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Title: **Recommendations to the Strategic Programme 2016-17 for Horizon2020 Societal Challenge 2: FOOD SECURITY, SUSTAINABLE AGRICULTURE AND FORESTRY, MARINE, MARITIME AND INLAND WATER RESEARCH, AND THE BIOECONOMY**

Report from the Advisory Group

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EXECUTIVE SUMMARY

The Advisory Group for H2020 Societal Challenge 2 (AG SC2) covers a wide area of research and innovation needs. The recommended strategic focus areas were described in 6 chapters based on a process where the AG members together addressed the challenges using a list of questions from the EC as a guideline and inspiration. Two one-day plenary meetings were supplemented by electronic and web based discussions in sub-groups according to chapters/thematic areas using a social media platform and guided by a group of elected facilitators (chapter authors).

The concepts emerged during this exercise can be comprised within the following broad strategic themes:

- Healthy personalized diets and consumer empowerment
- One-health perspective in food, agriculture and livestock
- Smart, holistic and sustainable solutions for efficient management of resources, forests and land
- Systemic approaches for developing the Bioeconomy in rural and coastal areas
- Integrated bio-based industries and biorefineries in the optic of circular approaches
- Marine and maritime research: fisheries, aquaculture, biodiversity and society

Based on assessments of major societal trends and challenges within each thematic area and the state-of-the-art, 5 sub-groups identified and agreed on the most important knowledge gaps and bottlenecks and formulated the related key priority areas for research and innovation. In general and across the thematic areas and sub-sectors of SC2 basic challenges are:

- using resources more efficiently and with more knowledge input as means to intensifying production and processing with less external inputs
- providing new methods for addressing individual needs in a societal perspective and
- handling natural resources in synergies between intensified production, economic growth and preservation and renewal of natural capital in a circular economy

Recommended strategies and key research priorities for this are centred on *the development of context dependent knowledge* for (1) Healthy and personalized food products, (2) Integrated approaches to securing human and livestock health, (3) Agro-ecological farming and forestry practices creating synergies between intensifying land use and preserving natural resources, (4) Provisioning of non-food biomass from different origins (including coastal areas) for new types of cascading biorefinery processing without compromising food production, (5) Improved management aimed at the preservation and utilization of marine ecosystems services using a holistic perspective, (6) Linking new types of aquaculture and fisheries with off-shore sectors inspired by integrated understanding of resources in coastal seas and oceans (ocean literacy).

The following list gives an unranked selection of key priorities across the sub-themes. The challenges in the fields concerned which require immediate action under the 2016-2017 work programme are:

- Scientific understanding of interrelationships between human physiology, microbial flora and food intake and the relationship between this flora and major life-style diseases
- Research of the linkage between endocrine disrupting chemicals in food and obesity

- Use of novel technologies and the use of in-process control and monitoring chemical and microbial food and feed contamination risks (exposures from production throughout the chain)
- New product innovation by the development of new flavours and textures, the use of bioactive ingredients targeting the health requirements of population groups
- Need for further insights into the determinants of consumer behaviour and impact in the home especially in relation to dietary knowledge, food and health considerations, environmental impact, influence of gender and education
- Clarifying causes-effect links between livestock systems and human health systems including the treatment of zoonosis in a One-Health perspective
- Animal health strategies for the eradication or effective management of diseases, including zoonosis, and research on how to avoid antimicrobial resistance
- Understanding significant differences in the use of anti-microbial medicine per animal between different production systems including systems with low use such as organic livestock production
- Linkages between product differentiation, quality and animal welfare in intensive production with reduced use of antibiotics and with significant reductions in major food borne pathogens
- Improve efficiency in the use of nutrients, water and other resources in conventional and organic agricultural systems, which build on and enhance ecosystems services, so called eco-functional intensification
- Moving from single-purpose monoculture to more diversified cropping systems including the use of perennials to reduce environmental pressure, improve ecosystems services and increase the total biomass production for food and non-food purposes
- Enabling agriculture to deliver important ecological services through an integrated approach to agricultural development, building on agro-ecological practices and combinations of food and non-food production with increased use of green types of green biomass from crops for combined food, feed and bio refinery production
- Agroecological and forestry research and innovation for assessing and improving the potential of ecological intensification of land use, combined with innovations in harvest and transport technology, operational planning, high-precision monitoring, business models and ICT for the rational, competitive and environmentally friendly procurement of biomass
- Unlocking the bioeconomy's opportunities for rural and coastal areas by mobilizing and strengthening their capacity for primary production and delivery of ecosystems services as well as by opening avenues for the production of new and diversified products, which meet the increasing demand for low-carbon short-chain delivery systems
- Reduce resource use in livestock systems by developing robust and efficient production systems through innovative management at farm level as well as at the level of the individual animals
- Development of viable livestock systems with alternative feed protein resources and reducing protein imports into Europe, and reduce competition between feed and food production.
- Improve pasture and grassland management in the livestock sector in a cost-effective, environmentally sound and manageable way that also incorporates animal health and welfare considerations, as well as ecosystem services. Explore better use of organic re-cycled products, using alternative feed resources for animal feeding and recycling industrial by-products to produce functional food while improving feed chains and without compromising food safety.

