a risk-taking perspective, to go beyond the state of the art. Cluster structures where more than one project is financed on one research topic might have specific benefits from stakeholder involvement in coordination processes.

As stated, PPPs are the new route, and different projects and instruments for basic science, applied science, and valorisation must be developed. Networking programmes connecting scientists and stakeholders must be renewed and implemented to exchange knowledge to and from EC projects, including research on national level. Overall, synergies and knowledge sharing between national programmes (like the intention behind the JPI programme) should be facilitated in Horizon 2020 and relevance and impact of the research should be strengthened through stronger industry-academia partnerships. For larger research clusters the platform efficiency should be strengthened through an open and competitive organisation utilising public-private partnering including not only research performing institutions and companies but also civil society stakeholders. The PPP approach should also be used to address the regulatory burden on research and innovation. For example, at present it is nearly impossible in Europe for a public research institution to bring GMO crops into production.

In order to increase research quality and impact, recruitment of the best brains must be secured through special emphasis on instruments encouraging young people to attend educational programmes, preferably addressing cultural dimensions that might present obstacles for optimal dispersion of knowledge. Student exchange programmes should be implemented at all relevant levels.

In terms of infrastructure development, Europe needs to focus massively on the development of data handling, longterm storage and accessibility, and advanced data analysis, including validation of models developed for complex systems dynamics. In addition, strategic focus should be put on systems biology in a cross-cutting approach with the other defined challenges within a number of fields of application, e.g. development of agricultural products of higher quality and value; prevention of antibiotics resistance; improvement of food safety (avoiding food-borne diseases, eliminating antibiotics remains); and improvement of feed, wastewater control and waste management.

Research and innovation activities addressing the complex challenge of "Food security, sustainable agriculture, marine and maritime research and the bio-economy" should be linked to and coordinated with relevant existing initiatives at the European level, such as ERA-NET, ERA-NET+, Article 185, and JTIs. Furthermore, joint programming initiatives (JPIs), namely FACCE (agriculture, food security and climate change) will play a leading role in the structuration and the efficiency of food and agriculture-related research during Horizon 2020, and they have already begun to provide an interesting framework for better integration of the ERA. Another important JPI is HDHL (healthy diet for a healthy life), which will also contribute to reaching the objectives. For these programmes, the support of the Commission should exceed the funding of secretariat functions, at least in their initial phase, in order to make the instrument efficient.

The European Institute of Innovation and Technology (EIT) would also contribute to reaching the goals of this challenge through Knowledge and Innovation Communities initiatives (KICs) on climate and a future KIC on food for the future. A food KIC would strongly contribute to a structuring of the research field and to create synergy between the three key components of the research triangle (research, education and business) to achieve the innovations necessary to provide solutions to the challenges identified. Based on the mechanism of PPPs (including regulatory authorities), a food KIC would connect the different stakeholders in order to get maximum efficiency.

It is essential to interconnect the various initiatives to avoid the duplication of efforts and to make sure that there are few omissions. Furthermore the visibility, transparency and coordination of these larger EC programmes should be improved in order to reduce the bewilderment in the research community caused by the increasing complexity of the panorama of programmes – and to ensure the best participation of excellent contributors to realise the European Research Area objectives.

INNOVATION IMPACT

Innovation is a rather complex issue. It happens all the time and those who are able to maintain openness in the process usually will succeed the best. Previously, innovation processes were rather closed in many companies and to some degree also in PPP projects. Now, open innovation is becoming more and more the common mode of operation. Even the food industry, historically very reluctant to share results, is adopting this mechanism and in Horizon 2020 openness between stakeholders should be encouraged and facilitated.

Since companies normally will not invest in participation in public research and innovation programmes unless there is some protection of future income from innovations in that area, agreement on intellectual property rights (IPR) are generally a prerequisite and should be prepared upfront. This would also lead to more relevant and efficient projects with higher impact since early IPR settlement would ease the communication and exchange of ideas in an open atmosphere before funding is achieved. This common EU practice is welcomed and needs to be sustained.

Traditionally, innovation is considered a linear process where research results are developed into applicable principles such as proof of concept and further implementation in practical production. By considering innovation as an interactive circular process the output will be potentiated and the impact shortened in time as well as expanded in volume, i.e. more will come out of a given research result at a given time. By introducing a dialogue with the end user where the end product, along one line of thinking, is considered the starting point of a new development, a circular process is initiated. This concept is also called the learning loop or user-driven innovation, and is ideally performed by involving university researchers, technology transfer providers and industry. Involvement of innovative SMEs is crucial for shortening the path from research to the benefit for citizens. This should include both knowledge intensive SMEs as well as SMEs with limited R&D, but with a need for being included in the knowledge loop for upgrading their business and innovation potential.

In order to support innovation, research projects need to have better access to funding that bridges the gap between invention and industrial uptake of new ideas, i.e. valorisation. Such gap funding schemes should allow the most promising technologies to be tested in a business plan approach. Patenting must be further encouraged and the involved companies should have an obligation to use the IP generated in joint research. On the other hand research institutions should have an obligation to develop IP together with industrial partners. However, the IP should be valorised by companies, not by research institutions. And, in general, patent policies should be reconsidered to motivate scientists to innovate rather than seeing them as a hindrance.

A great challenge is education at every level, first of all, to provide innovative industries in the sector with highly qualified personnel to help them capitalise on the results, but also to help citizens become informed about the new technologies and their acceptance of these. An effort in terms of education related to good, safe and sustainable food should be made towards citizens of all ages and with special focus on opinion makers. Professional communicators must be educated to transfer information and knowledge properly from research and science communities to commercial stakeholders, consumers and the general public. Within the area of food and health, life-long learning approaches should be developed for key professionals (e.g. doctors/physicians, teachers), on the most recent scientific developments and status, thus creating means to alter consumer food choices to the better. The European Federation for Food Science and Technology, which consists of approx. 100,000 independent food experts, can play a vital role in improving European food education and research qualities.

Innovation should indeed be a priority to ensure benefits of research results to citizens and society, optimally through economic impact, i.e. jobs. The agriculture and food sector can make a quantum leap to reduce the European innovation paradox and, hence, make progress in the competitiveness of the food industry and in innovation in the food sector, which would be a prime benefit to everybody. The complementarity between the European Innovation Partnership on Agriculture and a Food KIC should be enhanced through close cooperation, which will only be possible if the Food KIC is launched not later than at the very beginning of Horizon 2020. Finally, the involvement of companies and notably SMEs as well as unusual partners (venture capital, farmers, traders, retail and out-ofhome partners as well as end users) should be facilitated – which would be welcomed by the whole knowledge triangle community.

SECURE, CLEAN AND EFFICIENT ENERGY

ABSTRACT

Secure, clean, and efficient energy is rightly chosen as a key focus area in the Horizon 2020 agenda as it is essential to be able to provide the EU with clean, reliable and affordable energy midway through this century. Stronger national and transnational efforts, as well as better coherence and coordination are badly needed between national and joint European efforts, including public-private partnerships with all EU countries. This requires European-scale management and support in order to: (1) enable a decisive contribution to climate protection; (2) achieve European technology leadership; and to (3) give adequate support to European industry.

ABSTRACT CONTINUED
Horizon 2020 priorities should build on: (1) a revised SET-Plan based on a thorough review at the beginning of Horizon 2020, including a critical update of the road maps based on ambitious but realistic scenarios for the development and deployment of technologies, and (2) a complementary systemic approach to combine technological, economic, political, social and cultural research to facilitate the transformation of the energy system as a whole. Collaboration of social sciences and humanities with "hard sciences" must be recognised as necessary and organised and funded accordingly to meet the challenges at system level.

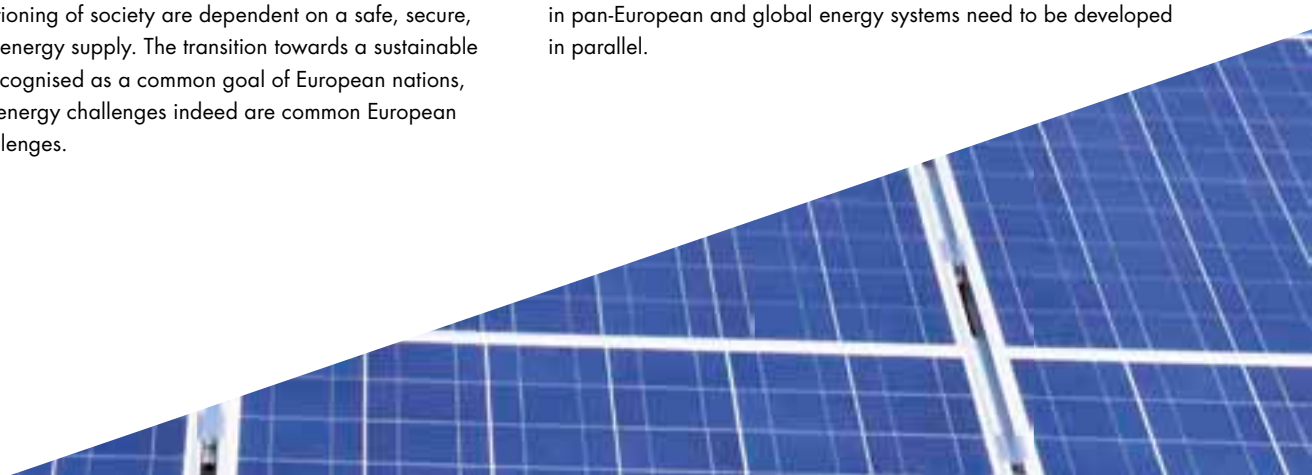
More efficient innovation programmes and new instruments are needed to couple educational efforts with research and innovation to ensure that enough trained talent is available to realise the ambitious roll-out scenarios for the different energy technologies, and for the transformation of the energy system as a whole. Direct mobilisation of universities in addressing systemic challenges should be given high priority. Mobility of scientists and students among research institutions and industry should be pursued through new types of flexible grants. Transfer of knowledge from universities to students and companies must be made in a more efficient way. Public technology procurement policies could be used to shorten the time from research to market.

Main criteria for selection of European projects in Horizon 2020 are scientific excellence, society needs and European competitiveness combined with more focus on outcomes and impacts. The composition of research consortia should give high priority to the quality of partners and their openness to new partners. Openness, dialogue, and competition are the proper values to ensure quality and rate of progress.

VISION
Secure, clean, and efficient energy is rightly chosen as a primary goal in the EU research agenda for 2014-2020. Much depends on the success of the Horizon 2020 programme in efficiently addressing these challenges if the EU is to become self sufficient with secure, clean, reliable and affordable energy midway through this century. People's wellbeing, industrial competitiveness, and the overall functioning of society are dependent on a safe, secure, and affordable energy supply. The transition towards a sustainable energy era is recognised as a common goal of European nations, as climate and energy challenges indeed are common European and global challenges.

Meeting the basic energy needs of the world population, as a whole, implies a significant, continued increase in energy demand over the coming decades. Achieving this and, in parallel, drastically reducing greenhouse gas emissions to acceptable levels, are contradictory challenges that require urgent and vigilant societal response. The efforts and changes toward a sustainable energy system are enormous and require a series of aligned activities over a long period of time. The radical transition from fossil to renewable energy needs new and much increased effort by many stakeholders, including suitable political frameworks and incentives. A paradigm change is required that moves from energy systems based on fossil fuels (coal, oil, natural gas) to more sustainable systems based on renewable (or nuclear) energy sources. The change must be sustainable with regard to ecology, security of supply, and economy – both locally and worldwide. The change driven by adoption of new policies and actions is urgent. According to the recent IEA World Energy Outlook 2011, the door is rapidly closing (by 2017) for limiting global temperature increase to 2°C, as four fifths of total energy-related CO_2 emissions are already "locked–in" by existing power plants and factories.

Europe has taken the first steps to substantially reduce its ecological impact and create an environmental friendly and economically sustainable economic basis for lasting growth. This is most recently documented by the Energy 2050 Road Map, the Horizon 2020 proposal and the SET-Plan. To fulfil the ambitious 2020 and 2050 greenhouse gas reduction targets set by the European Union, energy research plays a fundamental role as a source of needed insight and new technologies. Energy research has to enable and underpin a much more rapid transformation of European and global energy systems than is the case today. It should be given higher priority over the next decades, not least in the implementation of Horizon 2020. Energy research should be a more integral part of the green energy economy, i.e. combining innovation, know-how and technology to solve energy and climate issues. This will generate sustainable economic growth and create new, innovative workplaces and jobs. Countries need to focus on low carbon technologies specific to their geographic location, climate, state of the economy, access to energy resources, and exploration abilities. The methods of the integration of national energy systems in pan-European and global energy systems need to be developed in parallel.



The coming decade is in many ways both interesting and challenging: different clean energy technologies are approaching breakthrough; Europe has set challenging targets for carbon emission reductions, renewable energy use, and energy efficiency; and EU signals continued support along this line. Global markets for new energy technologies are growing fast and global competition is increasing. Europe has a good balance between a free market economy, efficient in driving new innovative technologies, and governments efficient in pushing publically controlled areas like major parts of the infrastructure. Europe should strive for global leadership in sustainable energy technology and increase its funding level of R&D in response to increasing global competition. European energy research should make clean energy technologies more cost-competitive, but also address energy system issues and other social issues arising from the large-scale exploitation of renewable energy sources. Energy services should still be available to all income groups.

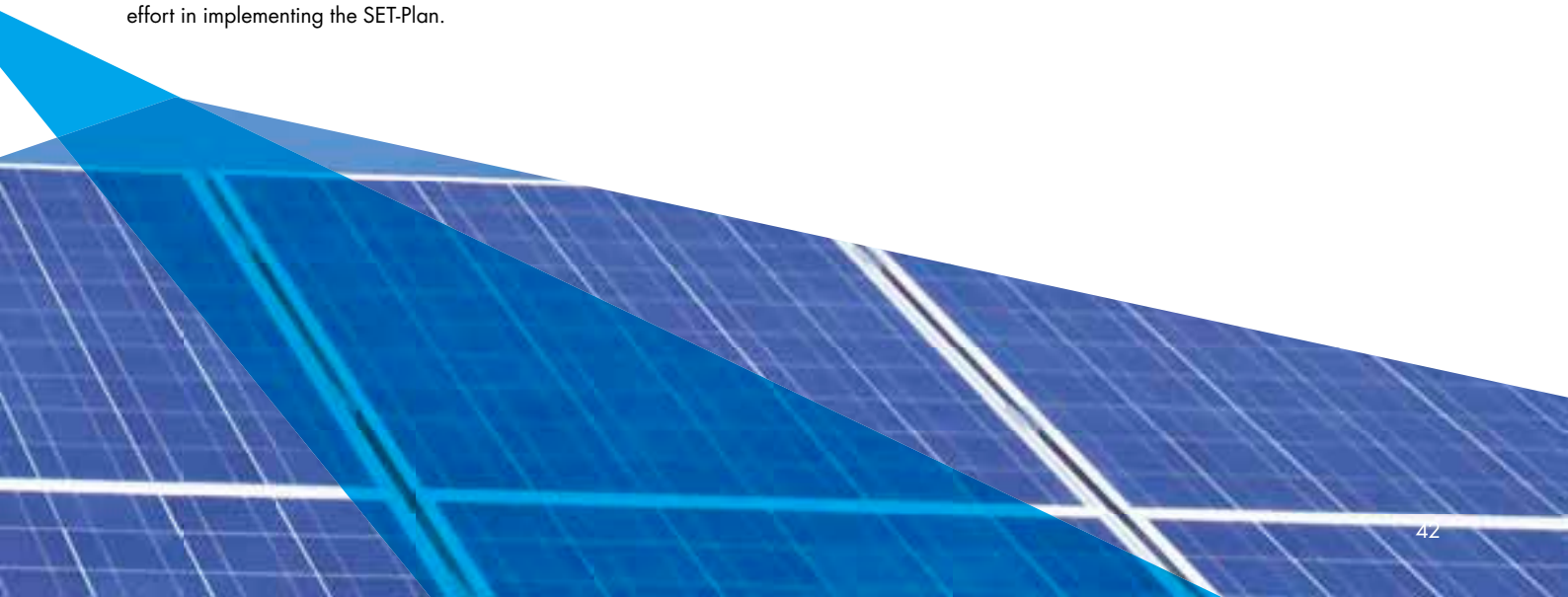
New, large research efforts should be promoted across the European Research Area (ERA) through networks of centres of excellence and efficient joint programming, leading to globally competitive joint programmes and projects. This requires development of an advanced research structure throughout the region, such as strong scientific centres focusing on basic research related to a whole spectrum of environmentally friendly and climate neutral technologies (including fission and fusion). Research activity must also include political and economic aspects. The European Energy Research Alliance (EERA) is pioneering efforts in joint programming which can serve as a model for other types of consortia worthy of support. Such joint efforts should be promoted to gain greater coherence in national research efforts and public support schemes. This will enable Europe to become the leading region in energy transformational technologies, in close association with a healthy and strong renewable energy sector. Realistically, the rate of transformation depends on efficient policy measures, such as an enlarged emission trading scheme, joint efforts to strengthen European energy infrastructures, and a more vigorous effort in implementing the SET-Plan.

NEEDS AND SOLUTIONS

European energy research should support European political aims, including the preparation and setting-up of a stronger European energy infrastructure. In line with the subsidiary principle, big challenges call for joint European efforts. Energy research conducted at the European level is the appropriate approach to match the challenges and to achieve the critical mass required for big and demanding projects, including research infrastructures and demonstration projects. Stronger national and transnational efforts are needed and require European-scale management and support in order to: (1) enable a decisive contribution to climate protection; (2) achieve European technology leadership; and to (3) give the highest possible support to European industry.

Scientific excellence needs to be the dominant criterion for the selection of projects and partners. Research teams collaborate because they need each other. Different teams may compete in gathering the best expertise as well as in developing a clear project plan and related budget to solve a concrete problem. Stimulating personal exchange of knowledge at a high level will pave the way to new ideas accelerating innovation.

The SET-Plan, including a whole spectrum of important technologies, provides a good basis for reaching EU 20-20-20 energy and climate objectives and it is an excellent strategy to guide European efforts in the short to medium term. The SET-Plan should serve as the starting point for the Horizon 2020 energy research agenda. Unfortunately, today it is underfinanced and too weakly integrated within the Framework Program. Current research budgets are by far not sufficient, considering the magnitude of the challenges. The SET-Plan has helped to identify common research goals and to develop and implement coordinated energy research strategies leading to a more optimised sharing of work in Europe. Most but not all of the important energy technologies are included in the SET-Plan.



Technologies such as energy storage, innovative thermal (heating and cooling) energy technologies, polygeneration, geothermal energy (including heat pumps), and materials for energy applications should also be developed and supported. If enough resources are made available, the full spectrum of technologies can be pursued. Otherwise, prioritisation is in place to ensure critical mass in the selected areas. The EC efforts to engage other financial resources like the EIB and the cohesion funds, as well as national and private funding, should be encouraged.

It is vital that the SET-Plan strategy is kept live through a thorough review at the beginning of Horizon 2020, including a critical update of road maps based on ambitious but realistic scenarios for the development and deployment of technologies. Nuclear energy (fission and fusion) should be included in such a critical review. So far, the SET-Plan has focused on ten important energy technologies. In Horizon 2020 this needs to be supplemented with crosscutting efforts with systemic and sometimes holistic points of departure. The focus of European energy research programmes should support research at the pre-competitive phase, as well as the integration of research with higher education and industry. By focusing on pre-competitive research, European energy research funding will support the weakest part of the innovation chain, so the societal and economic return on investment should be correspondingly high. European energy research can be of high value in the field of standardisation and other crosscutting issues, where common procedures simplify the boundary conditions for European industry. With early standards European companies will be better prepared for global competition.

There is huge potential for energy savings in the industry, including the construction industry as well as in the built environment and households. Research is called for on technical solutions, as well as on the socio-economic aspects of how the energy market should be changed so that it would be in the interest of the big electricity generating companies to save primary energy. Combined heat, power, and cooling production is, in the overall poly-generation perspective, one effective way for primary energy saving. This primary energy saving is not used widely enough in Europe and has untapped potential. It is not so much a question of having the right technologies but applying the technologies right.

The importance of energy transformation technologies has to be stressed throughout the Horizon 2020 actions. It would be worthwhile to add cross-disciplinary horizontal elements that are not technology specific, but could cover also, e.g. environment, business, socio-economic, and user aspects. In line with this, more emphasis could be given to social, system, and user-driven innovations, in contrast to the main focus on technology-driven innovation. This would also mean leaning more towards the end-use side of the energy chain than the energy production side.

SET-Plan Energy Industry Initiatives (EIIs) are targeted to realise several new large low-carbon demonstrations and full-scale power plants before 2020, including CCS demonstrators. A main objective is to identify and verify low-carbon technologies suited for commercial mass production, moving European industry towards the technology front and strengthening its global competitiveness. Though it is important to develop products together with industry, this seldom solves the real problems, such as finding new electro-catalysts cheaper than platinum, and many other fundamental obstacles to cost reduction. It would be excellent if this could be done in cooperation with industry, but such research is too risky to expect industry to fund it. To deliver the technological progress required, appropriate framework conditions, e.g. a strong basic and applied research foundation, close links between industry and research, and strong incentives for research and market introduction, are needed.

The role of basic energy science and of university research for Europe needs clarification in the SET-Plan. There is also a need to follow up on higher education. Linking university excellence to the SET-Plan through e.g. the European Platform of Universities engaged in Energy Research (EPUE) and EERA Joint Programmes could provide major additional value in both addressing workforce talent needs and research excellence aspects, in particular education of the energy scientist and engineer of tomorrow. More emphasis should be devoted to generic technologies like energy materials and energy storage. It is important to emphasise that energy research is a “no regret” option of energy policy – all scientific and technological advances are helpful as they are target-oriented towards a sustainable future.

Technological research needs to be accompanied by technology assessment and systems analysis, keeping an eye on the overall system and on societal aspects, like public acceptance. Systems analysis also helps to investigate and optimise different paths for the future and may thus provide valuable advice to the political system. More interdisciplinary work is needed on energy supply and demand to link technical, natural, social, and economic sciences. Problems should be identified through close collaboration with industry and in coherence with European energy policies. Applied and industrial research has to be linked more tightly to basic science and to academic teaching to ensure future European industrial competitiveness. Universities have untapped potential for advancements in both energy science and innovation by an enhanced engagement of both professors and students.

Several types of barriers hinder our progress. Some technologies remain expensive (photovoltaic / PV), not reliable enough, or based on rare and expensive materials. Improvement of their life cycle depends on the efficient collaboration of basic science (for new materials, new catalytic reactions, and understanding of physical loss processes) with engineering science. Some technologies are already mature, such as wind; however, their full-scale deployment is slowed by high costs and the difficulties of energy storage. Large-scale energy storage should receive more attention and more funding. Priority areas should be restricted to the R&D of technologies that enable the inclusion of renewable sources in the energy system.

The transport sector has not yet lowered CO_2 emissions, which poses quite a challenge to the overall EU decarbonisation objective. Accordingly, more research and innovation needs to address energy in transportation. There is a strong need for enforcement of clean transportation policy (switching of fuel sources), then strong support for research. For both power generation and transportation, biomass constitutes an underutilised decarbonisation resource that should be better exploited through research and innovation in bio-refinery concepts.

TECHNOLOGIES AND PRIORITIES

Horizon 2020 should underpin the competitiveness of new technologies now close to breakeven, making them competitive energy options, e.g. wind power, PV, second-generation bio-fuels, and at the same time prepare for next-generation technologies. All low carbon technologies will be needed, including renewable energy, but realistically also natural gas (with CCS) and nuclear power, in addition to more efficient use of energy in all sectors underpinned by smart grid technologies. The share of electricity in a global, low-carbon energy mix will increase, with a trend of significant grid access of intermittent renewable energy. This will pose serious challenges to the efficiency and stability of existing power grids. Largescale energy storage and distributed energy systems are desired, but are not yet available solutions. A particular systemic challenge will be the design and implementation of a transformation of the European electricity system to a smart two-way system on many scales (temporal, power, transmission grids, distribution grids, load levelling). As the role of electricity grows in all demand areas, stability and security of supply become key issues for system operators. Network islanding, as well as decentralised emergency back-up systems, needs to be part of system solutions. This calls for new standardised ITC solutions to be designed and tested on many scales. A big challenge is grid security and reliability and more research is necessary in this area connected to ICT.

How to deal with energy efficiency may need more sociological and policy research efforts. Energy efficiency is the most important option for future greenhouse gas reductions, but has remained in the shadow when dealing with energy research needs. Urban areas display a huge potential for increased energy efficiency due to their morphology (building density and distribution) and could become centres for innovation with significant impact in several infrastructure layers. By 2030 cities will house 60% of the world's population and roughly two-thirds of the world's energy is consumed in cities. Cities are also responsible for about 70% of global CO_2 emissions. Environmental problems in cities are also exceptionally challenging and such issues as definition and measurement of the energy efficiency of a city with a relevant set of KPIs require further analytic research. Research is also needed to find optimal solutions and transformative paths as well as to avoid lock-in effects due to inappropriate technology implementation.

The framework of smart cities provides adequate solutions for future urban challenges through radical innovations and new urban concepts. Integrated planning, design, and management of an entire energy system at city-level are the key for massive CO_2 and local pollutant reduction in urban areas. Furthermore, this particular integrative aspect has to be tackled on two distinctive scales: integrated, process-level, multiple stakeholder participation and systems approaches that embrace different infrastructural layers and technologies. State-of-the-art methods and concepts in urban planning merely focus on the implementation of single technologies and lack the necessary multi-disciplinary aspect for understanding the entire complexity of integrated urban energy systems and related processes. Hence, a strong demand for innovation and research focusing on distinctive areas combining urban energy technology integration and integrated implementation processes can be identified.

Energy systems research needs to be increased considerably for two reasons. First, present energy systems are not able to deploy large volumes of, e.g. variable renewable electricity sources; and second, this is a field where major innovations can still take place. Large-scale bio-fuel schemes also need more research, in particular to find sustainable ways of producing these fuels. Focus should not be on energy technologies alone, but also on the socio-technical systems, including organisational, social, cultural, and behavioural aspects.

Natural gas demand is expected to rise in the foreseeable future, as the only major balance power in large-scale grids where a high contribution from renewable energy sources is present, but even more as the only realistic replacement option for coal and for securing energy supply in many countries.

Public acceptance of new infrastructures (plants, power grids, and land area), efficient carbon pricing, and robust low-carbon energy markets are other critical challenges. Making low-carbon technologies competitive in emerging low-carbon energy markets will require radical improvements in efficiency and production cost. There is an urgent need for accelerating European research efforts in all these fields. Renewable energy sources have to become more cost-effective in the short and medium term through a combination of science and market-driven advances in technology, manufacturing, and implementation.

An exceptionally important area for new research is energy storage, especially in connection with electricity grids. Biogas and gasification of biomass should be emphasised and complementary to bio-ethanol production by fermentation. Combinations of technologies, e.g. gasification and electrolysis for production of synthetic fuels for transport sector, and energy storage may be highly important for the most efficient use and conversion or storage of renewable energy.

The role of capture and storage of CO_2 (CCS) has to be rethought, and the approach to CCS in the SET-Plan should be reviewed. At this point in time the demonstrators have suffered delays and acceptance by the population is fading in several countries. There is strong public debate, especially in countries that have already started investing in this technology. However, CCS may be an important and necessary transition-technology on our way from a high-carbon to a low-carbon society. Investments in new demonstration projects should gain from experiences and lessons learned from existing systems in operation or under construction. The results should give indications and recommendations for further development and scope of this technology.

Energy from renewable sources and energy efficiency will be the major pillars to achieve the European 2020 and 2050 targets. It is important for Europe to continue and enhance research and innovation related to these technologies in order to maintain European positions in the global commercial market. The availability of renewable energy sources differs widely within Europe, and it is important to begin the process of change by thinking from national perspectives towards a European approach. New super grids will probably be needed to balance variations in regional energy production and needs.

From a university perspective, it is important to continue giving high priority to basic and long-term research, such as material sciences.

For example, new and better materials for solar PV, better batteries, more affordable fuel cells and new membranes for natural gas conversion, new thermal energy storage materials like PCM, and materials-mediums for long-term storage. Nuclear-related research will still be needed and, in the long run, nuclear power may represent one of the most important and climate-neutral energy sources. Grid security, in particular super grids or smart grids involving a complex energy mix, represent important research and innovation areas.

Agricultural residues constitute a rich and untapped resource for energy production, but remain under-prioritised in the current European research and innovation agenda. This must be corrected. Focus should be given to processing of biomass in bio-refineries that allow for transformation of biomass to foodstuff, chemicals, feedstock, materials, electricity, heat, and bio-fuels.

The SET-Plan contains or can be expanded to contain all of the needed technologies, but is weak on the systemic integration of technologies. Compared with FP7 higher priority should be put on generic technologies, in particular energy materials and energy storage, but also on interdisciplinary research, for instance public acceptance, energy futures, technology innovation, and market penetration.

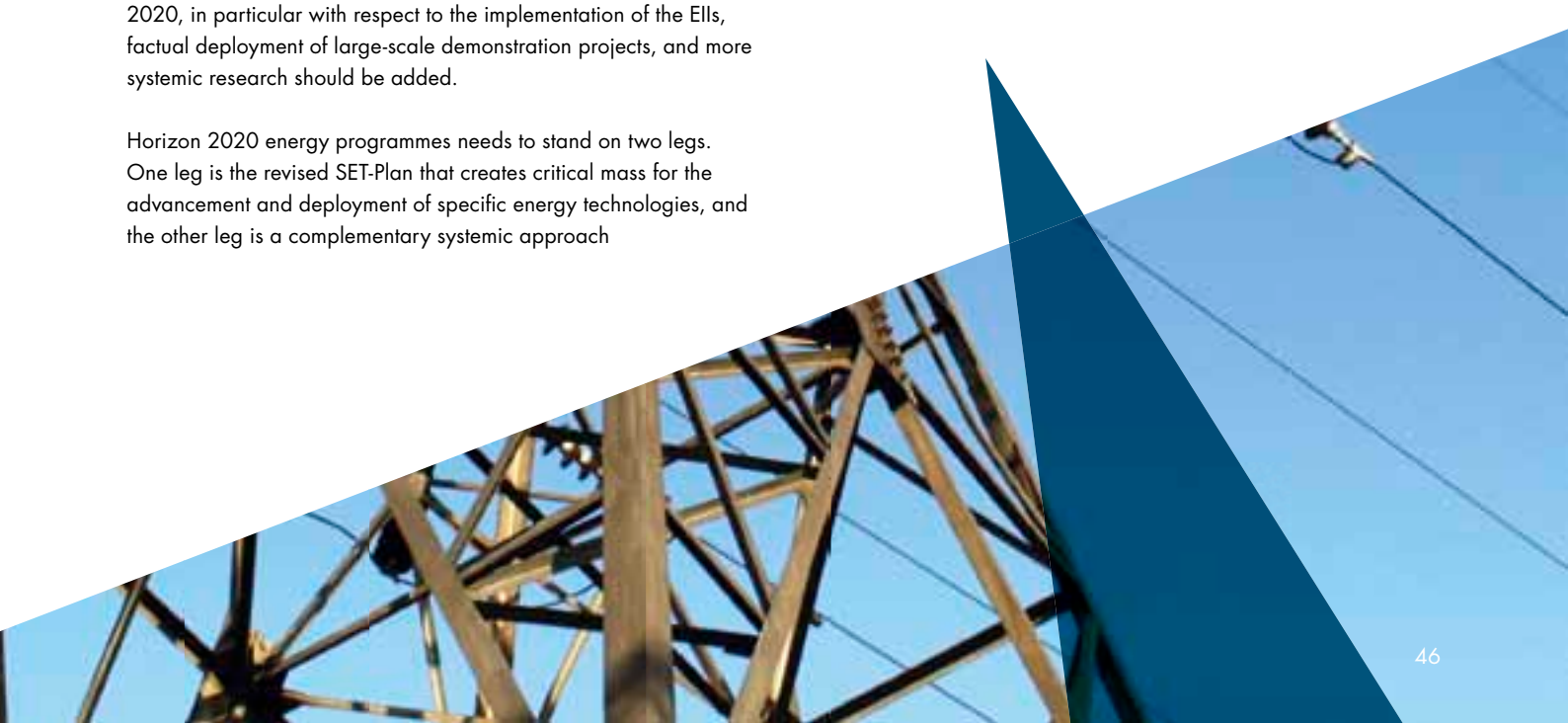
IMPLEMENTATION AND INSTRUMENTS

The SET-Plan provides a well-balanced technology roadmap incorporating relevant technologies needed to steer Europe towards a sustainable energy future. The SET-Plan has so far succeeded in promotion of more focused energy technology research and stimulated new modes of collaboration between energy research centres and industry. The main concerns of Horizon 2020 should reflect the SET-Plan priorities. However, SET-Plan technology roadmaps and performance should be reviewed in the early phase of Horizon 2020, in particular with respect to the implementation of the EIIs, factual deployment of large-scale demonstration projects, and more systemic research should be added.

Horizon 2020 energy programmes needs to stand on two legs. One leg is the revised SET-Plan that creates critical mass for the advancement and deployment of specific energy technologies, and the other leg is a complementary systemic approach to interdisciplinary solutions that combine technologies in new ways for optimal energy solutions, providing constructive linkages to other challenges like transport, climate, and resources and a safe and secure society. The systemic approach can potentially draw on a much larger knowledge base. Engaging the best talents and teams requires new instruments and procedures to identify research goals and hence the calls in the selection of consortia and the monitoring of results. Openness, dialogue, and output-oriented competition should be the guiding principles to ensure quality and impact.

The potential of university-based research and education has not yet been fully mobilised in support of the plan. New instruments are needed to couple educational effort more strongly to research efforts, innovation, and technology transfer to ensure that trained talents are available for the ambitious rollout scenarios for the different energy technologies and to transform the energy system as a whole. University students going into society (teaching, industry etc.) are probably the best links and bridge-builders between universities and surrounding society.

A key objective of the Horizon 2020 energy program should be to promote and support basic research on generic and emerging radically new concepts as well as game-changing technologies and systems, which should have larger shares of the budget than in FP7. Better cooperation is called for between the natural, technical, and social sciences, integrating systemic research projects and better cooperation between analysts and policymakers. Efficient united efforts can be achieved through joint programming as is being developed by e.g. EERA and EIT. The trend of EU research towards large projects (IP) and demonstration projects may result in research money being directed to industrial development.



This could reduce innovation potential and may not yield the best return on research funding. Efficient management and control of large integrated projects is demanding, and midsize collaborative research projects (EU contribution up to e.g. € 5 m) have often proven far more efficient and innovative. The trend in management should be a move toward joint programs in pursuit of clearly-defined strategic goals, combined with more emphasis on results and impact.

The success of the EIIs also depends critically on new research and technology input. There is, however, a risk that the large EII demonstration projects (of several hundred million euro each) may be locked-in on existing technologies, largely decoupled from relevant advances in science and technology towards 2020. Avoiding this and meeting EII needs will require new mechanisms for implementing Horizon 2020 R&D results and innovative concepts for ongoing EII projects. This should be addressed in Horizon 2020 and the activities should be focused more on the most promising and most cost efficient renewable energy sources. Large size projects and demonstration projects should be limited to a few cases only. They are usually expensive and less innovative. Demonstration projects should be developed and supported by fundamental research studies, including simulation of expected system operation. Every demonstration project should be accompanied by detailed fundamental and applied research studies.

Ideally, industry should pose the questions, while universities and research centres should try to answer them, keeping close contact with industry, but not necessarily always working in projects together with industry partners. Efficient research has clear objectives, essential partnership, and a demanding final customer: someone who needs the results that the research may provide. Europe has many renowned scientists working in physics, physical or biological chemistry, and electrical engineering fields. They could form powerful new cross-disciplinary teams. The dialogue should also include energy providers, regulators, energy users and those affected by energy consumption and generation. We need to employ a novel procedure of inclusive governance, i.e. forms of cooperation that link the main actors in science, politics, economics, and civil society. Demonstrator projects and living labs for medium-scale testing of smart grids and smart cities offer excellent crossing points for the dialogue between industry and academia as well as other stakeholders.

From a research / university perspective, exchange of knowledge and experience across nations and research disciplines is highly needed. Improved mobility among European scientists may be a critical element in successful implementation of the SET-Plan. Europe should also take an international lead in physics/chemistry, economics, and in selected parts of energy related research, in particular material sciences and performance/economic modelling of sustainable energy systems. University consortia could take on the challenge to lead large-scale problem-oriented modelling efforts.

Top-priority criteria for selection of European projects in Horizon 2020 are scientific excellence, society needs, and European competitiveness, combined with criteria for European cooperation, exchange of knowledge, know-how, and expertise and matching project partners. Coordination of research efforts can be achieved by alignment of European research strategies by all relevant stakeholders like the European Commission, member states, industry, research organisations, universities, regulators, and users. This could lead to a more harmonised European as well as national and industry implementation of these research strategies.

The urgent need for progress in energy technology should be recognised, and available public resources should be increased. Big societal issues need big research programmes and research infrastructures to address and provide the needed answers.

INNOVATION IMPACT

There is an obvious, urgent need for more innovative low-carbon technologies, in particular for radical innovations that lead to step improvements in energy efficiency, reduced greenhouse gas emissions, and production costs. This requires technological, but increasingly also scientific innovation. Emphasis should be on the entire innovation chain and on turning basic scientific results into technological concepts, products, and systems. More efficient innovation programmes / systems, in particular at universities, should be encouraged to achieve this. Mobility of scientists and students among research institutions and industry should be achieved through new types of more flexible grants. The SET-Plan provides a potentially solid platform for a dialogue between industry and R&D organisations and universities, which indirectly will speed up the innovation processes. High-quality, curiosity-driven, free research attracts the best young minds and guarantees that truly new ideas continue to be generated.

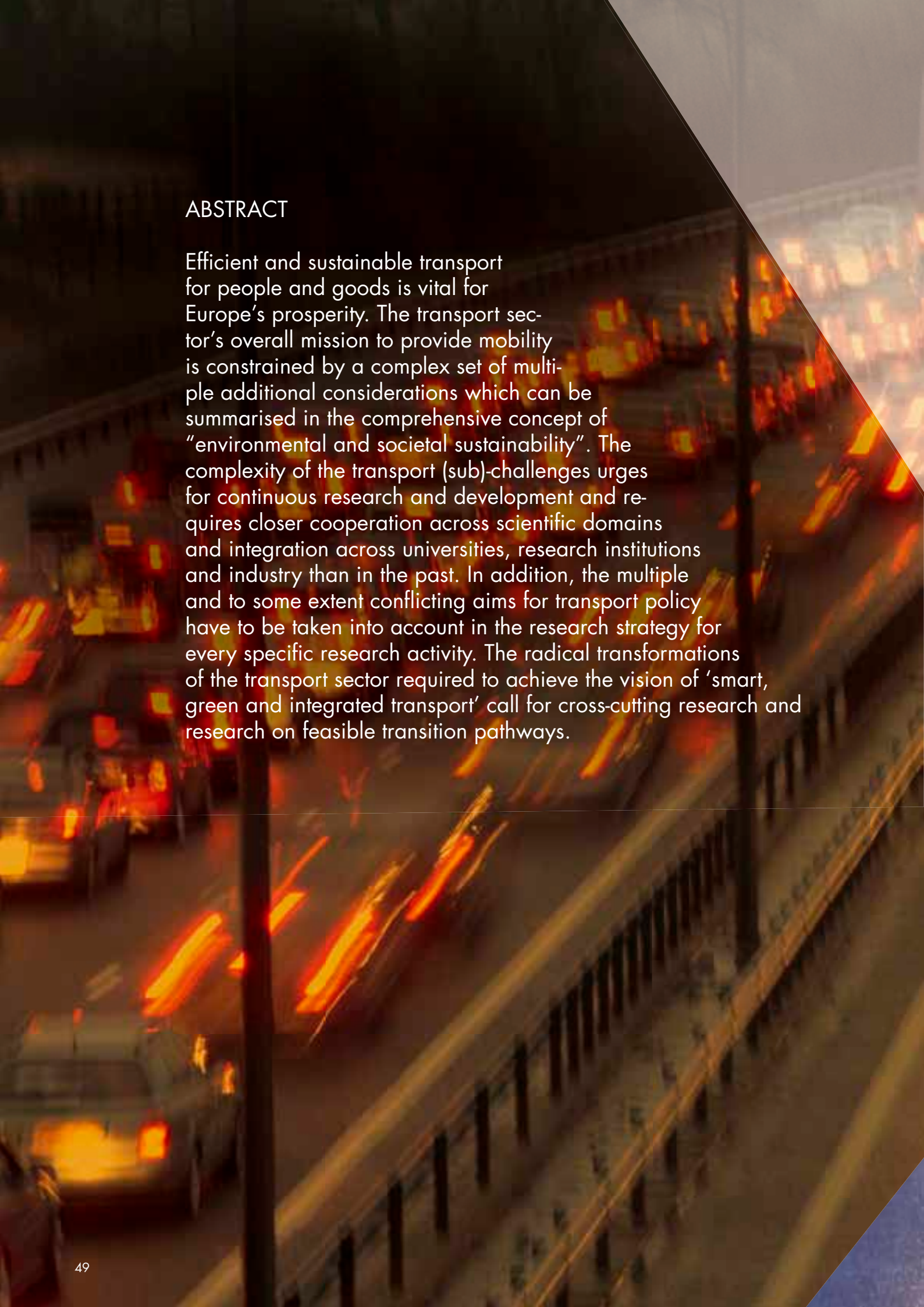
The transition toward sustainable energy will also require profound changes in the everyday life of European citizens and in the organisation of cities. Collaboration of social sciences and humanities with the "hard sciences" must be recognised as necessary and organised and funded accordingly. Social sciences can follow and analyse public reactions and provide guidance and a vision of possible scenarios toward energy transition. History, economy, and policy studies should be considered in European-wide deployment of new technologies. There is an urgent need for innovation, including economic, political, and legal aspects to enhance the transformation of our presentday society to a society based on low-carbon energy. The full potential of renewable energy technologies cannot be achieved if the markets do not express the real cost of fossil energies. Whether by application of environmental taxes or by other means, this "renormalisation" of price tags is a necessity. An important task for economists is to establish a socially acceptable and morally just way of including environmental concerns in the price of coal, oil, gas, and nuclear energy. This is certainly a cross-disciplinary task for social sciences and natural sciences to tackle together.