- Improve breeding and health in organic and conventional livestock by improved monitoring of clinical/sub-clinical and production diseases and metabolic disorders in ruminants and monogastrics
- Linking pollution mitigation to bioeconomy development: study of phytoremediation of contaminated land and algae-remediation of sea with combined production of unconventional biomass to be used in biorefinery. Exploitation of aquatic living resources for reduction of sea contaminants and dissolved nutrient loads in aquaculture effluents while exploring their valorisation as biomass
- Efficient transformation of regional typical resources also of coastal areas within a cascade processing chain including returning waste and nutrients to the land
- Optimized biotechnological production systems (e.g. through metabolic engineering and system biology) or optimized bio-catalysts are necessary for making new biomass-streams viable
- Increasing European crop-based protein products for feed and food by using green, fresh biomass in cascade bio-refining and returning residuals and nutrients to the soil
- Technological development in aquaculture systems (i.e. aquaculture in its widest sense including shellfish culture, algae culture etc.)
- Advanced fishing technologies and coupling these to new food production strategies in aquaculture.
- Development of smart solutions for catching fish alive, avoiding discarding, transferring small fishes to aquaculture
- Research needs to be carried out to better understand the complex interactions between the marine ecosystem and its services as a production system, and the provision of these public goods and services to the society as a whole.
- Other utilization forms of the seas, namely tourism and recreation in its different forms as a societal value need to be integrated in all, the marine spatial planning and the regional resource management as well as the fisheries management
- Ocean literacy: to make society understand the impact and change of human activities on the marine ecosystems and to adapt sensibly to the environmental megatrend of the seas, by adjusting its mode of utilization to both the benefit of society and the functioning of the ecosystems

The SC2 represents in itself a wide and interdisciplinary thematic area as it appears from the key priority areas. Besides, important cross-disciplinary linkages to other SC areas were identified:

- There is a need for research that will develop competitive food technologies for industry, with an integrated learning approach between the food sectors, ensuring a more sustainable, differentiated and competitive food production and affordable food products, which goes hand in hand with increased knowledge and ongoing learning of dietary and eating behaviours from the social sciences and with the environmental/sustainability standards retained by international institutions.
- There is a trend towards increased “soft” use of information and communications technology (ICT) for communication and knowledge exchange in agriculture. People organise themselves in networks across Europe and globally changing the rules of current organisation. The use of social networks, crowd sourcing and new ways of organising communication and knowledge exchange is increasing and provide important options for learning and innovation.
- This requires cross-disciplinary integration of environmental and ecological economics using a new approach integrating socio-economic research in a form which supports the pro-active and management-oriented focus of agro-ecology. This should be integrated with improved understanding

of social innovation in terms of organization of new business forms and collective processes in business development as well as public regulation arising from other SCs.

- Transversality in new technologies (biotechnology, aquaculture, marine biology, ecology, engineering, chemistry, ICT etc.) should be at the basis of solutions for bioeconomy development while preventing environmental degradation and natural resources deprivation.. These developments will also lead to new feedstock demands and related new technology developments.
- Due to the intersectorial and multidisciplinary nature of the bioeconomy, tackling the above mentioned priorities will necessarily embrace also SC5 (5.2.1; 5.2.3; 5.4.2) as well SC6 (6.3).
- Changes in agriculture or aquaculture systems must necessarily consider environmental implications. For example, innovative energy systems often have implications for land use and water quality. Research and innovation are needed to help Europe with a defossilisation strategy using less carbon from fossil fuels and more from biomass and food cycles.
- All these strategic orientations also set the premises for strong synergies with Part II of Horizon 2020 “'Leadership in Enabling and Industrial Technologies” and the Private and Public Partnership initiative for Bio-based industries.
- Biomass and other raw materials should be delivered while at the same time protecting biodiversity and supporting the development of rural and coastal livelihoods, harmonizing, benchmarking, potential, also developing specific Life Cycle Analysis (LCA) parameters referring to the specific eco-system and social context. (Links to: SC1, SC5, SC4, Excellence in Science, LEIT, PPP on Bio-based industry).
- Development of off-shore aquaculture for instance comprises technological development in marine engineering as well as material research (research of fatigue of material in high energy marine environments), basic ecological research on trophic relationships, disease research in One-Health perspective and behavioural research. The development of regionalized management is cross-cutting and includes all forms of utilization of the seas, from shipping to naval engineering, sea-bead exploitation, nature conservation etc. Moreover, the social aspects of fisheries management have come more and more into focus in the management of marine resources.

We also recommend that a set of more precise definitions and objectives related to the terms “Cross-cutting” and “innovation” are developed/given. This set of definitions should include and cover as well the aspects of (1) trans-disciplinarity (e.g. combining environmental and social sciences with natural and technical sciences), (2) linking interphases between different societal challenges (e.g. integrating aspects of food production and diets/health with consumer behaviour in R&I efforts) and (3) how to involve and engage different types of actors in joint efforts.

A number of key priority areas will be better researched in a wider international cooperation – beyond EU member states. Examples of these include:

- Food security and food safety rules for food production systems are mainly developed for global markets. Such rules are primarily developed in international bodies, but increasingly the US/EU axis seems to dominate international, regulatory developments in relation to food production and trade (TTIP) negotiations – Transatlantic Trade and Investment Partnership), (TATFAR –Transatlantic Taskforce on Antimicrobial Resistance). There is a general gap in awareness of policymakers on both sides of the Atlantic in relation to the need for a trans-disciplinary focus, linking social, environmental, agronomical and health sciences. However, the present movement in trade negotiations also opens a new opportunity to support such understanding through solid scientific collaboration across the Atlantic

- Some targeted areas of R&I activities appear to offer opportunities for mutual beneficial cooperation with Third Countries: a) Exploitation of forestry resources and marginal/contaminated lands in the Danube region; b) sustainable growth of coastal areas through valorisation of local typical agricultural crops, food-waste streams (e.g. fishery and fish processing, oil-mill) while mitigating environmental impact of aquaculture through marine-biotechnology in the Adriatic-Ionian and in the Baltic Regions
- The production of “unconventional” biomass, also through the exploitation of aquatic living resources, is an area of possible cooperation with Third Countries that are experimenting with similar biotechnology solutions. This includes US, Japan and South Korea, which are leaders in environmental related technologies in terms of patents granted
- International cooperation activities could bring mutual benefits from the sharing of different local traditional know-how and enlarging specific scientific expertise in the study of resilient plants and crops adaptable in marginal, polluted and arid lands. These cooperation activities could be envisaged within the EU-Africa dialogue on research and innovation and also involving ENP (European Neighbourhood Policy) Countries

INTRODUCTION

In accordance with the terms of reference the Advisory Group (AG) has aimed at identifying strategic priorities for research and innovation under the Horizon 2020 for the Societal Challenge 2:

FOOD SECURITY, SUSTAINABLE AGRICULTURE AND FORESTRY, MARINE, MARITIME AND INLAND WATER RESEARCH, AND THE BIOECONOMY

With this report the AG intend to give advice to the European Commission in the process of developing a strategic program for 2016-18.

The AG has done its best to follow instructions from the EC re objectives, process and guiding questions given at an introductory meeting and to subsequent workshop meetings at the DG research premises in Brussels. Besides the face-to-face meetings members have interacted via a social network, yammer, and skype meetings.

Due to the relatively wide area of SC2 to be covered by the AG it was decided to divide the work among several subgroups according to members' expertise. The names and expertise areas of the AG group is given in Annex 1. Each subgroup was facilitated by a member with responsibility for integrating input from all AG members and coordinating the writing of the respective chapters of the report.