To reach the ambitious targets of the EU energy policy, we need to intensify and accelerate technological progress, reducing innovation bottlenecks. In order to achieve this goal, the whole chain of innovation must be considered when revising old programmes or setting up new endeavours. Viewing the commercialisation or innovation chain as a whole and its elements more concurrently (i.e. not linearly) will speed up the pace from research to use. Users need to be more involved in the innovation processes. Innovation and technology development should not be pursued in isolation, without links to users and their needs. Living lab environments may be interesting to develop further in this respect. In addition to technology, push mechanisms that are typical for research and a stronger link to market pull instruments may be necessary to speed the commercialisation path. Technology procurement would be an interesting approach to shorten the time from research to market.

Better coordination between national efforts and joint European efforts with all EU countries included is badly needed. Coupling between innovation and industrial implementation has to take place at all levels. Industrial partners operating on the European scale should team up with strong consortia of centres of excellence. SMEs can benefit from European efforts through strong coupling to local centres of excellence, thus gaining access to networks of pertinent expertise. Public administration should encourage new entrepreneurial approaches at universities and foster connections between research centres and universities with problem-solving approaches.

Hence, a much stronger interplay between university research and education and development in industry should be encouraged. Issues of IPR (Intellectual Property Rights) and success payment should be addressed on a European scale. More innovation and diffusion of research results can be achieved through better networking and stronger links between demand and supply. The composition of research consortia should give higher priority to the quality of partners and less to political priorities, and also be more open to new partners. Innovations are necessary along the whole value chain, from fundamental science and new technologies to new services and policy tools. The first two require a substantial research budget, while the latter two require completely new thinking and new approaches to energy innovations. Assuring high scientific qualifications of the coordinator and the PIs of all partners, is also important in this context.

The final point to emphasise is that Horizon 2020 should be designed to match the challenges of globalisation. The goals and expected achievements of each programme should be reviewed in a global context, combined with regular and comprehensive overviews of the actual state of the art and needed progress. This should be done in an open process to enable stakeholders to see efforts and plans from a global perspective and help avoid wasting scarce resources on parallel and less effective efforts. This could be combined with new mechanisms to monitor and stimulate the introduction of European low-carbon technologies to the global market.



ABSTRACT

Efficient and sustainable transport for people and goods is vital for Europe's prosperity. The transport sector's overall mission to provide mobility is constrained by a complex set of multiple additional considerations which can be summarised in the comprehensive concept of "environmental and societal sustainability". The complexity of the transport (sub)-challenges urges for continuous research and development and requires closer cooperation across scientific domains and integration across universities, research institutions and industry than in the past. In addition, the multiple and to some extent conflicting aims for transport policy have to be taken into account in the research strategy for every specific research activity. The radical transformations of the transport sector required to achieve the vision of 'smart, green and integrated transport' call for cross-cutting research and research on feasible transition pathways.

SMART, GREEN AND INTEGRATED

TRANSPORT

ABSTRACT CONTINUED

The range of highly relevant transport research topics is broad. However, there are three overriding challenges facing the development of a competitive and sustainable transport system which are absolutely crucial and particularly hard to solve and where research therefore should be prioritised as an essential part of the solutions:

Smart: Congestion due to overexploitation of system capacity;
Green: Greenhouse gas emissions from transport's oil dependency;
Integrated: A modally divided and vulnerable transport system.

Meeting the political challenge of both improving mobility by smarter utilisation of a more integrated transport system and making it greener by radically reducing greenhouse gas emissions will require not only technological solutions but also better understanding of transport behaviour and the use of innovative and effective policy instruments. This calls for a more pronounced role for social sciences than in previous Framework Programmes. In many cases the efficiency of research can also be improved by strengthening the integration of scientific domains.

Technological innovation will still be of paramount importance as development of novel and more efficient technologies will be pivotal for reaching the main European transport policy goals:
- Cleaner and safer vehicles for all modes;
- Cost-effective alternative fuels, (electric) drives, propulsion technologies, battery and chemical storage of energy and new materials for vehicle construction;
- Advanced ICT for personalised real-time travel information with modal integration, metropolitan traffic management and smart payment systems;

to highlight a few exceedingly important areas which will require massive investments in R&D&I towards 2020 and beyond.

Apart from greenhouse gas (GHG) emissions the majority of the negative impacts from transport occur in and around major urban areas where the majority and an increasing share of Europe's population live. This calls for intensified research in the challenges related to urban mobility. A significant change of modal split away from cars is necessarily an essential part of the solution. This will also make cities more liveable, but it will require both sticks and carrots to achieve, e.g. urban road pricing schemes accompanied by more competitive public transport and facilities for cycling and walking.

Expectations for increasingly scarce funding for infrastructure improvements highlights the need for cross-modal integration as a means to improve overall efficient and sustainable mobility rather than effectiveness at modal level. Further development and implementation of concepts such as door-to-door mobility, seamless connectivity, and global interoperability can contribute to more customer-oriented services. In the future, transport may be more vulnerable to extreme events, and this calls for research in resilient systems.

Finally, traffic is still responsible for a death toll in the EU of about 35,000 annually and many more serious injuries. Hence, in spite of dramatic improvements in traffic safety over the last four decades, substantial research efforts are still indispensable. Reaching the 'close to zero' vision will require a paradigm shift toward a holistic system approach.

A substantial part of the chapter on transport is devoted to presenting a number of highly important yet indicative research topics organised under the following three headings: Mobility – behaviour and modelling; Balancing demand and capacity; and Governance, financing and organisation. The goal has been to also inspire the subsequent work with implementing Horizon 2020 in future work programmes and calls.

VISION

Smart, green and integrated transport is vital for a sustainable and prosperous Europe of the future and strategic transport research will be crucial for its achievement.

Transport innovations have, along with scientific achievements, technological developments and institution-building, been among the fundamental drivers of the economic development of Europe throughout history.

From exploration of other continents over the industrial revolution to the ongoing globalisation and urbanisation of the world, transport improvements have been a prerequisite for the gains made from inter-continental trade, the economies of scale of industrial production, and agglomeration benefits of mega-cities and conurbations.

But the need for transport innovations has not outplayed its role. A radical transformation of the transport sector over the coming decades will be an essential part of the strategy, when economic recovery after the current downturn and fiscal debt crisis must evolve into sustainable growth to meet the double challenge of addressing the global environmental imbalances and at the same time providing high welfare to an ageing European society. An even more efficient, as well as dramatically more environmentally friendly, transport system will be crucial for the European competitiveness in a globalised world.

The 7th Framework Programme (as well as previous FPs) has brought significant technological advances and substantially better

scientific understanding of the complex functioning of the transport system. A hugely important role for EU's research strategy is to look at the medium and long term (10-40 years), as this is usually beyond the horizon of transport industry and national governments. Therefore, a new joint European, strategic transport research programme cutting across themes and national priorities and fully aligned with the European transport policy for the period 2013-2020 is both justifiable and necessary. Hence, it is welcomed and fully justified that smart, green and integrated transport is put forward as one of the prioritised six societal challenges in Horizon 2020. In addition, sustainable solutions to the transport challenge will also have a positive influence on every one of the other five grand societal challenges.

NEEDS AND SOLUTIONS

Main challenges for a smart, green and integrated transport sector and fields where R&D&I is needed as an essential part of the solutions.

THE CHALLENGES FOR TRANSPORT RESEARCH

In general, the smart, green and integrated transport section in the current proposal for Horizon 2020 reflects well the main aspects of the challenges of the transport sector. The set out objectives for the transport system are ambitious and clearly consider the goals of the 2011 White Paper on Transport as well as the policy goals of the Europe 2020 strategy. Substantial research is necessary to fulfil the objectives and it will require that the transport challenge has a particularly central position in the actual implementation of Horizon 2020.

In the past, conflicts between policy goals, e.g. between mobility needs and environmental concerns, have been a main barrier for taking strong and outreaching political decisions. The majority of specific research activities highlighted under each of the four sub-headings (efficient and green transport; better and safer mobility; global leadership[1]; and policymaking) has a crosscutting nature in the sense that they can contribute to several policy goals. The research strategy for each specific activity has to recognise and address such potentially conflicting goals and the resulting 'implementation gap' rather than focusing on one or the other.

[1] "Global leadership for the European transport industry", strictly speaking, does not address the societal challenge for transport, but relates to the other specific programme on "Industrial leadership and competitive frameworks".

Discrepancies will also exist between the research priorities for achieving political goals and the immediate interests of industry driven by customer demand. Hence, it is equally important to influence private sector R&D&I by communicating clear long-termed political commitments and by firmly implementing incentives that will steer the transport industry's R&D&I in directions underpinning the goals and priorities in Horizon 2020 and accelerate market implementation of new, innovative solutions.

In addition, the complexity of the transport challenge calls for intensified and improved inter-disciplinary cooperation across natural science, engineering and social sciences, but still based on the strongest single-disciplinary foundation.

THREE OVERRIDING CHALLENGES

TThe range of highly relevant topics for new and further transport research is remarkably broad as reflected in the Horizon 2020 documents. With a view to transport's important role in revitalising Europe's competitiveness in the globalised world on the one hand and the seriousness of the global warming problem on the other, there are three absolutely crucial challenges facing the development of a competitive and sustainable transport system which are particularly hard to solve and where research therefore is an essential part of the solutions:

Smart: Congestion due to overexploitation of system capacity;
Green: Greenhouse gas emissions from transport's oil dependency;
Integrated: A modally divided and vulnerable transport system.

The three challenges are interrelated in the sense that the solutions to improving mobility by reducing congestion and achieving flexible modal integration are constrained by the concern for the climate change problem and vice versa.

REDUCING CONGESTION BY BETTER UTILISATION OF EXISTING CAPACITY AND CHANGED MODAL SPLIT (SMART)

The desirable economic recovery and revitalisation of the European economy as set out in the Europe 2020 strategy can be expected to revive the demand pressure on the transport system which without demand management and economic incentives will intensify congestion and eventually severely restrict our mobility and increase unreliability. This is of course not a new situation; economic progress and transport demand have been closely linked for more than a century. However, projected structural constraints on government budgets, reinforced by the current debt crisis, as well as limited availability of land and environmental constraints, will probably constrain infrastructure development in the coming decades. Hence, mainstream transport policy of the past, where growing transport demand has simply been accommodated by extending capacity, will not be sufficient to tackle congestion in the future. Demand management and optimising the utilisation of existing network capacity by widespread use of pricing and ICT will have to play a key role along with improving public transport and cross-modal integration. If not, we can end up in the paradoxical situation that too much transport will hamper our mobility, in particular in and around major urban areas.

TARGETS FOR GHG REDUCTION REQUIRE RADICAL TECHNOLOGICAL CHANGES AND FACILITATION OF THEIR MARKET UPTAKE (GREEN)

Transport is responsible for about a quarter of Europe's GHG emissions; and its share of GHG emissions as well as the absolute amount are rising. The fact that transport depends on (primarily imported from abroad) oil products for 96% of its energy needs, only adds to the problem with a view to the world's shrinking oil reserves. The GHG reduction target of 60% in 2050 (with respect to 1990) is ambitious, but the impact assessment of the 2011 White Paper on Transport concluded that it is feasible and at limited additional costs. However, reaching the goal depends on intensive investments in technological research over a broad range so as to achieve the breakthroughs as well as the necessary cost reductions of the required radically new solutions, and this applies both to vehicle technologies and to fuel standards.

Developing new technological solutions, like electric vehicles, will have to be closely linked to a better understanding of user behaviour, car buyers' risk aversion and preferences as well as mobility patterns in general in order to target and accelerate innovation by ensuring that the novel solutions match the needs and hence can gain a foothold on the market. Designing and implementing clever regulatory frameworks, including taxation and pricing schemes and level playing fields, are crucial to pave the way by creating the right incentives for the industry's R&D&I as well as the decisions of end users of vehicles of all modes and transport services.

CUSTOMER-ORIENTED CROSS-MODAL INTEGRATION AND RESILIENCE (INTEGRATED)

The earlier mentioned expectations for increasingly scarce funding for infrastructure improvements highlight the need for cross-modal integration as a means to improve overall efficient and sustainable mobility rather than effectiveness at modal level. This applies to both freight and passenger transport as well as for urban, interurban and intercontinental transport. Concepts such as door-to-door mobility, seamless connectivity, and global interoperability can contribute to developing more customer-oriented services. Deployment of robust co-modal systems calls for more advanced transport optimization methods which have become increasingly more vigorous as modern ICT such as Global Navigation Satellite System (GNSS),

Radio Frequency Identification (RFID), smartphones etc. further improves the quality of real-time tracking of goods and generate vast amounts of relevant data from real-life transport operations. Such data can be processed and made readily available for planning and optimisation at low costs. Implementation will require revision of organisational structures, advances in deployment of ICT for systemic data handling, innovative apps for personalised travel information as well as novel business models and innovative products. However, although integration and cross-modality are necessary, extensive system integration might also pose a risk. Extensively integrated information flows, management systems, infrastructure networks and mobility services increase dependencies and might be more vulnerable. It is necessary to address and to study risks and vulnerabilities not only as some add-on concern with regard to e.g. extremist actions, extreme weather or other exceptional circumstances, but as phenomena that resilient transport systems should be able to cope with as standard events.

A MORE PRONOUNCED ROLE OF SOCIAL AND BEHAVIOURAL SCIENCES

Meeting the political challenge of both improving mobility by smarter utilisation of a more integrated transport system and making it greener by radically reducing GHG emissions will require not only technological solutions but also better understanding of transport behaviour and the effect of policy instruments. Therefore, social and behavioural sciences have to play a more important role in the transport research strategy than in the past, both in relation to successful implementation of new technologies and optimal utilisation of the transport system, including the balance across modes. Consequently, these fields of research should have significantly more weight in Horizon 2020 than in previous Framework Programmes where by far the dominant share of the effort was devoted to technological R&D&I. It is welcomed that social and behavioural sciences will be fully integrated within each of the main pillars of Horizon 2020. Yet, one should be cautiously aware of the risk that the above-mentioned important social science aspects will not get due attention in the research priorities of the calls when compared with the obviously important, technology-oriented projects which are sine qua non, but also much more costly.

Therefore, the approach chosen here is to put emphasis on research priorities focusing in particular on behavioural, organisational and regulatory topics with a planning and policy-oriented perspective. This is done in confidence that synergies with other fora, e.g. the European Technology Platforms in Transport (and Energy), will provide the required visionary, and competent input on developing the next generation of innovative transport technologies.

TECHNOLOGICAL INNOVATION WILL STILL BE OF PARAMOUNT IMPORTANCE

Having said this it is important to maintain that development of novel and more efficient technologies will be pivotal for reaching the main European transport policy goals:

- Cleaner and safer vehicles of all modes;
- Cost-effective alternative fuels, (electric) drives, propulsion technologies, battery and chemical storage of energy and new materials for vehicle construction;
- Advanced ICT for personalised real-time travel information, modal integration, metropolitan traffic management and smart payment systems;

to highlight a few exceedingly important areas which will require massive investments in R&D&I towards 2020 and beyond. In fact, ICT will in the years to come have to be a key component in practically all new innovate solutions in transport. Hence, intelligent transport systems must shift from being considered as a separate research topic to be an integral part of most fields of transport R&D&I.

EFFICIENT RESEARCH BY STRENGTHENING INTEGRATION OF SCIENTIFIC DOMAINS

Research aimed to tackle the challenges of smart, green, and integrated transport requires a strengthened integration of technology and social sciences as a pre-requisite for undertaking an effective, efficient and timesaving approach. As an example, the greening of maritime transport presupposes input from a range of disciplines, and so does a holistic Safe System approach to road safety. Integrating social sciences in earlier stages of technological development is deemed necessary to minimise the risks of investing in what turns out as dead ends. Research strategies should in a timely fashion assess and predict impacts of new technologies and measures on the transport system as a whole. The impact assessment should take into account end-user behaviour and preferences and be evaluated against the societal needs and goals. Here, we need to strengthen the scientific understanding and our ability to quantify how the direct benefits of a well-functioning transport system, in terms of high mobility and accessibility, enable economic growth and make a city or region attractive for settlement of people and business.

PATHWAYS OF TRANSFORMATION

In addition to strengthened integration of research domains, the radical changes needed in the transport sector will require innovation in methodologies of studying dynamics, as social sciences are traditionally geared towards supporting gradual and stepwise changes rather than to transformations. Consequently, a European programme for research and innovation at the doorstep of a radical transformation of the transport sector should be open-minded, creative and allow for new questions.

Major technological shifts will typically take place over decades due to the lifetime of vehicles and infrastructure. For example electric or fuel cell vehicles could very well be pivotal to achieve a 60% cut in GHG emissions from transport but may take 20 years for them to obtain a major market share. Meanwhile efforts to make conventional cars gradually more energy efficient will postpone the point in time where radically alternative technology may become competitive and gain a foothold in the market. Furthermore, there are transition costs, e.g. for fuel infrastructure and gaining customer confidence, involved in moving away from a well-established, mature technology.

URBAN MOBILITY

Apart from GHG emissions the majority of the negative impacts from transport occur in and around major urban areas where the majority, and an increasing share, of Europe's population live. Yet, high mobility and easy access to a variety of activities are essential features in the attractiveness of cities. Hence, reaching the goal of the 2011 Transport White Paper to halve the use of conventionally-fuelled cars in urban transport by 2030 and contribute to more liveable cities will require sticks and carrots, i.e. an urban road pricing scheme accompanied by more competitive public transport and facilities for cycling and walking. As a part of this ICT and real-time traffic data will have to be deployed in advanced systems which are not yet mature enough for smart pricing and personalised travel information.

Optimal long-term solutions also call for integration of research and innovation in the interaction between infrastructure development and spatial planning, where travel behaviour and pricing are at the core, also taking into account the future demographic structure of Europe.

GLOBAL FREIGHT TRANSPORT

All three above-mentioned overriding challenges also relates to long-distance freight transport which call for further R&D&I. Maritime transport is an essential pre-requisite for the globalised world as international shipping caries some 90% of world trade volumes. Still, the vast majority of the goods are transported over land as the last and/or first part of the door-to-door shipment. Improved efficiency requires a highly flexible and reliable multimodal integration, also in order to reduce congestion in the hinterland to the harbours. Further, although sea transport is very energy efficient the big volumes imply that international shipping accounts for 3% of global CO2-emission and the alternatives to the current oil dependency is far from ready.

A ZERO VISION ON ROAD FATALITIES REQUIRES A PARADIGM SHIFT TO A 'SAFE SYSTEM' APPROACH

The 2011 Transport White Paper aims for halving road casualties by 2020 and moving close to zero fatalities in road transport by 2050. Due to the impact on society it would be of interest to include (serious) injuries in further policies and research as well, and thus link road safety with health policies. Although we have observed a dramatic decline in fatalities and mortality rates in EU member states, it cannot be expected that traditional safety measures are likely to reach a zero level. Reaching ambitious targets such as 'move close to zero' requires a paradigm shift and a Safe System approach is considered to be a very promising such transformation. The road system should be redesigned taking into account the fallible and vulnerable human being.

This approach should holistically integrate all components of the road transport system (roads and traffic, human behaviour, smart and safe vehicles) and should align safety management decisions with broader transport and planning decisions using technological innovation opportunities. Further and multi-disciplinary research is needed to design such a system approach and explore how to get it implemented.

TECHNOLOGIES AND PRIORITIES

Indicative topics to be prioritised in European transport research towards 2020

The main aim of this section is to provide constructive inputs with a view to bringing the current version of Horizon 2020 one step further by identifying and describing a set of highly important research topics.

The suggested topics can in most cases easily be interpreted as prioritised fields of research, but without claiming that other topics could not also have found their way onto the list. In particular, as explained above, emphasis has deliberately been put on behavioural, organisational, and regulatory topics with a more planning and policy-oriented perspective. The goal is to provide highly relevant, important, and innovative topics which can inspire the Commission when providing work programmes and calls within the framework of Horizon 2020. The topics are organised within three levels of abstraction: research in the actual understanding and measuring of mobility and travel; the regulation of travel by balancing demand and capacity; and finally the governance, financing, and organisation of transport service provision.

The research topics mentioned below include references to sections in the chapter on "Smart, green and integrated transport" in the Horizon 2020 specific programme proposal. As a result, each topic lists the sections it relates to in the programme.

MOBILITY – BEHAVIOUR AND MODELLING

Mobility as a potential to move is assumed to be essential for the development of social activities, economic performance, technological capability and the societal dynamics of Europe, and also underpins the draft on "Smart, green and integrated transport" in the Horizon 2020 programme proposal. Many disciplines have dealt with understanding and measuring mobility. Too little is still understood today, however about this latent variable and its associated value to society. Mobility is a potential for movement that is determined not only by infrastructure capacity, but by the interplay of a number of environmental, technological, economic, social and cultural factors which need to be better understood in order to guide investments and regulatory changes in an optimal way. This goes for goods as well as persons. Improving our understanding of mobility and our ability to measure and manage it ought to be at the core of European transport research in order to handle the climate challenge and provide better mobility and welfare to European society. Some examples of important research topics in this field are:

- **Improved understanding of travel and travel demand.** Trips, as used in much transport analysis, have always provided a limited and limiting view of travel, as only the main part of the journey is included. A reconfiguration of our understanding of travel would look at total door-to-door travel as a combination of modes, thus also including slow modes, which are currently under-recorded. Such a reconfiguration would allow for decisions taken in terms of the weakest part of the journey. Reconsideration of travel demand ought also to include trends, which could allow for better explanations. Hence, a megatrend affecting transport demand is the rapidly ageing population in all industrialised countries. However, other demographic changes are the process of individualisation visible in e.g. changing household types (more single-person households) and living arrangements (multi-local forms of living, such as living-apart-together) and the process of internationalisation, i.e. a growing share of people with a migration background in the European population. Furthermore, a trend in new forms of car ownership like leasing and sharing should allow for new thinking about the decisions to buy a car. Such decisions are often a compromise between different priorities – whether it is to be used for local trips, long distance trips, or with one person or many people travelling. In order to establish a more comprehensive view of travel, advance estimation of transport demand and improve mobility for the entire European society such issues should be studied in more detail. (H2020: 4.1.3; 4.2; 4.4)

- **Microscopic European travel and transport data.** There is a lack of microscopic travel, transport and infrastructure data to support the development of European transport models for decision making. Provision and availability of detailed data can contribute to analysing impacts of taxation, changed demography, and to do cost-benefit analysis of new infrastructure projects. It is therefore necessary that national and European data for passenger and, in particular, freight movements are maintained and improved where necessary. A continuous effort should secure that national survey data are made available and comparable at European level. Surveys should preferably be continuously ongoing in order to identify dynamic trends in the European transport patterns. Widespread application of modern ICT for registration of traffic, payments, and operations control etc. opens up for new, affordable possibilities for detailed data collection which should be utilised for research purposes. Exchange of experience and development of standards through European projects will be necessary to pave the way for this. (H2020: 4.1.2; 4.4)

• **Integrated transport, land use and energy models at European level.** There is a huge need to develop further a new class of integrated transport, land use, and energy models at the European level. Such models exist already in energy systems research but are less common in transport systems research. The European energy system and the European transport system are massively parallel as technological systems and fundamentally strategic infrastructures. If properly developed, such models can be used to support negotiations on investment priorities to mitigate climate change without sacrificing economic growth. Models are needed for freight as well as passenger transport. (H2020: 4.1; 4.4)

BALANCING DEMAND AND CAPACITY

In the coming decades building and enlarging transport infrastructure are likely to be constrained, due to limited government budgets, limited availability of land and environmental constraints. Hence, managing transport demand through land use planning and economic incentives are likely to be pronounced issues on the political agenda. Furthermore, demand management and obtaining a modal shift in favour of less polluting modes is a precondition for achieving GHG reduction goals and reducing local air pollution and noise. Within and across all modes research is needed to tackle these challenges. Though already many EU research projects have dealt with economic incentives and issues of land use planning, additional research is needed addressing specific issues, which also include maritime and air transport. More accurate accounting methods of the wider impacts of European transport infrastructure will also be increasingly important with scare funding for transport infrastructure. Examples of relevant research topics within this field are:

• **Linking land use and transport planning.** Short distances between and higher densities of housing, offices, schools, shopping, and recreation centres contribute to solving a range of environmental, climate and spatial problems, because they make it easier to promote public transport, bicycling and walking. Such a development is necessary to achieve the 2011 Transport White Paper goal on urban transport, but is not given much attention in the proposals for Horizon 2020. To assist in such a development we need better integration of land use planning and transport planning, and as an input to this, better integration in transport models of household and company localisation decisions and transport behaviour. The core questions for research are how to control land use development and retrofit existing urban areas to sustainable transportation; how to develop attractive mobility solutions bridging between access, choice, and resource efficiency, and how to manage transport infrastructures, traffic, and environmental qualities in dense, urban settings? (H2020: 4.1.3; 4.2.1; 4.4)

• **Getting the prices right by smart pricing.** Over the last decade several cities and countries around Europe have implemented an ICT-based pricing system for road traffic to reduce congestion and pollution. However, although a full national road pricing scheme with charges varying with when, where and what you drive is generally believed to be the solution of the future, it has not been implemented anywhere yet, among other things due to the technological uncertainties and political risks involved. The obvious economies of scale and user benefits of a European-wide compatible system call for EU leadership in a strategy for research, innovation, and deployment of a system which is of course more precise and robust. The principal technological challenges have probably now moved beyond research and into the innovation phase, where EU standards are important to speed up development. But optimal exploitation of a road charging system by the member states is dependent on intelligently designed, dynamic pricing schemes for freight and passenger transport, including pricing in public transport. For this purpose substantial research is needed to achieve in-depth knowledge and quantitative explanations in several fields ranging from e.g. dynamics of network congestion, impacts on supply chains and distribution systems, wider impacts on land use and the urban economy, to implementation paths including incidence, use of revenue, communication and political acceptability in the population. (H2020: 4.1.3; 4.2.1; 4.4)

• **Wider economic impacts of major transport infrastructure investments.** In society, there is a general understanding of the importance of transport infrastructure as a precondition for an efficient and dynamic economy. Classical cost benefit analysis has developed in recent decades into more advanced appraisal methods that more adequately value time savings (though to a less extent for business travel) and encompass environmental and safety impacts and other derived effects. However, our understanding of how direct benefits in terms of high mobility and transport cost savings transform into industrial competitiveness and economic growth is still poor. In particular, how wider economic benefits, in terms of complex and diffuse impacts such as agglomeration benefits, regional development, and dynamic effects in labour and housing markets can be measured and included without double counting should be analysed in a European context. (H2020: 4.1.2; 4.4)

GOVERNANCE, FINANCING AND ORGANISATION

During the past 25 years, so-called new public management (NPM) reforms have marked the organisational shaping of the public sector, and not least the transport sector. Important features of these reforms are the unbundling of public sector organisations into corporatised units, competition, performance measures, output controls and private sector styles of management. Within transport, these reforms in particular are visible within railways and public trans-

port, where previous governance structures, organisational forms and ownership in many countries have changed radically. Recently, post-NPM reforms have been launched characterised among other things by increased awareness of political steering and coordination. Both types of reforms are co-existing. An ex-post evaluation of these changes in governance, financing, and organisation related to the sector's performance is needed in order to consider if the current structures are the most suitable for the challenges of the twenty-first century. The question is what works and what does not work? Furthermore the institutional structure should be evaluated in the light of the implementation gap between political objectives and actual implemented measures. Inherent to this research is the question of transferability of lessons from one context to another. Adequate institutional structures are pivotal to achieve the 2011 Transport White Paper goals. More specifically the following research topics could be suggested:

• **Public-private partnerships.** A growing number of transport infrastructure projects cannot be funded solely by public budgets due to the shortage of tax revenues, high public debt, and the recent economic and financial crises. Private capital investments in the construction, operation, and maintenance of public transport infrastructure are attracted more frequently in contractual models like design-build-operate-finance-maintain (DBOFM) in order to stimulate innovative design and use of modern technology, shorten design and construction times, reduce life-cycle costs and achieve more efficient project management. The sharing of risks between the public party remaining responsible for legal acts, concessions, specification of public and user requirements, supervision, acceptance and payment on the one hand, and the private party fulfilling the contractual obligations and getting remunerated is changing from project to project and country to country. A comprehensive and independent analysis of the impact of contractual models, input and output delivered for existing PPP projects in different transport sectors with regard to e.g. robustness, efficiency, value for public money, user benefits, and environmental impact is necessary to evaluate the long-term viability of mixed public-private transport business arrangements. (H2020: 4.1.2; 4.4)

• **A customer-oriented European railway system.** Railways have played an important strategic role in the European transport policy from the start and significant initiatives have been taken and implemented in several EU directives. In spite of this, European railways have not developed the necessary intermodal competitiveness to turn around generally declining markets shares and weak productivity increases. Speeding up the harmonisation of the railway sector is necessary to optimise capacity, interoperability, operation, and management to make railway services more integrated, and by that ensure

that the railway systems can provide a dependable, green alternative to other modes. The slow progress of transforming the railway sector despite strongly stated political commitment calls for more research on how to organise, regulate, and incentivise the sector so as to set off its full potential as a leading actor in making transport sustainable in a still more urbanised Europe. Radical changes are required to achieve the political ambitions for railways. However, the research in new solutions has to be conducted taking into account the political and institutional barriers in individual countries for creating radically different, harmonised framework conditions and in recognition of the inherent complexity of operating on the same railway tracks local, regional, and international services as well as of balancing passenger and freight. (H2020: 4.1.2; 4.2.2; 4.4)

• **Urban public transport.** Radical improvements in the quality and cost effectiveness of urban public transport are required to achieve the 2011 Transport White Paper's goals. At the same time, the integration of transport and land-use planning must be improved. These objectives raise important questions about the organisation and governance of urban public transport. At present there is a variety of approaches in Europe, ranging from comprehensive public provision through private provision under contract with public authorities to a completely free market approach. The completely free market approach may offer the best approach in terms of innovation and cost reduction, but by itself is unlikely to achieve a seamless public transport system or integration with land-use planning. These objectives inevitably require a degree of public intervention in the form of regulation or contracts. How to achieve this whilst maintaining the maximum potential for innovation and cost reduction is a key research question, and answers will benefit urban mobility and the environment. (H2020: 4.1.3; 4.2.2; 4.4)

• **A learning-oriented governance architecture.** The governance of transport policy needs to enhance its capacity to better distinguish past accomplishments as well as failures, and to integrate such experience in the identification, implementation, and monitoring of future measures. This is indispensable in providing for a new direction and in meeting the ten goals put forward in the recent 2011 Transport White Paper. This approach requires the development of enhanced capacity for ex post evaluations, application of diagnostic indicators, identification of contextual versus general determinants of outcomes, and the creation of strategic frameworks for joint knowledge exchange, deliberation, verification, and application. The cultural, political and economic underpinnings for learning architectures connecting transport governance effectively to surrounding societal needs and developments are to be studied. The real role and influence of components such as strategic transport planning, performance measurement, and decision support systems as mechanisms for application of evidence and knowledge and subsequent implementation in specific transport enhancements need to be critically examined. (H2020: 4.4)

INSTRUMENTS AND IMPLEMENTATION

Issues of importance to strengthen efficiency and effectiveness of European transport research.

To allow for the best minds to participate in EU-funded transport research simplifying the financial and administrative rules is a decisive factor: shorter time to contract and reduced administrative burdens as well as quicker acceptance of the external auditors' approved methods of accountability are important. Reduced size of consortia might also be a possible recommendation, so as to reduce costs and the administrative burden.

Often the exchange of disciplinary and cultural perspectives among the researchers in large research consortium is too limited, which implies that research projects are too fragmented and fail to fully exploit the learning potential. To help enhance the benefit of different perspectives a new criterion could be applied when the Commission assesses research applications, namely the establishment of research stays of various lengths among the consortium partners according to the needs of the project. If researchers representing other institutions and countries stay for some weeks or longer at a partner, this will contribute to interdisciplinary and intercultural learning, and benefit the research carried out.

Moreover, different research institutions and a number of stakeholders are often involved in transport research projects in one way or another, however sometimes at a late stage of the research process, thus implying limited value added. For transport research where extensive stakeholder involvement is particularly important, e.g. because stakeholders possess particularly important knowledge, an assessment criterion could be that representatives from society, public administration, business and/or NGOs are involved in the research application from the very beginning and consequently contribute to formulate research questions etc. Further dialogue throughout the research process in some cases is indispensable. However, not all transport research applications should be evaluated against such a criterion. Some research may be opposed by stakeholders if it does not serve their interests.

INNOVATIVE IMPACT

Improving the link between research and end users and thereby increasing application of research.

Transport research and innovation can significantly contribute to solving the challenges of the transport sector, however only if research results are applied in politics, by industry, and by citizens. Basic and applied transport research is an important part of the innovation chain. However, they usually cover only the first steps in the innovation chain, whereas higher levels are treated by the industry or government. Therefore, in order to foster the implementation and deployment of innovative research outcomes, and in order to monitor their impact, close cooperation of transport research with industry, policy, and administration throughout the whole innovation chain is highly important and should be reflected in Horizon 2020. Shortening the path from research to end users is essential, though all transport research can and should not produce directly for either politics or the market.

Demonstration projects and field operation tests are necessary and important in transport. However, the way funding is set up often puts up an artificial divide between research and demonstration projects. A lot more is to be learned from demonstrations if simple experimental design is introduced to them but this requires schemes of integration between the research and practitioner community, which needs to be adequately resourced.

New funding tools for start-ups and innovation-oriented companies should be specifically aimed at research and innovation "products" of precompetitive research. The help of the European Investment Bank and other banks must be solicited here as part of a "mechanism" to be designed specifically for the task of transferring research results to both market and society.

Abstract

With the global population currently at 7 billion and projected to be at least 9 billion by 2050, and an increasing per capita consumption, the human demand for the Earth's natural resources has never been larger. With this human pressure on the Earth's living ecosystems (e.g. biodiversity) and abiotic resources (e.g. rare Earth metals), the estab-lishment of mechanisms for intra- and intergenerational sharing of essential natural re-sources becomes the greatest challenge to the continued development of all human societies. The primary role of research in developing these mechanisms must be to provide the knowledge necessary to underpin sound and responsible decision making. Input from all research disciplines is necessary to provide this knowledge. While the ul-timate goal of research relating to this challenge is to sustain societal development, at the heart of research focusing on developing more responsible use of natural resources must also be the development of an understanding of societal transformation process-es. A large global market is anticipated for technologies and processes that improve the efficiency of resource use and/or that can provide substitutes for natural resources under pressure. However, transition to sustainable resource use will also require a change in values and thinking. One important contribution Horizon 2020 can make to these processes is to provide means whereby scientists from different academic fields are brought together to address possible transitions and how to achieve them.

CLIMATE

ACTION, RESOURCE EFFICIENCY AND RAW MATERIALS

ABSTRACT CONTINUED

Climate change constitutes one of the most urgent global resource challenges facing society, where the resource in question is our common atmospheric receptacle for the greenhouse gas wastes of society. Development of actions and strategies for dealing with this challenge can, potentially, provide models for dealing with resource scarcity issues coming on line (biodiversity, ecosystem services, water, phosphorous, ores and metals etc.).

A general paradigm for dealing with resource scarcity is reducing the need for – and more efficient use of – the resource, combined with the adaptation of human activities to changed conditions and/or the recognition of resource scarcity. In dealing with resource scarcity in general, and climate in particular, a major challenge is to channel the knowledge gained on the mechanisms of the Earth system into political and societal actions. This requires cross-disciplinary and interdisciplinary approaches that integrate the research conducted in many fields within the natural sciences with that conducted in other disciplines (including engineering, statistics, social science, and hu-manities) to provide solution-oriented results to decision makers.

Resource scarcity is a global issue, although it is not experienced to the same extent everywhere and not all regions enjoy the research infrastructure necessary to support good decision-making. Therefore, regions such as the EU that rely strongly on re-sources from all parts of the world and have well-developed research capacities, should not limit their research activities to their own geographical regions. Existing knowledge on the causes of climate change, for example, provides a sufficient basis for society to act immediately on reducing potential human interference with the climate system. Such knowledge is also being further developed for other aspects of the declining re-source base. Therefore, the focus in Horizon 2020 should be to underpin decisions de-signed to increase the efficiency and impact of the societal response. This will, howev-er, include research on the climate and other resource systems in order to better un-derstand systemic interactions, the collection of base-line information, and the estab-lishment of monitoring activities to assess the efficacy of different mitigation and ad-aptation approaches.

VISION

We as a global society are collectively faced with the grand challenge of transforming our societies to create a sustainable future. Incremental change is not longer an option, if we want to reduce the risk of potential catastrophic outcomes from continued climate change and ecosystem decline. The Earth's climate is changing faster than projected in key regions, notably the Arctic, but climate change is just one of a broader suite of global changes. Others include ocean acidification and de-oxygenation, land and water shortages, and the loss of biodiversity. The Earth holds finite reserves of materials out of which we construct and sustain our societies. Some of these materials are absolutely essential for life, such as the rock phosphorus used in agriculture to grow food. Rising commodity prices in the last ten years show that demands for material resources are exceeding supplies. As we depend entirely upon the Earth system and its component ecosystems for our survival, there is a real possibility that the human demand for resources may lead to global crises in the production of food and the supply of clean water in the form of unexpected climate emergencies, and much more. In addition, such crises may occur simultaneously and interact with one another. The essential resources and services provided by the Earth system and its ecosystems must be fairly shared among the current global population, also taking account of the needs of future generations. Currently in Europe we are consuming more than our fair share of the Earth's resources, and use many of them (e.g. fisheries) unsustainably.

The traditional paradigm for progress is growth, i.e. expansion into unlimited space. However, limits to planetary resources clearly indicate that the further development of humankind will be driven by qualitative changes in the content and structure of socio-economic systems – that is, transformations in our industrial processes and societal structures – rather than by just upsizing existing inventories. It is a deception to think that consumption and growth can continue in their current form, which assumes excessive environmental space, which moreover has endless capacity to absorb disturbance. A truly green economy cannot be based on the current growth paradigm and research into the building of an alternative, sustainable economy must urgently be instigated.

This overwhelming necessity for rapid transformation is also physically set by the international 2°C target for climate protection. Former historical transformations such as the Industrial Revolution happened more or less accidentally, not on the basis of systems analysis and science-based foresight. By way of contrast, the transition to sustainability has to happen over the next decades, and Europe can and should take the lead in bringing that transition about in a deliberate way. However, there is a blatant lack of data and knowledge on how transformations evolve and how they can be shaped proactively. Therefore, a prominent component of Horizon 2020 should be research on transformations to global sustainability (transformation research), which must be an integrated part of each of the six challenges identified in Horizon 2020. In the draft version of Horizon 2020, a set of main goals for European research related to climate and resource issues was formulated. This text was subjected to comments from a broad range of European scientists from a variety of aspects of climate and natural resource research. A synthesis of their responses and visions for future climate and resource-related research is presented here.

There is general agreement that the draft Horizon 2020 outlines some extraordinarily important research goals, which should be vigorously pursued. However, the unsustainable use of natural resources permeates all parts of our current society, thus causing the nature of the climate and resource challenges to be allembracing, and almost all research to be potentially relevant. For this reason, it is of utmost importance to see each research contribution in relation to its potential societal contribution.

Anthropogenic climate change is a response to overuse of Earth system resources in the sense that it is related to the capacity of the atmosphere to retain greenhouse gas waste without unsettling the radiation balance and, thus, the climate system. Resource economising actions, including a reduction in greenhouse gas emissions, represent a crosscutting challenge that cannot be considered on its own, but needs to be evaluated as part of the overall challenge of developing a sustainable path for society. The resource challenge must, therefore, be embedded in the remaining challenges. Furthermore, consistent actions require a worldwide perspective. Climate change is, for example, a global phenomenon and must be treated as such, but causes and impacts often involve local aspects, and mitigation measures must be embedded in individual countries' prospects. Internationally, however, it must be ensured that a solution in one area does not create problems elsewhere. Only by taking an integrated systems approach can consistent and efficient responses to the resource challenge be developed. Ideally, therefore, the final version of the Horizon 2020 document would see all six societal challenges described in an integrated framework of sustainable development instead of being considered in isolation from one another.