At the second meeting a format in the form of a structured Excel table was developed for describing strategic ideas in a brainstorming approach, where all AG members could contribute from their areas of expertise to give ideas. Thus, during April and May all members were invited to provide input by describing a strategic idea or suggesting material for "strategic intelligence and sense making" in the form of the excel file available at a yammer site. This was developed by the group of facilitators as a format to respond to the questions raised by the Commission in the slides and papers presented.

Based on this input the group of facilitators developed narratives by transforming the input and the questions into strategic recommendations in a text format, again guided by the Commissions questions as much as possible while allowing for individual adjustments according to topics etc. While writing the narrative, the contributors were requested to include data and other information with references to key reports, documents, foresights etc. as so-called "intelligence" and "sense making" in order to support the proposed strategic focus.

The group of facilitators developed a guideline and template for the contribution of sub-groups to the final report. The template outlines the AG feedback on strategic research and innovation priorities for 2016-17 around 5 sections:

- Priorities selected from the Specific Programme;
- Drivers and Trends;
- Bottlenecks, future challenges, gaps in R&I, potential treats;
- Inputs, strategic recommendations related to research and innovation;
- How success would like.

As terms of reference, contributors were requested to:

Analyze the Specific Programme (council decision 2013/743/EU) looking at the following of factors that were listed in the Consultation Paper:

F1) Analyzing how key issues (austerity, societal change, aging population; big data; globalisation; resource constraints; environmental concerns, etc.) affect research prioritisation
F2) Mobilising resources to build scale and critical mass;
F3) Exploiting the existence of mature research and innovation agendas building on European knowledge strongholds and business strengths which require a significant investment and for which such investment would act as a clear leverage;
F4) Realising impact and maximising the chances of securing world class scientific and innovative breakthroughs as they help generate excellence through European and international competition and cooperation;
F5) Providing genuinely cross-cutting approaches, notably by addressing challenges and areas cutting across different specific objectives and parts of Horizon 2020;
F6) Aligning implementation with major political initiatives and/or improving synergies with national programmes, while identifying the most important and most urgent research and innovation issues
F7) Improving synergies with international projects and fostering international cooperation

The guideline used for this is enclosed as Annex 2.

The ideas included in chapters represent a selection based on the AG members' competences and the literature digested by the members. Some themes within the SC2 are not covered extensively in the report due to insufficient expertise in the AG.

In working with the transformation of ideas into the final chapters we have sought to strike a balance between – on the one hand – being so specific that the strategic ideas represent a selection of pertinent (sub-)challenges and are not merely a reproduction of existing and general texts and – on the other hand – not being so specific that the proposals will look too much as Work Program topics.

In other words, the strategic ideas intend to signal a prioritization within the items mentioned in the Specific Program and guided by a selection of the most pertinent challenges within an area (or cross cutting between areas) in light of foresights (drivers and trends) , selected bottlenecks and visions of where R&I could make a difference and create successes.

1 SUSTAINABLE AND COMPETITIVE AGRI-FOOD SECTOR FOR A SAFE AND HEALTHY DIET

SECTION 1

Priorities selected from the Specific Program

The overall priority to develop a sustainable and competitive agri-food industry to deliver safe, nutritious, affordable, high quality and healthy foods to help reduce the burden of food, lifestyle and diet-related disease via informed consumer choice and innovation within the food industry to enhance competitiveness and create growth and employment.

The construction and management of resource-efficient and sustainable food production and food supply chains to improve the long-term sustainability of crop- and animal-production systems. Innovative and sustainable resource-efficient technologies and processes generated, diversified and underpinned with scientific evidence throughout the food chain.

Nutritional needs, a balanced diet and the impact of food on physiological functions and on physical and mental performance and the links between diet, demographic trends (such as ageing) and chronic diseases and disorders. Addressing consumer needs, communicating and educating consumers on healthy lifestyles and nutrition.

Chemical and microbial food and feed contamination risks; tackling exposures from production and storage to processing, packaging, distribution, catering, and preparation at home.

Innovation-led improvements to food safety standards and tools for risk-benefit assessment and communication leading to enhanced consumer trust and protection in Europe and globally.

SECTION 2

Drivers and Trends

Globalisation: Globalization and population changes as well as life-style changes are likely to provide access to new markets for safe and health-promoting foods in the fast-growing middle-class populations in countries in transition as well as in developing countries with fast-growing economies (incl. sub-Saharan Africa). Such developments need to be supported by scientific research on sustainability. A focus on innovation and planning is critically important in helping manufacturers enhance their long term viability and success in what is an increasingly competitive marketplace. At the same time cultural values connected to patrimony and the environment need to be maintained and supported and a greater emphasis given to supporting for local foods and seasonal supply.