Societal transformation to sustainability cannot be achieved without taking human interactions with the Earth system as a whole into consideration. It could reasonably be argued that land use (which also impacts carbon sinks as well as climate, water and food availability, which generate biodiversity loss and are also impacted by climate change) is the most immediate resource challenge facing society. However, the climate change challenge immediately affects many sectors and regions. The focus, therefore, in the following is the climate challenge. However, actions directed towards amelioration of the climate change challenge are indicative of the types of actions required for achieving sustainable resource use more generally.

The climate system is complex and many of its processes and interactions not yet fully understood. A better understanding of these is necessary to provide more reliable predictions of future climate evolution and for assessing its impact on ecosystems and society. However, while furthering our knowledge on basic processes within the Earth system and human interactions with these is essential, some of the main challenges related to climate action and natural resource use are not posed within the natural sciences. We already understand many of the consequences of anthropogenic climate forcing, and there is no shortage of knowledge on links between, e.g. greenhouse gas emissions and environmental changes. Nevertheless, there is a lack of public acceptance of the insights already acquired, and a lack of willingness to change individual and communal behaviour based on these insights.

A key challenge for climate science is, thus, an improvement of the communication of the risks involved and how to cope with them. These aspects should be emphasised more heavily in future research. Presently, policymakers and journalists often use scientific uncertainties as an excuse for inaction. Also common current scientific practices, such as discounting future benefits and damages by economists, lead to ignoring actual risks. One must hope that the focus would be redirected to considering risk in a societal context and the relationship between risk and the application of the precautionary principle.

At present, human impact on the Earth system is to a large extent rooted in behaviour rather than in meeting basic needs. It remains to be understood what transformation in our values has led behaviour to develop to what it is, and what values need to be strengthened so it can be directed towards a more sustainable path. Research into these topics should be strengthened. In order to optimise the societal response to climate change and resource scarcity, climate and other resource economising actions should be implemented, monitored and evaluated in constant dialogue with all stake-holders. An important challenge, therefore, lies within the framework of solution-oriented research, drawing from all academic disciplines and related to developing the appropriate societal responses needed to implement the knowledge already gained into the collective values and behaviour of our society, with the purpose of changing these towards a model where human societies respect and live within the resource boundaries imposed by the Earth system.

Through the United Nations Framework Convention on Climate Change Conference of the Parties process, a large majority of the world's leaders have arrived at a consensus that human-induced global warming should be contained to within 2oC compared to global average temperatures prior to the onset of the Industrial Revolution. Given that this is the limit to the degree of anthropogen-

ic climate change society considers acceptable, then research tells us that about half of that atmospheric capacity to absorb society's greenhouse gas waste has already been used. The current climate action discussion among politicians can then be seen as relating to how the rights to use the last half of the resource should be distributed among current and future generations. Distribution of rights to the Earth's limited resources will be an increasingly important political issue in coming years and it is not clear whether or how they can be successfully addressed. Will it, for example, be possible to reconcile the aims of increasing food production necessary for a growing population with the aim of conserving (and restoring) ecosystems, while simultaneously striving for equity? Obviously, trade-offs and compromises are required, but how should they be chosen? More research in all disciplines is needed to underpin such societal discussions, and a broadening of the discussion is necessary to include the interdependence of global population size and the demand for global resources.

In terms of society's short-term economic development, however, it seems clear that there will be an increasing demand for technologies and processes that increase the efficiency of society's use of natural resources (energy, water, food, rare metals, phosphorous etc.) and the development of alternatives for resources where demand is approaching supply (i.e. renewable energies instead of fossil fuels). Thus, research aimed at improving resource efficiency is likely to lead to products for which there will be a growing market. Further research into the design of recycling systems for key finite resources (e.g. phosphorous) will also help increase the recycling-based, material part of the economy, which is likely to be economically beneficial in the future.

While increasing efficiency of resource use is essential to achieving sustainability, it should be noted that efficiency can counteract resilience, a most essential quality in times of change and impending breaks. Research must, therefore, also address resilience of natural as well as societal and economic systems and strive for a better understanding of what makes systems resilient against what disturbances, considering different time frames and system borders.

NEEDS AND SOLUTIONS

The research needs required to deal with climate change and other resource issues are varied and at different levels of complexity and ambition. The total set of research needs can be thought of as being assembled in a sort of "knowledge tower." The base of the tower consists of data collection systems while, at the very top are placed the grand societal experiment testing solutions developed on the basis of research. The content of such a knowledge tower relating to the climate and resource challenge could include ground level (which should include major infrastructural initiatives established by Horizon 2020):

- Monitoring networks (biodiversity, climate change; Long-Term Ecological Research (LTER) etc.);

- Large-scale marine and terrestrial infrastructure for climate impact studies;

- Establishment of a European climate computing facility providing both computational capacity but also a European "meeting place" for climate scientists, encouraging the development of a truly European climate research community (i.e. a "climate CERN"); and

- Provision for sharing of data, for example, meteorological networks and others.

1st level:

- Basic disciplinary research to develop a better understanding of interactions within the Earth system as a whole, including the climate system;

- Research focusing on anticipating change and recognising the potential for surprises in Earth system. Such research could lead to the development of early warning systems relating to nonlinear changes in the Earth system and integrated risk analyses; and

- The introduction of the discipline of complexity science into Earth system thinking.

2nd level:

- Inter-comparisons of different models such as, for example, those describing the potential impacts of climate change. Such inter-comparisons would provide a more comprehensive picture of the potential impacts and improve our understanding of the uncertainties and the risks associated with anthropogenic climate change. In addition, such comparisons will contribute to future model development; and

- Capitalising on the diversity of European research by linking various geographically separated modelling initiatives into integrated global assessments and new European Earth system models.

Top level:

(where the potential for Europe to lead the world in the transition to sustainable resource use is realised)

- Integrated interdisciplinary approaches and transdisciplinary[1] research focusing on solutions; and pilot schemes or experiments aiming at solutions to the resource challenges facing society (e.g. focusing on sustainable cities and sectors).

New research approaches are necessary in order for society to develop a responsible relationship with the natural resources that sustain us. That research cannot be carried out in isolation from stakeholders, including the public at large, and scientists should be encouraged to involve stakeholders from the inception phase of the research.

The transition to sustainability demands a plethora of new science and technologies. Recent experience with new technologies, including genetically-modified organisms (GMOs) and carbon capture and storage underground (CCS) indicates great potential for public disquiet and blocking of their deployment. The traditional model of 'downstream engagement' with the public – telling them about a new technology once it is developed, in the anticipation of acceptance – has failed catastrophically in several recent cases (e.g. GMOs). Although the transition to sustainability is framed in benign terms, many aspects of it could generate public backlash. To succeed, Horizon 2020 needs to engage the public and multiple stakeholders much earlier and more comprehensively in the development and deployment of new sustainability technologies. Ultimately, the citizens of Europe need to feel proud ownership of the transition.

The draft Horizon 2020 document acknowledges in several places that certain activities need to be carried out at EU level and beyond. However, it is important that the final document more strongly emphasise the global and international character of climate and resource challenges. Climate change is global in nature, requiring worldwide attention and solutions. Many solutions, which work at the local scale, are already being applied in many countries (recycling, wind energy etc.), but need to be conducted in a global context. EU and other industrialised countries / regions with well-established research capacities must take responsibility for research into the means of climate mitigation and adaptation, also for those parts of the world with less-developed research facilities.

To tackle the global problem of climate change, there is a general need to carry out research and find solutions in coordination with emerging economies, where funds for climate-related research are scarce, and where potentially large demands on resource supply can be anticipated in the immediate future. Such worldwide collaboration is necessary to guarantee that a European solution, which ensures our own continued access to natural resources, does not hamper development elsewhere. At the same time, this offers an opportunity to learn about values and methods developed in those cultures that could be of help to societies in Europe. An obvious example is building styles adapted to hot, dry weather. The EU can also make a strong contribution to developing countries, such as Africa, concerning adaptation, by providing access to knowledge about climate change and its impacts.

In addition, many areas that play a central role in the functioning of the global climate system (Arctic, tropics, deep oceans, marine coastal upwelling regions etc.) are situated outside the political borders of the EU. Research into the impact of climate change on these areas must be conducted regardless of specific location.

Several of these key areas are located in our immediate geographical neighbourhood, many of which can be regarded as "pristine". Of these areas, especially the Arctic and subarctic terrestrial and marine ecosystems are experiencing rapid climate changes as a consequence of environmental problems created elsewhere, not

[1] Interdisciplinary research refers to studies that integrate different disciplinary perspectives (ideally including natural and social sciences), while transdisciplinary research focuses on simultaneously including non-scientific knowledge and user-needs into the study. For example, articulating the research questions together with major stakeholders in the problem constitutes a transdisciplinary or participatory research approach.

least in the EU. In addition to degradation of the intrinsic value of these ecosystems, the environmental impact on these areas has important consequences for e.g. the supply of natural resources to Europe. Research into the dynamics and climate change impacts of these regions should be a primary focus.

TECHNOLOGIES AND PRIORITIES

There is general agreement among the responses from the scientists canvassed here that priority number one in climate-related research is the integration of climate change and other resource limitations in all aspects of societal decision making.

The scientific understanding of human impacts on the climate system is already more than sufficient to initiate political action designed to equitably share all climate-related resources, thus leading to a general adaptation of our individual and collective behav-iour where necessary. This needs to be supported by a better understanding of societal values and their roles in enhancing or preventing societal transformation.

In addition, a number of other critical research issues associated with different levels of the knowledge tower presented in the previous section were also identified. These follow (no priority in importance is implied by the order of presentation):

BETTER UNDERSTANDING OF MECHANISMS AND INTERACTIONS IN THE EARTH SYSTEM, INCLUDING THE CLIMATE SYSTEM.

The main focus of the suggested research areas in the draft Horizon 2020 is on the development of future climate predictions, adequate for regional applications. However, the improvement of such predictions requires continued research aimed at furthering our understanding of the complexities in the underlying Earth and climate systems at many different temporal and spatial scales. This important research should, of course, be continued as long as new knowledge is to be gained. Main research areas include:

- Research into mechanisms behind climate change and their interactions on spatial and temporal scales, in particular using the past;

- Research into the hydrological cycle and its interaction with the Earth system;

- Assessment of vulnerability to climate change of specific ecosystems and societies; and

- Better understanding of the interactive role of biological processes of the climate system and their responses to climate change.

This includes responses of biodiversity. One effect of globalisation is the drastically improved dispersal possibilities for species, which will affect the response of biodiversity in diverse, non-uniform ways.

ESTABLISHMENT OF BASELINE INFORMATION AND MONITORING OF IMPACTS

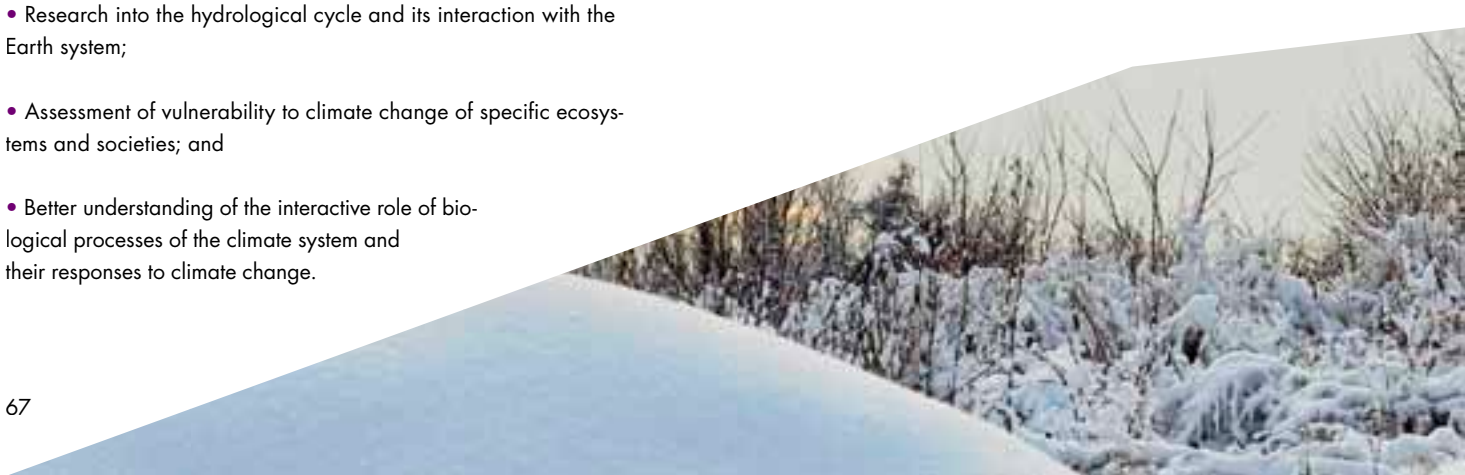
There is an urgent need for long-term observations to provide baseline information on the current status of the functioning of our planet and its ecosystems, especially those ecosystems still deemed "pristine." A natural system is forever changing, and the main question is how much change an ecosystem can take before it becomes unbalanced. Knowledge on baseline and natural variability is a prerequisite for the following research areas:

- Improvement of our understanding of the functioning and interactions of different ecosystems (including components, processes, biodiversity and services) and their interactions with human society;

- Improving the predictive capability of climate models, ecosystem models, and resourceuse models by systematically combining models with observations through advanced data assimilation methods. Baseline information is a necessity for making informed models and predictions concerning the human impacts on the global climate system, our society, and consequently also the European community and economy;

- Assessment of the severity of impacts on ecosystems caused by current climate change. Special attention should be made to the impact on biodiversity. Contrary to most other resources, this important resource is not recyclable. When a species has gone extinct, it is lost forever. Yet, not only do we depend on biodiversity, it may also hold important answers on how to minimise future impacts of climate change, how to treat diseases and how to create new resource opportunities. Extra care must therefore be taken to preserve this resource;

- Monitoring of impacts to identify trends that need to be considered by policy-makers, thereby providing early warning indicators for anticipated feedback processes and impacts that are expected to develop in the future (ocean acidification etc.);



• Research is also needed into the preservation of wilderness areas in Europe, restoration of such areas, and their importance for conserving valuable ecosystems and biodiversity. These regions represent a form of natural resource capital that, ideally, should be passed to future generations; and

• As mentioned in the draft of Horizon 2020, a coordinated data-gathering network is needed to provide comprehensive long-term observations of climate and ecosystems, and monitors the climate impacts on ecosystems. Several such networks are already established, but more are needed. In particular, these networks must cover the high latitudes areas, where ecosystems are experiencing very rapid changes. The information gained must be easily usable and readily accessible by a wide scientific community.

UNDERSTANDING UNCERTAINTIES IN THE PREDICTION OF FUTURE CLIMATE CHANGE AND ITS ECOSYSTEM CONSEQUENCES

Models constitute important instruments to predict future consequences of global change. Reducing the uncertainty of model predictions and assessing the robustness of model outcomes essentially relies on the improved understanding of climate, ecosystem, and resource management mechanisms due to, for example, process studies and advanced data assimilation methods between models and observations. Thus, the improvement of model predictions draws heavily on progress made in the two previously mentioned research areas.

It is an important and necessary element of especially climate research to improve our understanding of climate change and use this knowledge to improve the climate models, hence providing more accurate future climate projections (see above). However, climate models can never provide forecasts with the degree of certainty and detail that nonclimate researchers expect or need. People are mainly concerned about local impacts of climate extremes, which is the aspect that is most difficult to quantify. A detailed prediction of, for example, extreme weather events, and especially the interactions of these events with sea level rise (e.g. high storm tides), may be beyond scope. However, the accuracy of the predictions can at some point probably be estimated more realistically than is possible today. Climate and ecosystem model analyses must be understood in terms of uncertainties, and efforts must be made to ensure the proper communication of these uncertainties to policymakers and the public. In addition, changes tend to become essential to ecosystems, as well as societal and economic systems, only beyond a certain level of change. Decision makers might profit significantly by scientists' ability to constrain this level well, as this can translate into time left for action.

Main research areas include:

• Reducing model uncertainties by statistical comparison of model outputs;

• Increasing the spatial resolution of models and improving the representation of processes;

• Studies of predictability on a decadal timescale as well as predictability limits for highrisk and high-uncertainty events. These must be followed by strategies for decision making in case of their occurrence;

• Constraining critical levels of change;

• New approaches to modelling biological processes in ecosystem models; and

• Including more advanced societal and economic models in future climate prediction models.

Access to large supercomputing facilities is needed for running the level of complex models required for predicting future climate change and its impact on ecosystems. To obtain more reliable climate scenarios at smaller spatial scales, greater effort should be made regarding the development of supercomputing facilities for climate change research (i.e. the climate CERN described in the previous section). Future computer architectures will require new model development as well as training for the most efficient use of these. Increased open access to model results will be important for impact studies and to help develop services for climate adaptation.

DEVELOPING AND ACCESSING METHODS OF MITIGATING CLIMATE CHANGE AND RESOURCE SCARCITY

It is time to consider practical solutions aimed at mitigating the impacts of climate change and resource scarcity that are inevitable over the next decades. Identifying problems and solutions at all levels and scales that can be acted upon is important. Major research areas include:

- Quantification of resources available for human consumption. Researchers and policymakers in concert should accomplish this assessment and the goal must be to deliver as much of the natural resources intact to future generations as possible. This research must include the issue of global population levels;

- Research into the means and consequences of possible mitigation strategies;

- Development of eco-innovation technologies that can extract and use resources more efficiently than presently possible. Whether we can count on innovation to mitigate climate is an open question, but in any case eco-innovation must be encouraged;

- Designing recycling systems for key finite resources;

- Development of alternatives for resources where demand is approaching supply;

- Due to its non-recyclable nature, biodiversity deserves a special focus. Facilitation of the migration of species from valuable natural ecosystems may be an option; and

- Research into the most efficient ways of changing our shared behavioural patterns.

DEVELOPING COST-EFFICIENT ADAPTATION TO CLIMATE CHANGE

The development of new technologies and behavioural patterns are important means of mitigating climate change. However, there is also a need to develop adaptation strategies to cope with the changes that are inevitable, given the current level of human impact on the climate system. Research into the consequences of possible adaptation strategies is, therefore, also important.

While climate change is global, adaptation is essentially a local problem and tools that allow local decision makers to determine at what level of change natural systems and societies become vulnerable need to be developed. Adaptation strategies require the development of climate projections at spatial and temporal scales relevant for users (regional and decadal). They will also need to develop integrated approaches, combining climate, impacts, and vulnerability aspects, to be elaborated with users. Providing information and expertise relevant for adaptation is a challenge for research.

Main research areas relating to adaptation include:

- Constraining critical levels of change;

- Developing interdisciplinary approaches to integrate climate, impacts, and vulnerability approaches;

- Strengthening the ability of the impact community's research results to support decision making, for example through inter-comparison of impact models;

- Understanding how societies and ecosystems adapt to climate change, in particular using the past as well as experimental approaches;

- Developing co-construction approaches to adaptation with stakeholders;

- Understanding the interaction between mitigative and adaptive actions; and

- Understanding of the costs of adaptation, taking time scales into account.

RESEARCH ON THE UNEXPECTED

Much societal decision making is based on the assumption that change happens incrementally. However, there is increasing evidence that dramatic, nonlinear events can and do occur in all types of systems. Understanding and predicting such possible developments and installing early warning systems based on this understanding are essential, provided that society is equipped to deal with such abrupt changes. Preparing society for such events also requires research.

DEVELOPING NEW TECHNOLOGIES

New technologies will be essential for meeting the climate and resource challenge. There is already a growing global market for technologies that improve energy efficiency and replace fossil fuels. However, it is also anticipated that this market will expand to other types of resources. In addition to technologies devoted to improving resource efficiency, or replacing critical resources, the overarching challenge of developing sustainable societies necessitates that technologies being developed within the other challenges identified in Horizon 2020, and essential to meeting those challenges (i.e. new battery technologies, desalination etc.)) must be analysed for their impact on resource use before being widely introduced.

INSTRUMENTS AND IMPLEMENTATION

Much knowledge on approaches for transition to a sustainable society can be gained from experimenting with different practical solutions under different societal contexts. The complexity of, for example, climate change, along with the central role of societal values and behaviour for efficient climate action, implies that maintaining a dynamic and participatory approach is essential. Climate actions must be implemented, monitored, and subsequently evaluated in order to improve practice. This involves continuous processes of dialogue between researchers, stakeholders, decision makers, and society with the aim of changing our communal behaviour. Stakeholders must be heavily involved in the learning process based on the successes and failures from such conducted experiments.
The implementation of climate change action will require our society to grow a culture of climate, ecosystem, and resource-use responsibility, hence demanding extra efforts of researchers in areas of communication and education. The improvement of communication abilities and platforms between researchers, decision makers, and the public is important for progress towards a sustainable society. In particular, communication to stakeholders and policymakers of estimated uncertainties on – and accuracies of – scientific model predictions and associated future risks is a major issue. This is especially important as political and scientific considerations in concert should go into decisions regarding the desired extent of buffer zones around predicted future scenarios in order to account for model imperfections and unanticipated impacts. Improved quality of communication

will allow the acquired scientific knowledge to more easily be incorporated into political decisions, thus ensuring that these decisions be underpinned by scientific research.

Nevertheless, behavioural change will not come about simply as a consequence of more information when that change is not clearly in an individual's immediate selfinterest. Research shows that it is the values underlying the behaviour that need to be addressed, such as more intrinsic or selftranscendent values vs. more extrinsic or selfenhancing values. Research is needed to show how to manage a shift in focus from what we live on, to what we live for, in order to solve problems such as climate change, biodiversity loss, or inequity. Currently, there is a credibility crisis with respect to scientists, in general, and the advice being transmitted from the scientific community to policymakers, in particular. In some respects, this crisis is based on a misunderstanding of the role of scientists in policymaking. It is important to differentiate between research and policy decisions and this distinction between the two realms should be clearly emphasised in the final Horizons 2020 document.

Nevertheless, scientists can and should provide knowledge for informed decisions by policymakers, including the potential implications of different policy options. Another reason for the apparent loss of credibility in people's perception of scientists and their advice is the increasing dependence on third-party funding to carry out research. Potential dependence on interest groups can jeopardise the credibility of the messages scientists give to policymakers. Researchers should remain independent from short-term economic and political interests. Too-strong links with industrial or short-term economically successful research may endanger independent research and bias the selection of research direction. In view of the current volatile financial situation in the EU, it is important to have cost-effective research programmes that are robust in a changing economic environment.

Credibility also depends on the scientific community learning to critically reflect its own role in climate change and unsustainable behaviours. This addresses operational aspects, such as travel, meetings, paper, computer, and Internet use, as well as the values underlying their conventions and rituals. A set of criteria for sustainable research should be developed and its implementation made part of the selection criteria in Horizon 2020. It should then be made part of the contract for all research grants – not only in the climate field.

INNOVATION IMPACT

In the draft version of Horizon 2020, the general focus is on the prospect of immediate financial gain from technological developments relating to resource use. As noted above, it is likely that technologies and processes that lead to more efficient resource use, or relieve the pressure on critical natural resources (such as fossil fuels), will lead to economic gain in the short term. However, it is important not to focus solely on optimising 'the bottom (economic) line' on the short term without keeping overall long-term goals with respect to human society's use of natural resources insight. Superoptimising economic return in the short term can lead to enormous societal (economic and other) losses in the long term. The balance between short-term and long-term societal development should be brought more strongly to the fore in the document. Specifically, it should be emphasised that the overall goal of research within the field of climate action and resource utilisation must be to underpin the future development of society. It is time to recognise that research, through giving an understanding of systems as a whole, can help policymakers to understand the consequences at all levels of various political decisions and thereby contribute to bringing societal demand for natural resources to within the actual global supply of these resources.

The continued development of society is dependent upon the innovation of society as a whole in such a way that development acknowledges the limited nature of many essential natural resources. This innovation can be stimulated by the inclusion of the following mechanisms in Horizon 2020.

MECHANISMS ALLOWING AN INTEGRATED AND INTERNATIONAL APPROACH

Climate change and sustainable resource management must not be contemplated in isolation but should be considered central crosscutting issues embedded within each of the other societal challenges specified in the draft document Horizon 2020.

Research projects should be encouraged to engage with stakeholders to produce science which most efficiently can be made relevant for society. Additionally, incentives furthering cross-disciplinary, interdisciplinary, and transdisciplinary research, preferentially including both the natural and social sciences, must be introduced. A global and international approach must be encouraged and mechanisms supporting such an approach – for research as well as innovative applications – must be put in place. Strong coupling instruments are required to link the best disciplinary research groups with each other and enable seamless communication and synergies among them.

Processes involving continued dialogue with stakeholders, as well as the establishment of integrated and interdisciplinary research, are time consuming and such projects must, therefore, be allowed to run for an extended period of time.

MECHANISMS FOR IMPROVING COMMUNICATION

The common, human endeavour is to find a way of living within the means of the planet. Everybody must see themselves as stakeholders in the research that seeks to understand the problems of unsustainability and finding solutions. Scientists need to be visible and audible, and be encouraged to spend time giving knowledge to stakeholders, policymakers, and the public.

To be beneficial, good communication is a prerequisite for research in all areas. However, scientists may need support and appropriate training to be able to provide such good communication. Climate change has become a vehicle to carry forward the debate on a variety of aspects concerning global change and sustainability. This tendency of overload weakens the debate and causes it to be contradictory at times. It is important to ensure that climate change does not evolve from 'an inconvenient truth' into a convenient scapegoat for other human pressures.

Direct communication between climate scientists and politicians at the local, national, and global levels must be developed and encouraged.

In addition, the scientific evaluation criteria must be reconsidered for scientists to fully and actively engage in matters of informing the general public and politicians about climate change. Scientists should be given credit for engaging in the public debate and in the political processes, and not only be given credit for publishing in peer-reviewed literature.

Direct communication between climate scientists and politicians at the local, national, and global levels must be developed and encouraged.

In addition, the scientific evaluation criteria must be reconsidered for scientists to fully and actively engage in matters of informing the general public and politicians about climate change. Scientists should be given credit for engaging in the public debate and in the political processes, and not only be given credit for publishing in peer-reviewed literature.

MECHANISMS FOR PRACTICAL IMPLEMENTATION OF RESEARCH

Research with the potential to have a positive impact on society too often ends up not being implemented and, therefore, has no impact in practice. For scientific projects where there is a potential danger for this situation to occur, there should be a mechanism to follow up on the project to promote its practical implementation. Such implementation processes should be conducted in dialogue with stakeholders.

EXPLORING DIFFERENT AVENUES

This is a time where innovation is needed and different avenues must be explored. Innovation generally takes trial and error and efforts which do not immediately succeed. The funding agencies will have to take some calculated risks to allow this aspect of the research to succeed.

IMPACT STUDIES OF PREVIOUS EU RESEARCH PROGRAMMES

There is a need for detailed evaluation of the impact of previous EU research programmes on climate change to determine the efficacy of these in terms of policy and good practices.

ABSTRACT

The focus on 'inclusive, innovative and secure societies' provides a highly welcome challenge to the social sciences and humanities (SSH). This societal challenge is well justified not only because these qualities are particularly vital for future European society, but as importantly, because the *relationship* between these three characteristics is crucial and hitherto understudied. Inclusion, innovation and security are frequently studied by separate research communities (and similarly politically addressed independent of one another), but already existing research in these various fields support the premise that they are closely linked. Some links are based on synergies, where, say, inclusion and security are important conditions for innovation, or growth through innovation can enable further inclusion and security. At other points, tensions can be identified, e.g. when some forms of innovation or security potentially marginalise certain groups and thus reduce inclusion.

SOCIETIES

INCLUSIVE, INNOVATIVE AND SECURE

ABSTRACT CONTINUED

In reaction to the existing proposal of the Commission, the present report aims to show how it is possible to pursue a focused strategy more consistently and ambitiously. As currently presented, a considerable risk remains that this challenge of 'inclusive, innovative and secure societies' will become at best the three sub-challenges of 'inclusion', 'innovation' plus 'security', with the potential for further disintegrating into separate topics (calls). Integrating them demands carefully attending to the cross-cutting themes within this broad challenge (which de facto covers most of the social sciences and a good deal of the humanities, plus some informatics, etc.) as well as formulating some currently still absent linkages to other challenges.

The Horizon2020 proposal tries to achieve coherence and integration of the research agenda by narrowing the focus towards "hard" technologies, especially statistics, assessments and measures of efficiency (evidence-based lessons). It shows a corresponding tendency towards a somewhat technocratic definition of the nature of challenges (e.g. in the security part, critical infrastructure protection is prioritized over international politics). Indeed, inclusion-innovation-security *can* be viewed from a technocratic angle and the relevant form of knowledge be generated around data and efficiency assessments, but this represents a limited political and social vision that underestimates the power of citizens and communities to contribute to the realisation of inclusion, innovation and security.

Corresponding to a vision comprising a broader mobilisation of societal energies are forms of research that employ a wider selection of methodologies and theories to study the dynamics of society as productive and generative, rather than as the site of problems to be solved. Society must become the solution. Europe faces dramatic challenges that cut across established fields: creating cultures and mentalities of openness and innovation, reinventing the welfare-state, recreating politics and handling new lines of inequality and diversity within Europe. Research needs to go beyond technical questions to more controversial areas like global power shifts, sources of the economic crises and malaises affecting political participation, legitimation and self-steering. In such times of deep change, not all statistical relationships will remain stable, and European social knowledge therefore needs both improved databases and theoretical work. The social sciences and humanities can play key roles in relation to both the other five grand challenges and the significant ones, they have identified themselves. It is particularly important that researchers in the SSH engage scholars in the hard sciences in a joint effort to cultivate research-based innovation regarding the way expertise and democracy interact.

VISION

We share the vision of a reinvented European welfare state in a globalising learning economy. This requires Europe to position itself as a leader in promoting inclusiveness in numerous aspects of daily life, bringing innovation from the laboratory to society worldwide. As a result, Europe should work towards becoming a truly knowledge-based economy, cultivated by a creative attitude. Such openness to change is incompatible with both societal insecurity and with a form of security seeking that turns into defensiveness and fortress-building. An open and secure Europe can become a global hub in networks of newness.

Europe faces new global leaders – and a new power structure – in the globalised economy, notably China, India, and Brazil. Consequently, Europe must radically rethink its innovation and growth agenda, taking into account that new global powers and economies change the ways Europe competes, innovates, and grows. Europe faces a radical, structural change in the global knowledge economy and must be prepared to cope with the consequences.

Both in classical foreign policy and in the area of science, technology, and innovation policies, new policies for Europe have to be formulated with unrestrained, cleareyed attention to the depth of these changes. It is important to avoid newspeak such as talking in general terms about abstract changes, challenges and opportunities – for instance, in relation to rising powers in the global East and South. Only by concrete analysis of these shifts will it become possible to see the comparative advantages of Europe. For instance, the move away from dominance by the West opens new opportunities if analysed carefully. A decentred global power structure creates more room for an actor with historical connections, diplomatic skills, and reflexivity about one's own values and perspectives. These opportunities can only be realised, if research and social-scientific understanding are allowed to face the unpleasant aspects of the current sea-change, name names, and conduct research that does not emerge under calls phrased in technocratic terms. Societal changes necessarily demand research on highly political issues.

Innovation and creativity are essential to future societal growth, both economic and social. Creativity and innovation are meta-issues, as these capacities can be used to foster social innovation and promote inclusiveness. Innovation can contribute in important ways to economic growth as well as the resolution of societal problems, like security issues and problems of inclusion. Shaping a climate conducive to this is a complex challenge, where many different disciplines and fields of study hold partial insights, and policies in many different fields – from education to foreign trade policy – interact.

Such work demands on the one hand that visions are formed with attention to real-world problems and on the other are informed by research results and theoretical understanding of the issues at hand. In the policy arena and in public debate, one may plead for a stronger disentanglement of normative visions from analytical information. A relevant and powerful research strategy for the EU would benefit from a clearer analysis of the main challenges and recent changes in general conditions for societal development. Four issues should be stressed here: (1) the new global reconfiguration of power and its dynamism; (2) the financial and economic crises; (3) the transformative power of emerging technologies; and (4) the necessity of handling crosscutting dynamics in relation to the other five challenges in this report. All four issues make it important to rethink and research how innovation, inclusion and security interact. Research in the social sciences and humanities can contribute to the political, economic, and civic development of European welfare states by challenging established ways of defining the tasks that often reflect the conditions of preceding periods.

The **main messages** that have emerged from the process are:

• The social sciences and humanities (SSH) have a dual contribution to make to Horizon 2020. The previous chapters clearly show how SSH research plays an important role in solving the other five societal challenges. The necessary cooperation in these areas raises new challenges for both natural sciences and SSH. However, it is equally important that genuine SSH research has identified dramatic societal challenges in its own right. The SSH should be supported in both forms. If seen solely in its first-mentioned role, the SSH risks being reduced to social-engineering and behaviour-manipulation – for instance, how to make people receptive to health campaigns or get policymakers to agree on climate deals. There is an equal need to analyse issues where the end, and not only the means fall within the realm of SSH research, e.g. what models of a welfare state are viable under contemporary conditions, what barriers exist to innovation in Europe, and how Europeans today enact politics when classical participation declines. Conversely, it is important to be aware of the significant contributions of the natural and medical sciences to solving problems defined by the SSH.

• In relation to the five other societal challenges, SSH scholars have a special obligation to critically investigate and foster reflections on questions like: how did we get to these questions? A major contribution of the SSH over the last two centuries has been that data are no longer viewed as objective, but as intersubjective.

Data are given meaning in discourses, which can be national, sector-specific or disciplinary. The EU builds on this reflexive awareness by translating findings among national discourses. We need to know more about the mechanisms that make such translations among nations, domains, and paradigms productive.

• European societies are in rapid transformation. This may change previous patterns and thereby upset established correlations. We therefore not only need statistical data and evidence-based lessons, but, equally so, conceptual and theoretical work on deep shifts in the dynamics of societies. Empirical indicators should be theoretically informed and connected to research questions, rather than to bureaucratic agendas. Production of Europe-wide datasets is important and highly promising. Much more work needs to go into getting this right, as premature lock-in can constrain future research.

• This is no time for business as usual. Basic questions, that might have been taken to be answered in the past, are reopened. In a global knowledge economy, characterised by deep changes in the international division of labour and a decreasing role of states in general, why is a European level needed at all? Economies, politics, and research do not follow state boundaries. In trans-governmental networks, Europe can play a crucial role, but not for the old reasons. A timely understanding is needed to determine what it means to thrive in new forms of networks. Concretely, research programmes should be more open to non-European participants. Quality and innovation can only be achieved by cooperating with the best in any given field. 'European research' should not mean research inside a European boundary, but Europe-centred and initiated networks.

• The international dimension has to be brought back in through specific analyses of an emerging world order. Rather than abstract formulations (avoiding dangers, achieving cooperation), research should be guided towards locating specific challenges in the global constellation, with a willingness to analyse powers and actors concretely and by name (e.g. the rise of China).

Attention should be given especially to analysing and operationalising specific forms of cooperation that emerge in the era of global power dispersion and non-western powers.

• Similarly, current economic woes need to be addressed squarely. Europe faces severe economic difficulties of strong social and political import. Serious attention needs be devoted to understanding the sources, nature, and shape of these crises. Europe is not served by following the widespread fashion of only talking about 'opportunities' and 'challenges' when research actually can help by investigating the causes of serious problems if allowed to use 'negative' designations, also in specific research calls;

• Among the many important cross-linkages to the five other societal challenges are: how health both supports and is furthered by inclusion and innovation (and security, in a wide sense of the word); the centrality of transport and energy as infrastructures that condition the achievement of inclusive, innovative, and secure societies; and the importance of thinking climate sustainability thoroughly into all technological developments in society.

• But most strongly, the whole innovation theme is a meta-issue that reappears numerous times in the other challenges, because innovation in research, technology, and usage is both discussed specifically, sector by sector, for the other challenges, and generally, as an undertaking of societal evolution in the present challenge. It will be crucial to connect and contrast knowledge about innovation that emerges 'bottom up' from specific fields with more generic innovation research to both optimise specific procedures in research and development and to adjust society in ways that generally foster innovation. Ultimately, the challenge is how to be innovative about innovation.

• Protecting epistemological pluralism, the scientific equivalent of bio-diversity, can strengthen the robustness of results towards social changes. Funding multiple (sometimes smaller) projects is often better than huge grants to those 'safe' projects that all reviewers support. Real innovation and scientific progress typically arrive in processes that also allow failures; only they generate big winners that are really new. 'No risk' strategies are counter-productive.

• Evaluation criteria and processes must be adjusted to secure multi-disciplinarity. General principles only get translated into actual projects if concrete scoring systems for evaluation overcome the documented structural bias against inter-disciplinarity. Since this has to be done in a manner that ensures quality and academic standards, innovative assessment systems have to be designed.

• Open calls, and calls with different degrees of specification, should be included. Detailed specification of calls overreaches the ability to predict the future. When new developments like the Arab Spring occur during an FP period, it should be possible to initiate research.

• Improved framework conditions – as now promised – have to be defended against predictable attempts to strengthen control systems. High quality should be the main criteria. Increased simplification and trust in researchers and academic institutions are needed. Results matter more than multiple indicators and deliverables.

• Innovation can be achieved by embedding the 'problem definition' with societal actors, citizens, and communities – not limited to the top-down agendas of policymakers and business elites.

NEEDS AND SOLUTIONS

The Horizon 2020 proposal identifies important societal challenges, to which the social sciences and humanities can contribute. At this point, the structure of the proposal – separating innovation, inclusion and security – blocks the view to even larger challenges that cut across these issues. Some of the more pressing are:

• **Cultures of innovation and openness need cultivation at many layers from individual to European.** Europe often produces *inventions*, but misses out in *innovation* phases, either of commercialisation or uptake by users, consumers, and citizens. Psychologists have identified a general culture or attitude of defensiveness and the cultivation of a more open, transformational attitude as a way of being is a complex, many-layered challenge for Europe. Large investments in knowledge generation do not lead automatically to economic growth, because barriers to commercialising research may exist. Knowledge-intensive entrepreneurship particulary of SMEs represents an effective transformative mechanism that can break old barriers and convert new knowledge into economic activity. Furthermore, Europe has to foster demand-led innovation. An increase in demand-led innovation means involving industrial users, consumers and clients more in the innovation process and increasing the role that they play in stimulating innovations and new ideas. This could contribute to realising the enormous potential European researchers have by providing clearly defined societal goals and an efficient cooperation platform to facilitate exchanges and collaboration. However, the variety in demand articulation requires that the demand for knowledge not be left to private industry and/or government agencies as macro-actors, but be democratised and diversified further. A rhetoric of 'readiness for change' has been around for years, happily embraced by leaders in business and politics, but rarely has this been taken as an opportunity for scientifically based stuctural adjustment and more often as an opportunity to moralise. Scientific knowledge already goes far beyond the slogans of pundits and management gurus; but insights have to be integrated from far more disciplines than hitherto achieved. Comparative case studies would help to identify barriers and solutions. Variations among sectors, regions, and company structures are among the important variables where Europe's diversity can be better exploited as providing a laboratory. The Chinese technocratic regime runs whole regions as tests. For many reasons, this will likely not be the European way, but existing variations can be much better used as sources of information and learning.

• **The welfare state must be reinvented.** It is a basic European characteristic and for many: a key value. But the present crisis has shown that the current European growth model is not sustainable. Taking into account the seriousness of recent crises in financial capitalism and the fact that economies increasingly are driven by financial market concerns such as the debt crises and the Euro, the political and economic causes of, not only the crises as such, but also the increasing socio-economic inequalities and tensions along lines of class, geography, ethnicity, gender and generation need to be addressed. Reform of existing welfare and social-security arrangements will necessarily produce winners and losers on a grand scale. Analyses therefore have to go beyond the technical – to a broader examination of interconnected social, economic, and political alterations. Many disciplines, from economic history and comparative institutionalism to macro-sociology, can enrich the understanding of options and constraints. A general restructuring of rights and duties is on the agenda, and could easily amount to a general rethinking of 'labour'. The comprehensiveness of this challenge makes it mandatory that it be examined in interdisciplinary and innovative teams, not only across many disciplines within the SSH but also taking into account the numerous links to the other five panels.

• **Politics is being recreated in new forms.** Throughout Europe, political participation has waned and mistrust to political institutions and elites is prevalent. If locked into currently dominant images of politics, politics seems to disappear. Confronted with the financial crisis, some member states even move to technocratic cabinets, and citizens wonder about national sovereignty, vis-à-vis demands from international political organs, impersonal 'markets,' and transnational agencies. Yet, simultaneously new forms of involvement and political judgement occur for instance in social media; and collective self-monitoring and steering takes place in networks and expert systems, where contestation and deliberation is performed but not in forms normally recognised as legitimate. This research challenge too is multi-dimensional, because we need to get back to basic "components" of politics such as: participation, legitimacy, contestation, and collective governance – both rethinking and experimenting with new ways to enact these. Tensions increase between national and European governance and global economic, political, and civic processes. The social sciences, as well as public policy,

tend to be caught at the national level. Dynamics impacting inclusion, innovation, and security cut across national, regional, Europe-wide, global, and other levels in new ways, and societal strategies have to be open to the repositioning of instruments up and down the scale – or sideways to new formats. A particular challenge regards the relation between knowledge and democracy – how to make politics knowledgeable and knowledge responsive and responsible.