Resource efficiency, climate change and sustainability: Increased global demand for food and other bio-based products needs to be translated into growth and employment without further compromising the ecosystem. The globalization of markets is not necessarily compatible with protection of resources and therefore the importance of investigating and supporting biodiversity and the resilience of ecosystems will rise.

Food chain integrity and sustainability have become significant issues for the food sector and are driven by consumers becoming more conscious of the impacts on the environment of their food consumption patterns as well as by the economic costs associated with waste management, energy costs, water usage and regulation. A better understanding of the factors affecting the sustainability of production and consumption will be a driver of trans-disciplinary innovation.

Food and health: The impact of diet on our health is undoubtedly a challenge for society and will be a future driver of innovation within the food industry. Chronic non-communicable diseases, including cardiovascular diseases and diabetes are major, life-style and obesity related diseases, directly related to food consumption and are estimated to account for almost 60% of global mortality[1].

The impact of food on physical development has received increased attention and recent evidence indicates that unhealthy diets are also risk factors for mental disorders[2]. Dietary solutions and innovations related to the prevention of major life-style diseases are being identified, based on new scientific discoveries. The interest from consumers for foods designed to prevent life-style diseases and for personalized diets will most likely increase dramatically over the next decade. Indications that food can impact life-style diseases through a specific interaction with the intestinal micro-flora open novel opportunities for disease prevention through healthy eating[3]. An ageing population, a better informed society, social learning and a general consumer demand for health-giving and health preserving food products will drive innovation supported by scientific research.

Associated knowledge gaps need to be addressed, for example, concerning the interrelationship between human physiology, microbial flora and food intake (including microbial flora added to or inherently in the food) and the relationship between this flora and major life-style diseases.

Traditionally developing countries were thought to only need sufficient food, not health-promoting food or novel foods - this understanding has to be challenged. The new situation (in a global sense we have enough food, developing countries will develop faster than we envisioned 10 years ago[4] and middle-class population sections will grow dramatically over the next decade) brings the potential for innovation and growth, locally and internationally, increased European export potential and the potential for innovative development and cooperation programs.

Food safety and security: There is an increased global demand for safe and secure food underpinned by food safety and quality standards. The European promotion of science-based food safety standards and control can be translated into growth and employment. A number of developing and transition countries (including China) have a specific and rising demand from the growing middle class for safer food. Businesses must ensure they are well placed to take advantage of future growth and in doing so bring new innovations to markets.

[1] Unwin and Alberti: Chronic non-communicable diseases. Annals of Tropical Medicine and Parasitology 2006, Vol. 100, 5-6, pp. 455-464
[2] Jacka et al Food Policies for physical and mental health. BMC Psychiatry 2014, Vol. 14, 1.
[3] Mathis and Benoist: The influence of the microbiota on type-1 diabetes: On the threshold of a leap forward in our understanding. Immunological Reviews 2012, Vol. 245, 1, pp. 239-249
[4] World Bank Press Release, April 7, 2014: Economic Growth for sub-saharan Africa projected to 5.2% in 2014

Food supply chain: The food supply chain is complex. With a higher level of concentration, retailers have more turn-over and better financial standing/capital intensiveness, giving them stronger buying and bargaining power. This increased power can disadvantage suppliers and primary producers and widen the gap between primary producer and consumer. Rising prices of raw materials, energy and water, and waste management have an increasing impact on food production, price structure and systems developments. New knowledge relative to efficient and optimized use of all parts of the food production systems will affect not only European, but global food production systems.

One Health: Documented disease trends show that 60% [5]of all Emerging Infectious Diseases are zoonoses (i.e. stem from animals). A global trend has developed over the last decade supporting an increased understanding of the importance of linking data from animals, food and humans to foodborne disease trends and preventative measures. Since 2004 this concept has been referred to as 'One Health'.[6] In effect the One Health paradigm has been embedded in the European Zoonosis Directive since 1992 and several European success stories in relation to improved food production stem from this (Salmonella, Antimicrobial Resistance, etc.). In a broader sense One Health thinking also relates to more sustainable, animal friendly food production systems, with reduced antibiotic use and a reduced carbon footprint.

Relative to maintaining a competitive food production system in Europe, the European potential to implement Farm-to-Fork surveillance of the food chain represents a major opportunity to further develop the One Health concept. Scientific documentation of successful outcomes in Europe will spread globally and lead to increased competitiveness and health benefits.

Globalization is about joining global value chains and delivering products, services and technologies within a One Health paradigm supporting and promoting a healthy and sustainable food production system. The European One Health success stories could drive future risk-prevention in the food production. Innovation strategies need to emphasize comprehensive and sustainable solutions to enable efficient production, storage, manufacturing and distribution of food in support of sustainable agricultural land-use and improved animal and human health.

SECTION 3

Bottlenecks, future challenges, gaps in R&I, potential threats

There are many cross-cutting issues in relation to food creating an overall need for more interdisciplinary and transdisciplinary research in the future. Typically agri-food research institutions have a preference for disciplinary excellence rather than cross-disciplinary research which can have a significant impact on research fields. There is a challenge also in creating strong links between socio-economic sciences and humanities and technical/biological sciences. Societal challenges linked to food production are often understood and described solely in one of these two realms, although in reality they should be seen in conjunction. Costs in relation to poor health for example should be integrated with the economics of food production. Cross-sectoral research could pave the way for better and more coherent policies (and thus food industry potential). Thus, in general, there is a need of a transdisciplinary-approach and integration among research disciplines between processing, food quality and safety, nutrition/health and sustainability,

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[5] Jones et al.: Global trends in emerging infectious diseases. Nature 2008, 451, 990-993

[6] World Bank: People, Pathogens and Our Planet Vol. 1: Towards a One Health Approach for Controlling Zoonotic Diseases, 2010, Report No. 50833-GLB, The World Bank, Washington DC

bringing together nutritionists, clinicians, environmental and/or consumer specialists process engineers and technologists.

Various research measures have enabled the food sector to enhance and develop its innovative capabilities. Fundamental to enabling this is an effective technology transfer system which leads to higher levels of research outputs being commercialised. There needs to be greater involvement in research of SMEs across the food chain but also greater connection between research and all stakeholders in the chain (SMEs, farmers, retail, production, authorities etc).

To tackle the challenge of increased global demand for food and other bio-based products, the development and implementation of targeted, cost effective and environmentally sustainable technologies and regulation instruments are necessary. The basis for such innovative solutions lies in a focused research effort towards supporting, but also guiding and controlling European food production systems. Likewise there is a need for a coherent use of consumption data and other resources to inform the potential for changes in consumer preference.

Environmental degradation and climate change will have a strong, direct and indirect impact on health and on the availability of resources, threatening the resilience of eco-systems and the long-term safe supply of food and other vital services. The implications are not well understood and require further scientific input.

There is a need for new scientific interdisciplinary research including agro-ecosystem management, by exploiting the traditional knowledge derived from local agronomic practices to provide high quality and sustainable food. In general, there is very little knowledge of long term processes and methods to deal with complexity. Future challenges include a better understanding of the links between agronomical/food system efficiency and eco-system services. There are significant gaps in our knowledge in relation to agro-ecosystem efficiency taking into account long term processes.

Historically, the focus of research and advice at farm level was to increase production, productivity and profits, whereas now the emphasis is on achieving those aims in a sustainable way which often implies changing farm practices and using different technologies. Agriculture often adapts technologies developed for other sectors but there is a need for a wider participatory approach involving a range of stakeholders.

A significant (fundamental and basic) amount of research is needed in order to document potential links between the composition of food, human microbial flora and life-style diseases, and thereby a potential innovative solution to some of the major non-communicable diseases worldwide. Epidemiological studies suggest an association between increasing human exposure to certain chemicals and development of reproductive disturbances and metabolic disorders[7]. Solid scientific data and improved understanding in this area could form the basis for significant changes in the global spread of life-style diseases through innovative food production based solutions.

[7] Thayer et al.: Role of environmental chemicals in diabetes and obesity: A national toxicology program workshop review. Environmental Health Perspectives 2012, Vol. 120, 6, pp. 779-789

The increased use of food supplements has led to a vast number of plants or plant preparations used as ingredients. There is a lack of data on possible adverse effects of plant-based food supplements which could be a problem in high-intake consumers.

The development of research expertise in personalised nutrition is a prerequisite for capturing a share of the emerging personalised health market.