• **Divergency and Diversity are redefining European Unity.** Consequences of the European crises are far from equally distributed in geographic or social terms. New, core-periphery patterns are forming in Europe with changing connotations of both "North-South" and "East-West". The standard formula of 'unity in diversity' is under pressure. The question is what now unites? Inclusiveness means reducing regional disparities within and among the member states and regions of the EU. Being an inclusive society also means having a greater level of tolerance in terms of culture and income, not to mention avoiding the emergence of ghettos and other disadvantaged areas. Inclusiveness and a resilient society mean greater learning, but the financial and institutional conditions necessary to promote more learning are currently absent in many regions and especially in rural communities. Relationships with neighbouring countries are significant and therefore a decline in national and European peripheries should be avoided. Geographical considerations should be an integral part of every policy field, not added as an afterthought separately on regions. A vision of a better Europe includes all citizens having command over the resources necessary to develop their lives according to their interests and values. This requires less inequality than is currently the case and perhaps, most importantly, that everyone has access to a job to earn a living. One essential element is that all children be given a good start to develop their inborn capacities in primary, secondary and if possible tertiary education. Recent research in these key areas has come up with quite clear conclusions in individual fields that are often very poorly integrated into society-wide strategies and analyses. Future research has to be organised in ways that avoid disconnecting more 'micro' and local knowledge about, e.g. inclusion, equality, and education from macro conceptions of general processes.

• **Analyses and policies need to be international.** The international level seems marginalised, still, in the current version of the document. Europe's role as a global actor appears misplaced; covered solely under the heading, 'inclusion'. Bringing out explicitly how there is an international dimension to all three challenges would be innovative. Particularly pressing is to get the international back into analysis of security policy. Section 6.3 in the Commission's proposal is predominantly oriented towards security in the form of critical infrastructure protection and resilience (6.3.1 and 6.3.4), which indicates a focus on strengthening of Europe's own structures irrespective of the sources of threats and risks, i.e. looking inwards for security. The only threats specifically hinted at are those associated with border management and cyber-security, which carries the risk of indirectly castigating non-European migrants as the main source of insecurity. By not mentioning causes in the section on crime and terrorism, the proposal forfeits an opportunity to shape the future. Notably, a proper security policy at the international level will be crucial in influencing the amount of future problems (including terrorism). Solely focusing on self-solidification by making Europe's own systems and societies more resilient is too defeatist and self-defeating – here, international analysis should be the key to formulating effective policies for security.

This international example illustrates our general argument that research into sources of challenges and thereby into general economic, social, and political transformation – which often demands more abstract theory – is needed to understand the conditions for inclusion, innovation, and security. Research contributes to solutions in these areas both by relatively concrete instruments and practices and, very often, by designating areas that need more political attention because they cause exclusion, stagnation, or insecurity.

TECHNOLOGIES AND PRIORITIES

As shown in other parts of this rapport, necessary technologies often exist but implementation is impeded in both industry and a broader public by political and social issues. Here SSH can contribute to handling other societal challenges by entering into cooperation with researchers in the 'hard' sciences. Creativity and innovation are fundamentally needed for all societal change. Scientific-technological innovation can no longer be considered an exogenous variable, but these black boxes can be opened in terms of the contents of patents and publications. The relationship between academia and industry, for example, may in different fields be most functional at the national, micro-regional, macro-regional, and/or trans-regional level.

Technology is important but different fields and regions require different types of technology and have different needs. CEE countries, for example, are suffering from an informational and technological divide and also from poorer accessibility to international datasets, networks, etc. Isolation due to language barriers must also be decreased.

As noted above, social sciences and humanistic knowledge is often closely connected to nation-states. This challenges comparative and cross-regional research. Initiatives like the ESS (European Social Survey) and EVS (European Values Study) provide European research data from surveys, but in many fields access to empirical data from other regions and countries is limited. To enable social

scientists to go beyond the borders of their national statistics and address border-crossing issues concerning innovation, inclusion, and security production, access to empirical data concerning a wide range of social scientific and humanistic issues should be underpinned through a common, European data strategy.

Few, if any, would dismiss the importance of technology in setting the scene for an integrated European research area as well as for the way the social sciences and humanities relate to society and political processes. To also serve a social purpose, technology should be linked to the advancement of civic education projects designed to further involvement of citizens. New technologies can provide new opportunities in the collection of empirical material about current transformations and it can also be utilised to develop new ways of disseminating knowledge and entering into public discussion for the SSH.

A necessary element of "inclusive, innovative and secure societies" is to give scholars the opportunity to develop their methodologies (which can be based on new technology) in order to produce new research results. Researchers should explicitly acknowledge and analyse the tensions between conflicting aims and principles. SSH research holds the potential to expose the hard tradeoffs, policy dilemmas, and both intended and unintended effects of existing and proposed policies.

Technologies and methodologies should be developed in some areas with the explicit understanding that they function as a road to reflexivity at the European level. Issues such as inclusion, creativity, and the increased attention paid in the security field to emergency management point to the need to clarify how these guiding categories are produced and negotiated. There is clearly strong variation across Europe in terms of what forms of inclusion are emphasised, what counts as creativity, and what the threshold is for defining emergencies. An important role for the social sciences and humanities is generally to foster self-reflection on processes of this nature, but in the case of Europe there is an added need to Europeanise this reflexivity to clarify how the constant negotiation of powerful categories is increasingly a negotiation at the European level. An important – and novel – research agenda concerns the interaction between the capacity for communication/translation among subsystems (such as science and the economy, intelligence agencies and parliaments) and among nations.

INSTRUMENTS AND IMPLEMENTATION

Careful attention to the involvement of stakeholders in research should be attended to closely from the start; for example, to the actors who play a relevant role in an innovation system and those who could be included in a policy framework. This in turn will also

lead to identification of the most appropriate policy instruments. New indicators and new metrics need to support implementation and policies. Efforts should be devoted to launch indicators that are more in tune with innovation in a knowledge-based society. These must take into account that a knowledge-based system tends to operate in terms of uncertainties and expectations, differently than that of a classical political economy. The dynamics are more footloose and less embedded, but models of anticipatory systems, e.g. simulations, can help to expose the various dynamics of expectations.

While innovation in one sense is ultimately boundary-less, it typically works so that some aspects of an innovation can be directly implemented in real life and are directly useful to society. Sometimes researchers fail to acknowledge the feasibility aspect of their innovation. On the other hand stakeholders are often not interested in scientific results, per se; therefore, a crucial task in research and innovation policy is to convince stakeholders, at various levels and in various sectors, about the opportunities of knowledge-intensive governance. A key factor shaping relations between practice and research is what culture and attitude around science and knowledge, the government, and political elites convey.

Research, however, should go beyond government and industry, cultivating links to social movements, NGOs, and representatives of civic society in order to find the most viable solutions. Strong norms raise doubts about research critical to the establishment, which is seen as critical and political, while useful expert knowledge produced for the establishment is viewed as normal and non-political.

The ambition in Horizon 2020 to support and promote excellent research with a social impact with contributions from various disciplines should be reflected in the evaluation criteria and processes.

On a practical level Horizon 2020 can contribute to the development of a new way of cooperating, for example by supporting collaborative research, particularly in fields where sharing equipment due to financial constraints is not necessary (as it is in parts of the natural and medical sciences, where consequently cooperation is more easily fostered). Doing comparative research and confronting different methodologies, references, and repertories with each other, are necessary, but the amount of national funding available for this kind of research is often limited. In other words, relying on national funding alone would most likely restrict collaborative research to the domain of wealthier European countries and institutions. Maintaining a high level of excellence and staying focused on targeted scientific objectives means that the size of research networks must be adapted to suit the objectives. In practice, small and medium-sized projects guarantee excellence and quality results. Encouraging the early setup of networks is productive to developing strong scientific collaborations, especially as certain fields in the social science and humanities community are still quite fragmented. Funding social platforms also seems to be a good approach for involving stakeholders in defining research agendas.

Specific research funding instruments can be developed to optimise the benefits from the fact that 'societal challenges' research often happens at the intersection of policy-oriented expertise and academic knowledge anchored in university departments. If the distinct social roles and internal dynamics of these communities are recognised – and mutually respected – it is possible to optimise procedures, deliverables, and funding regimes for the purpose of getting the two (here ideal-typically categorised) communities to challenge each other in helpful ways.

In selecting problems and research areas it is important to keep in mind that innovative research and activity grow from the bottom up. High-level research should be promoted in all areas – including the social sciences and humanities – without red tape that requires milestones and deliverables in advance. The outcome of frontier research is inherently unknown. It should not be deduced from the existence of separate excellence programs like ERC, that research targeted at the six societal challenges will not be frontier research. As argued by 'mode 2' and 'triple helix' literatures, old conceptions of basic and applied research have been overtaken by a new situation, where often frontier research happens 'in the context of application'. Identifying with precision all of the needs and potentials of European research in advance is impossible, but articulating what they might be is an ambition worth pursuing. Thus, finding a way to give scholars the opportunity to communicate research priorities with reference to an ever-changing world is important. One option is to devote part of the funds for open calls for proposals within the framework of collaborative research. Given the existence of 'fully open' calls under ERC, closing the gap might be achieved through scaling, where some calls within each grand societal challenge are more specified, and others are at a higher level of generalisation, allowing for not-yet-defined agendas to emerge and be pursued. This would be an innovation compared to previous FPs, where the procedure has been to subdivide and subdivide to a certain, but relatively consistent degree of specification. Premature lock-in can be avoided by supplementing this with more general, open and competitive calls covering a large part of the theme.

INNOVATION IMPACT

The key to adopting innovation is an educated public with an open attitude, willing and able to try and explore new approaches. This involves both education that fosters an appreciation of change and creativity and the transmission of innovative ideas as a social goal.

Horizon 2020, with its emphasis on the importance of inclusion-innovation-security, has the potential to help the SSH to contribute to strengthening European societies. Innovation impact in these fields has to be conceived in relation to a wide range of actors and structures in society.

To adopt innovative practises in the way societal actors compete and cooperate to achieve inclusion, innovation, and security, it is necessary to both generate societal knowledge about the changing nature of these social 'values' – inclusion, innovation, and security are not stable goals, but change their meaning and form under new conditions – and to make it relevant to especially those actors who shape processes and conditions for others. The possibilities for this are conditioned by the change, pointed to above, in the relationship between citizens and governing institutions. Also, the nature of collective self-reflection and self-organisation in Western societies is undergoing dramatic change, and for *research on* innovation, inclusion, and security to have innovative impact on *actual* innovation, inclusion and security, it is crucial to update institutional arrangements. These are big and obviously controversial issues, because the specific questions of science policy raise questions about 'democratising expertise' and 'expertising democracy' that unavoidably tie into more general questions about possible innovations for democracy about reflexive and knowledge-based governance. These are challenges both at the level of the nation-states and for the EU.

In relation to the market and growth, promoting diffusion by identifying the relevant actors and networks of knowledge and promoting inter-organisational networks of learning will be useful. Opening up the potentials of a knowledge-based economy, however, demands a diffusion of action driven more by imagination and less by finite optimisation. A further democratisation of the demand for innovation may help to break the oligopoly of global players on knowledge markets. Emerging technologies provide opportunities for the implementation of new and better-informed arrangements at different levels of aggregation.

Entrusting the dissemination and exploitation of results to experts in dissemination is probably a way to shorten the path from research to the benefit of citizens. The scientific coordinator of a research project is not necessarily the best actor for promoting ideas on these issues or for managing this type of work. A solution could consist of developing dedicated calls for proposals to fund support projects on the dissemination and exploitation of research projects. Furthermore, open access to data and findings is crucial to facilitating wide access to research results by all kinds of communities and has to be strongly supported and developed.

Innovation has been around as a slogan long enough that there is a risk of taking a static understanding of it. But both the nature and conditions of innovation are constantly changing, and many different fields within the social sciences and humanities contribute to our understanding hereof. It is therefore highly appropriate that the last section of the last challenge directs the question of 'innovation impact' at the field of innovation. A key task for Europe is to become innovative about innovation, and the social sciences and humanities have important contributions to make, especially when innovation is analysed in association with inclusion and security.

Framework conditions for research

Horizon 2020 provides the framework for solving some of the major societal challenges Europe faces. The focus of this report is the research foundation, pathways, and contributions necessary to solve those challenges. While analysing which research is needed and how it should be prioritised, issues regarding the organisational conditions under which the research is to be carried out must also be considered. One recurring issue is the need for simplifying the Framework Programme, but other topics also arose concerning framework conditions for carrying out research in societal challenges. Some of the key findings are listed below.

AN OPEN PROGRAMME AND A GLOBAL CONTEXT
A global approach must be encouraged and mechanisms must be put into place to support an international approach for both research and innovative applications. Strong coupling instruments are required to link the best disciplinary research groups with each other to enable seamless communication and to promote synergies. Ideally the ability of researchers in the member states to collaborate should not be subject to restrictions in order to allow the most excellent minds to work together. Transnational cooperation should be strongly encouraged in Horizon 2020 and synergies between national programmes should be facilitated. Moreover, this collaboration should be set in a global context utilising the value of working in partnership with research communities around the world.

CROSS-DISCIPLINARITY
The pronounced need for multidisciplinary and crosscutting approaches, especially with regard to societal challenges, emphasises how essential it is to develop new and appropriate instruments without increasing the administrative burden. For this purpose the Commission may find useful models and concepts already implemented in member states, e.g. instruments for academia-industry collaboration that includes both research and innovation. Here, examples could be the Top Institute model (the Netherlands), the CTI model (Switzerland) and the recent SPIR model (Denmark) – and also concepts in the EIT/KIC initiative would be relevant.

Incentives furthering cross-disciplinary research, including both natural and social sciences, must be introduced. Researchers should be encouraged to engage with stake-holders to produce science, which most efficiently can be made relevant for society. Programmes and systems, particularly at universities, should be encouraged to achieve this. New entrepreneurial approaches at universities should be encouraged to foster connections between research centres and universities with problem solving approaches.

INCREASED INTERACTION – NETWORKING AND MOBILITY
Europe needs a strong new generation of researchers trained to tackle the different aspects of research. Critical in this training programme is cross-disciplinary and international mobility. The Marie Curie Actions is very important in this respect and should be sustained. The mobility of scientists, students among research institutions and industry should be reinforced and greater flexibility introduced in the existing schemes. Among others, a widely understood taxonomy for research careers across Europe will improve scientific cooperation.

STAKEHOLDER INVOLVEMENT
There is a need to improve the transfer of knowledge from research and science communities to commercial stakeholders and the general public. Therefore, the interaction among research centres, institutions, governmental bodies and industry must be further increased. Networking programmes that put together scientists and stakeholders must be renewed and implemented to promote the exchange of knowledge and to valorise research on national level. Stakeholders need to be involved, not only in terms of dissemination and impact, but at all stages of research. Stakeholders should include members of NGOs and the voluntary sector as well as representatives of government and industry. More flexible ways to involve stakeholders during the projects should be pursued. Research should always have the potential for surprise so the assessment criteria must always reward novelty and accept that all the potential impacts will not be known a priori. Openness between stakeholders should be encouraged and facilitated. Excessive secrecy and rights agreements as the first prerequisite for any collaboration are killing innovation. A condition for getting an activity funded should be that communication and the exchange of ideas be carried out in an open atmosphere. When the free exchange of information and ideas is achieved, the most interesting results are obtained. Patent policies should be reconsidered to motivate scientists to innovate. Intellectual property rights issues and success payment should be addressed on a European scale. More innovation and diffusion of research results can be achieved through better networking and stronger links between supply and demand.

STRONGER ROLE FOR UNIVERSITIES
The potential of university-based research and education needs to be mobilised, in terms of researchers, thousands of people remain an untapped resource. The research efforts of individual member states need to be better integrated and coordinated on a European level.

EDUCATION AND TRAINING
A major threat to European leadership in research resides in the decreasing attractiveness in several European countries of this field for students. Europe should improve its attractiveness by taking proactive decisions and promoting the training of students in experimental approaches and in data-based decision making very early at school as well as by leading a strong effort to propose attractive careers, research positions, and create career paths for young researchers. Efforts must also be made to develop an intense communication programme for researchers to present their results to the widest audience possible in all media. Efficient innovation and dissemination of results through integration in education should be encouraged. In addition, training in the development of research policy and agendas is also important.

SCIENTIFIC QUALITY AS THE MAIN SELECTION CRITERIA
The composition of research consortia should give higher priority to the quality of partners and focus less on political priorities. This would help to improve the quality of results. Innovations are necessary along the whole value chain from fundamental science and new technologies to new services and policy tools. The first two require a substantial research budget, while the latter two require completely new thinking and new approaches to the flow of innovation. Assuring the highest possible quality of the research is the most efficient basis. Guaranteeing high scientific qualifications of the coordinator and the PIs of all partners is also important in this context.

BOTTOM-UP RESEARCH
In selecting problems and research areas it is important to keep in mind that innovative research and activity grow from the bottom up. High-level research should be promoted in all areas without red tape that requires milestones and deliverables in advance. The outcome of frontier research is inherently unknown. It should not be deduced from the existence of separate excellence programmes, like ERC, that research targeted at the six societal challenges will not be frontier research. One option is to devote part of the funds for open ('white') calls for proposals within the framework of collaborative research. Given the existence of 'fully open' calls under ERC, closing the gap might be achieved through scaling, where some calls within each grand societal challenge are more specified and others are at a higher level of generalisation, allowing for not-yet-defined agendas to emerge and be pursued. Premature lock-in can be avoided by supplementing this with more general, open, and competitive calls covering a large part of the theme.

SUFFICIENT RESOURCES
Earmarking sufficient resources to each societal challenge is necessary in order to provide significant impact. Europe has all of the competences necessary to deal with the scientific issues and significant opportunities should be made available for all excellent researchers in Europe, while fostering creative competition. All the scientific areas in the challenges are of high importance and it is essential that all fields are well-covered by Horizon 2020, not only during the multiannual framework but also each year.

LONGER PROJECTS
If stakeholder involvement means that research projects become more complex, then larger projects need to be funded for longer time periods, preferably with 5-7 year grants/contracts instead of three-year projects. This would reduce the amount of time scientists spend on application writing.

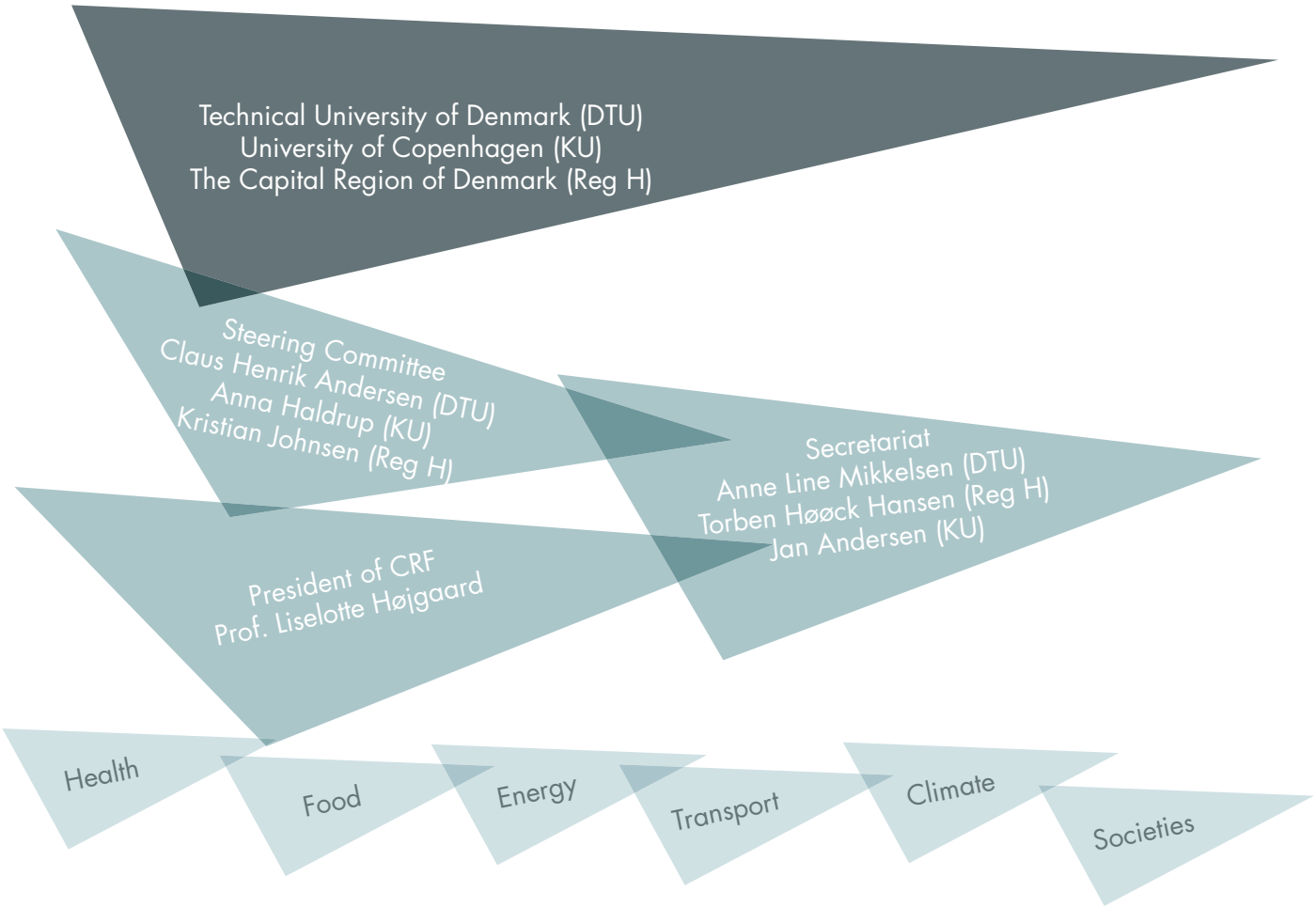
RESEARCH INFRASTRUCTURE
Research excellence requires outstanding research infrastructures that not only under-pin research but also lead its development and create an attractive climate for world-class researchers. Data collection and input need to be harmonised and more advanced IT tools are needed to connect databases. Furthermore, novel research methodology including new mathematic and statistical tools will be needed and the establishment of relevant facilities is required. There is encouraging progress for research infrastructure in Europe and the European Strategy Forum on Research Infrastructures (ESFRI) should be implemented. Securing further founding for the ESFRI project could be effectively linked to the Structural Funds.

OPEN ACCESS TO SCIENTIFIC PUBLICATIONS
A system of scientific publications with free access to all (published) information is needed. Open access could be provided through institutional repositories by the authors or by directly publishing in open-access journals with publishing costs paid by the author's institutions, their grants, or philanthropic support.

SIMPLIFICATION
Horizon 2020 should strive towards less structure and bureaucracy, more facilitation of meetings between peak performing competences and entrepreneurs, as well as support without too much filtering. There is a need for an alternative approach to the current suggested models, where the funding filtration mechanism is overly difficult and structured to the point that too much funding goes to the development of yet more structures. The good ideas for innovation are consequently lost along the way. To allow for the best minds to participate in EU-funded research, simplifying the financial and administrative rules is essential and could include e.g. a shorter time to contract, reduced administrative burdens and the acceptance of external auditors' approved methods of accountability. In view of the current volatile financial situation in the EU, it is also vital to have cost-effective research programmes that are adapted to a changing economic environment and to avoid duplicate research.

The Horizon 2020 proposal will simplify the rules for participation, including the abolition of time sheets for full-time staff. This is an important issue; however it should be extended to part-time workers. In health research a high proportion of researchers work part time, as they are physicians and researchers at the same time. The bureaucratic burden of the time sheets makes this funding less attractive, and "best practice" for NIH, MRC, and Welcome Trust should be consulted.

CRF organisational structure



Professor Liselotte Højgaard	Professor Peter Olesen	Dr Jørgen Kjems	Head of Department Niels Buus Kristensen	Professor Katherine Richardson	Professor Ole Wæver
Professor Deborah Smith	Director Kees de Gooijer	Professor Kjell Hugo Bendiksen	Programme Director Dr Christian Piehler	Professor Johan Rockström	Professor Loet Leydesdorff
Tine Willum Hansen	Anna Munck Laybourn	Nicolaj Tofte Brenneche	Claus Hedegaard Sørensen	Mai Winstrup	Kristoffer Kropp

References

An ESF Forward Look. Implementation of Medical Research in Clinical Practice, May 2011. http://www.esf.org/emrc

An ESF Forward Look. Investigator-Driven Clinical Trials, Marts 2009. http://www.esf.org/emrc

BECOTEPS (2011) The European Bioeconomy in 2030: Delivering Sustainable Growth by addressing the Grand Societal Challenges

Climate Estimates developed by PricewaterhouseCoopers for "sustainability-related global business opportunities in natural resources (including energy, forestry, food and agriculture, water and metals)"

COM (2007) 723: A European Strategic Energy Technology Plan (SET PLAN) – Towards a low carbon future.

COM (2010) 2020: Europe 2020 - A strategy for smart, sustainable and inclusive growth Europe 2020 Flagship Initiative

COM (2011) 112: A Roadmap for moving to a competitive low carbon economy in 2050.

COM (2011) 144 Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system

COM(2010) 187 Simplifying the implementation of the research Framework

COM(2010) 546 Innovation Union

Council of Europe 2002. Developing a Methodology for Drawing up Guidelines on Best Medical Practices. Recommendation

Rec(2001)13 and explanatory memorandum. Strasbourg.

Eco-innovation Observatory "The Eco-Innovation Challenge - Pathways to a resource-efficient Europe - Annual Report 2010", May 2011

EMRC White Paper II "A Stronger Biomedical Research for a Better European Future', September 2011". http://www.esf.org/emrc

ETP Food for Life, Strategic Research and Innovation Agenda (2011)

ETP Plants for the Future (2007) Strategic Research Agenda 2025, www.PlanTP.com

EU on the path to a resource and energy efficient economy, Study and briefing notes", March 2009

Eco-innovation - putting the Excellence with Impact – Facts and figures British Medical Council: www.rcuk.ac.uk/Publications/policy/framework/pages/FactsandFigures.aspx and www.rcuk.ac.uk/documents/framework/framework.pdf

FP7 Interim evaluation http://ec.europa.eu/research/evaluations/pdf/archive/other_reports_studies_and_documents/fp7_interim_evaluation_expert_group_report.pdf and

FP7 Interim evaluation http://ec.europa.eu/research/evaluations/pdf/archive/other_reports_studies_and_documents/commission_response_fp7_ie_report_2011.pdf

Glasziou P, Chalmers I, Rawlins M, McCulloch P. When are randomised trials unnecessary? Picking signal from noise. BMJ 2007; 334:349-351 www.arztbibliothek.de/mdb/edocs/pdf/literatur/coe-rec-2001-13.pdf

McCulloch P, Altman DG, Campbell WB et al. No surgical innovation without evaluation: the IDEAL recommendations. Lancet 2009; 374:1105-12

OECD Global Science Forum. Facilitating International Cooperation in Non-Commercial Clinical Trials, October 2011. www.oecd.org/dataoecd/31/8/49344626.pdf

Rawlins M. De testimonio: on the evidence for decisions about the use of therapeutic interventions. Lancet 2008; 372:2152-61

Sackett DL, Rosenberg WM, Gray JA et al. Evidence-based medicine: what it is and what it isn't. Clin Orthop Relat Res. 2007; 455:3-5

SCAR (2011) The 3rd SCAR Foresight Exercise; Sustainable food consumption and production in a resource-constrained world, Standing Committee on Agricultural Research (SCAR), February 2011 – and references therein.

Straus SE, Tetroe JM, Graham ID (2011) Knowledge translation is the use of knowledge in healthcare decision making. J Clin Epidemiol. 64:6-16

Thornton H. Patients and health professionals working together to improve clinical research: where are we going? European Journal of Cancer 2006; 42:2454-2458

WBCSD (2010) Vision 2050: The New Agenda for Business, World Business Council for Sustainable Development: Geneva, www.wbcsd.org/web/projects/BZrole/Vision2050-

White Paper 2008-13: "Together for Health: A Strategic Approach for the EU 2008-2013". http://ec.europa.eu/health-eu/doc/whitepaper_en.pdf

Database from Socio-Economic Research Projects for Policymaking, DG Research and Innovation, EUR 24822, 2011

European forward-looking activities: Building the future of 'Innovation Union' and ERA, Studies and Reports, EUR 24796, 2011

Security Research in the European Union: evaluation of the Seventh Framework Programme - reply to the annual report of the Council, Assembly of Western European Union, 59th session, Doc. A/2094, December 2010.

www.lindalliance.org

www.nice.org.uk

Participants

Family name	First name	Affiliation	Country
HEALTH			
Andersen	Peter Høngaard	H. Lundbeck A/S	Denmark
Armitage	Jane	University of Oxford	United Kingdom
Bisagni	Anne	INSERM	France
Draghia-Akli	Ruxandra	European Commission	Belgium
Hansen (2)	Tine	Rigshospitalet	Denmark
Højgaard (1)	Liselotte	Rigshospitalet	Denmark
Knowles	Jonathan	EPFL	Switzerland
Lidgren	Lars	Lund University	Sweden
Nutt	David	Imperial College London	United Kingdom
Pihlajaniemi	Taina	University of Oulu	Finland
Smith (1)	Deborah	University of York	United Kingdom
Toppari	Jorma	University of Turku	Finland
Ulfendahl	Mats	Swedish Research Council	Sweden
Vivier	Eric	Centre d'Immunologie de Marseille-Luminy	France
Wiestler	Otmar	University of Heidelberg	Germany
FOOD			
Darcy-Vrillon	Beatrice	INRA	France
De Gooijer (1)	Kees	Food & Nutrition Delta	The Netherlands
Elvevoll	Edel	University of Tromsø	Norway
Gellynck	Xavier	Ghent University	Belgium
Girona	Joan	IRTA	Spain
Gruissem	Wilhelm	ETH-Zurich- Plantbiotechnology	Switzerland
Hall	Timothy	European Commission	Belgium
Kampers	Frans	Wageningen UR	The Netherlands
Lange	Lene	Aalborg University	Denmark
Laybourn (2)	Anna Munck	The Danish Council for Strategic Research	Denmark
Olesen (1)	Peter	ActiFoods ApS	Denmark
Risvik	Einar	Nofima	Norway
Sonesson	Ulf	SIK - The Swedish Institute for Food and Biotechnology	Sweden
ENERGY			
Bendiksen (1)	Kjell H.	University of Oslo	Norway
Chwieduk	Dorota	Warsaw University of Technology Institute	Poland
Evans	Glyn	European Commission	Belgium
Fracastoro	Giovanni	Politecnico di Torino	Italy
Fransson	Torsten	KTH	Sweden
Hamacher	Thomas	Technische Universität München	Germany
Kjems (1)	Jørgen	DTU	Denmark
Linderoth	Søren	Technical University of Denmark	Denmark
Lund	Peter	Aalto University	Finland
Schuetz	Reinhard	Austrian Institute of Technology (AIT)	Austria
Tofte Brenneche (2)	Nicolaj	Copenhagen Business School	Denmark
TRANSPORT			
Banister	David	University of Oxford	United Kingdom
Blythe	Phil	Newcastle University	United Kingdom
Damiani	Alessandro	European Commission	Belgium
El Koursi	El Miloudi	Ifsttar	France
Folke	Snickars	KTH	Sweden
Fridstrøm	Lasse	TØI	Norway
Hansen	Ingo Arne	Delft University of Technology	The Netherlands
Kristensen (1)	Niels Buus	DTU	Denmark
Nash	Chris	Leeds University	United Kingdom
Piehler (1)	Christian	DLR	Germany
Polak	John	Imperial College London	United Kingdom
Psaraftis	Harilaos	Nat. Tech. Univ. of Athens	Greece
Sørensen (2)	Claus Hedegaard	DTU	Denmark
Van Dender	Kurt	International Transport Forum, OECD	France
Wegman	Fred	SWOV Institute for Road Safety Research	The Netherlands

Family name	First name	Affiliation	Country
CLIMATE			
De Boissezon	Birgit	European Commission	Belgium
Gattuso	Jean-Pierre	CNRS-Universite Pierre et Marie Curie	France
Jeholm (2)	Annette	University of Copenhagen	Denmark
Joussaume	Sylvie	CNRS/IPSL	France
Kromp-Kolb	Helga	BOKU University of Natural Ressources and Life Sciences	Austria
Leemans	Rik	Wageningen University	The Netherlands
Lenton	Tim	University of Exeter	United Kingdom
McGlade	Jacqueline	European Environment Agency	Denmark
Richardson (1)	Katherine	University of Copenhagen	Denmark
Rockström (1)	Johan	Stockholm Resilience Centre and Stockholm University	Sweden
Rosing	Minik	Natural History Museum, University of Copenhagen	Denmark
Santos	Filipe	Lisbon University	Portugal
Schellnhuber	Hans Joachim	Potsdam Institute for Climate Impact Research (PIK)	Germany
Thorhallsdottir	Thora Ellen	University of Iceland	Iceland
SOCIETIES			
Bader	Veit	University of Amsterdam	The Netherlands
Burgelman	Jean-Claude	European Commission	Belgium
Chryssochoou	Dimitris	Panteion University	Greece
Felthaus	Jimmy Bruun	Research and Innovation	Belgium
Guiraudon	Virginie	CEE (CNRS/Sciences Po)	France
Kropp (2)	Kristoffer	University of Copenhagen	Denmark
Laffan	Brigid	University College Dublin	Ireland
Leydesdorff (1)	Loet	University of Amsterdam	The Netherlands
Lubart	Todd	University of Paris	France
Wæver (1)	Ole	University of Copenhagen	Denmark
OFFICIALS AND REPRESENTATIVES			
Østergaard	Morten	Minister for Science, Innovation and Higher Education	Denmark
Hassel	Nina	Ministry of Science, Innovation and Higher Education	Denmark
Midtgaard	Thomas	Ministry of Science, Innovation and Higher Education	Denmark
Toudal Pedersen	Uffe	Ministry of Science, Innovation and Higher Education	Denmark
Bjarklev	Anders	DTU	Denmark
Bjørnholm	Thomas	University of Copenhagen	Denmark
Høgh	Kim	The Capital Region of Denmark	Denmark
Wegener	Henrik	DTU	Denmark
Andersen	Claus Henrik	DTU	Denmark
Haldrup	Anna	University of Copenhagen	Denmark
Johnsen	Kristian	The Capital Region of Denmark	Denmark
Andersen	Jan	University of Copenhagen	Denmark
Høøck Hansen	Torben	The Capital Region of Denmark	Denmark
Mikkelsen	Anne Line	DTU	Denmark
Wederking	Birgitte	CreoDk	Denmark

Panels

Family name	First name	Affiliation	Country
HEALTH			
Andersen	Peter Høngaard	H. Lundbeck A/S	Denmark
Armitage	Jane	University of Oxford	United Kingdom
Bisagni	Anne	INSERM	France
Giuseppe Pelicci	Pier	European Institute of Onclology	Italy
Hansen (2)	Tine	Rigshospitalet	Denmark
Højgaard (1)	Liselotte	Rigshospitalet	Denmark
Knowles	Jonathan	EPFL	Switzerland
Lidgren	Lars	Lund University	Sweden
Nutt	David	Imperial College London	United Kingdom
Pihlajaniemi	Taina	University of Oulu	Finland
Smith (1)	Deborah	University of York	United Kingdom
Smith	Ulf	Sahlgrenska University Hospital	Sweden
Syrota	André	INSERM	France
Toppari	Jorma	University of Turku	Finland
Ulfendahl	Mats	Swedish Research Council	Sweden
Vivier	Eric	Centre d'Immunologie de Marseille-Luminy	France
Wiestler	Otmar	University of Heidelberg	Germany
FOOD & AGRICULTURE			
Darcy-Vrillon	Beatrice	INRA	France
De Gooijer (1)	Kees	Food & Nutrition Delta	The Netherlands
Elvevoll	Edel	University of Tromsø	Norway
Gellynck	Xavier	Ghent University	Belgium
Girona	Joan	IRTA	Spain
Gruissem	Wilhelm	ETH-Zurich- Plantbiotechnology	Switzerland
Kampers	Frans	Wageningen UR	The Netherlands
Knorr	Dietrich	Technische Universität München	Germany
Lange	Lene	Aalborg University	Denmark
Laybourn (2)	Anna Munck	The Danish Council for Strategic Research	Denmark
Murcott	Anne	University of Nottingham	United Kingdom
Olesen (1)	Peter	ActiFoods ApS	Denmark
Risvik	Einar	Nofima	Norway
Sonesson	Ulf	SIK - The Swedish Institute for Food and Biotechnology	Sweden
ENERGY			
Bach	Brigitte	Energy Department, AIT, Wien	Austria
Bendiksen (1)	Kjell H.	University of Oslo	Norway
Bordonau	Joseph	CEA Saclay France	France
Borel	Corinne	UPC Barcelona	Spain
Chwieduk	Dorota	Warsaw University of Technology Institute	Poland
D'haeseleer	William	Leuven	Belgium
Fracastoro	Giovanni	Politecnico di Torino	Italy
Fransson	Torsten	KTH	Sweden
Hamacher	Thomas	Technische Universität München	Germany
Kjems (1)	Jørgen	DTU	Denmark
Linderoth	Søren	Technical University of Denmark	Denmark
Lund	Peter	Aalto University	Finland
Schuetz	Reinhard	Austrian Institute of Technology (AIT)	Austria
Tofte Brenneche (2)	Nicolaj	Copenhagen Business School	Denmark

Family name	First name	Affiliation	Country
TRANSPORT			
Banister	David	University of Oxford	United Kingdom
Blythe	Phil	Newcastle University	United Kingdom
El Koursi	El Miloudi	Ifsttar	France
Folke	Snickars	KTH	Sweden
Fridstrøm	Lasse	TØI	Norway
Giannopoulos	George	Hellenic Institute of Transport	Greece
Hansen	Ingo Arne	Delft University of Technology	The Netherlands
Kristensen (1)	Niels Buus	DTU	Denmark
Nash	Chris	Leeds University	United Kingdom
Piehler (1)	Christian	DLR	Germany
Polak	John	Imperial College London	United Kingdom
Psaraftis	Harilaos	Nat. Tech. Univ. of Athens	Greece
Sørensen (2)	Claus Hedegaard	DTU	Denmark
Van Dender	Kurt	International Transport Forum, OECD	France
Wegman	Fred	SWOV Institute for Road Safety Research	The Netherlands
CLIMATE & RESOURCES			
Dahl-Jensen	Dorthe	University of Copenhagen	Denmark
Duarte	Carlos M.	Mediterranean Institute for Advanced Studies	Spain
Gattuso	Jean-Pierre	CNRS-Universite Pierre et Marie Curie	France
Jeholm (2)	Annette	University of Copenhagen	Denmark
Joussaume	Sylvie	CNRS/IPSL	France
Kromp-Kolb	Helga	BOKU University of Natural Ressources and Life Sciences	Austria
Leemans	Rik	Wageningen University	The Netherlands
Lenton	Tim	University of Exeter	United Kingdom
McGlade	Jacqueline	European Environment Agency	Denmark
Richardson (1)	Katherine	University of Copenhagen	Denmark
Rockström (1)	Johan	Stockholm Resilience Centre and Stockholm University	Sweden
Rosing	Minik	Natural History Museum, University of Copenhagen	Denmark
Santos	Filipe	Lisbon University	Portugal
Scheffer	Marten	Wageningen University	The Netherlands
Schellnhuber	Hans Joachim	Potsdam Institute for Climate Impact Research (PIK)	Germany
Thorhallsdottir	Thora Ellen	University of Iceland	Iceland
Winding (2)	Mai	University of Copenhagen	Denmark
SOCIETIES			
Archibugi	Daniele	Italian National Research Council/University of London	Italy
Bader	Veit	University of Amsterdam	The Netherlands
Chryssochoou	Dimitris	Panteion University	Greece
Erikson	Robert	Stockholm University	Sweden
Guiraudon	Virginie	CEE (CNRS/Sciences Po)	France
Kovács	Ilona Pálné	Transdanubian Research Institute	Hungary
Kropp (2)	Kristoffer	University of Copenhagen	Denmark
Laffan	Brigid	University College Dublin	Ireland
Leydesdorff (1)	Loet	University of Amsterdam	The Netherlands
Lubart	Todd	University of Paris	France
Malerba	Franco	Universita' Bocconi	Italy
Stjernfelt	Frederik	Aarhus University	Denmark
Wæver (1)	Ole	University of Copenhagen	Denmark

(1) Panel chairs
(2) Rapporteurs

DTU Technical University of Denmark

Technical Universtity of Denmark
Anker Engelundsvej 1
DK - 2700 Kgs. Lyngby
Tel: +45 45 25 25 25
www.dtu.dk

The Capital Region of Denmark

Kongens Vænge 2
DK - 3400 Hillerød
Tel: +45 38 66 50 00
www.regionh.dk

UNIVERSITY OF COPENHAGEN

Nørregade 10
DK - 1165 København K
Tel: +45 35 32 26 26
www.ku.dk