There is also a need for further insights into the determinants of consumer behaviour especially in relation to dietary knowledge, food and health considerations, environmental impact, influence of gender, impact in the home, education and so on. There is a major research gap in relation to the links between risk assessment and communication, consumer behavior and economical implications of consumer choice and food standards. There is a need for research that will develop competitive food technologies for industry, with an integrated learning approach between the food sectors, ensuring a more sustainable, differentiated and competitive food production and affordable food products, which goes hand in hand with increased knowledge and ongoing learning of dietary and eating behaviours from the social sciences and with the environmental/sustainability standards retained by international institutions.

Food security and food safety rules for food production systems are mainly developed for global markets. Such rules are primarily developed in international bodies, but increasingly the US/EU axis seems to dominate international, regulatory developments in relation to food production and trade (TTIP negotiations – Transatlantic Trade and Investment Partnership), (TATFAR - Transatlantic Taskforce on Antimicrobial Resistance). There is a general gap in awareness of policymakers on both side of the Atlantic in relation to the need for a trans-disciplinary focus, linking social, environmental, agronomical and health sciences. However, the present movement in trade negotiations also opens a new opportunity to support such understanding through solid scientific work.

In the primary production sector there is a need for increased research into aspects relating to product differentiation and quality, and to animal welfare aspects. European agriculture has shown the world that efficient, large-scale production is possible with reduced use of antibiotics and with significant reductions in major food borne pathogens such as Salmonella. Consequently, the poultry industry has the potential to markedly increase in volume, supplying a global growing market in animal protein, provided research is generated to support the transition from bulk to quality[8], potentially making it the preferred alternative to pork and beef. Likewise there is a need to develop communication technologies to provide real-time, rapid food safety information to support informed food-safety decisions and on-line process control for hygiene on processed food.

Spreading innovative research-based systems from the EU to the rest of the world will only succeed if scientific research can document feasibility and overall economic sustainability of Farm-to-Fork surveillance and control systems for foodborne diseases. US-EU trade negotiations will probably put a renewed focus on the different control philosophies. Scientific documentation will be paramount in promoting European solutions in discussions with for example the inter-governmental, standard-setting FAO/WHO Codex

[8] Applegate et al.: Probiotics and phytogenics for poultry: Myth or reality. The Journal of Applied Poultry Research, 2010, Vo. 19, 2, pp. 194-210

Alimentarius Commission. However, a scientifically coherent framework to consider such inherently different factors related to a globalized food production system is missing, and a specific effort is needed to link applied science and the development of basic methodology in this area. Agriculture is the new economy.

SECTION 4

Inputs, strategic recommendations related to research and innovation (Key Priority Orientations)

Improving measures and strategies to reduce food waste, exploiting food waste streams and extracting bioactive components and other materials for use in food and feed and researching the most efficient ways to separate and re-utilise different types of food waste will minimise waste and improve sustainability[9]. Defining new economic values of food wastes will support new growth.

There is a need for new scientific interdisciplinary research including agro-ecosystem management, by exploiting the traditional knowledge deriving from local agronomic practices - to provide high quality and sustainable food. [10]

Food chain research may also focus on life cycle considerations, supply chain management, energy and environment in connection with waste management, recycling, and choice of packaging materials, as well as strategies to minimize food waste[11]. Specific attention should be made to food waste in the catering sector, which has losses of up to 50%. A sustainable resource-efficient food production sector is also connected to the development of new bio-refinery systems, including the use of new protein extraction, purification and modification technology, increasingly important in the food value chain[12].

The inter-sectorial and collaborative approach of social innovation strategies need to be investigated as a potential solution to some of our societal challenges in relation to sustainability.

Research into novel processing technologies to enable new food formulations and the use of novel technologies and the use of in-process control and monitoring technologies to ensure food quality and safety will improve competitiveness in the food industry and stimulate jobs and growth[13]. Some novel technologies are known to enable efficient disruption of cellular structure and thereby assist in the extraction process but more research is needed. Likewise research of the linkage between endocrine disrupting chemicals in food and obesity will enable innovative solutions related to our diet.

Targeting new market opportunities such as developing functional foods, diversified foods for children and the elderly, dedicated non-allergenic foods and so on to improve the health profile of processed food, demands significant research, supported by realistic scale up, development and commercialisation. The costs involved in bringing novel foods to the market need to be supported so consumers can benefit from

[9] See for example: Gutierrez-Martinez et al.: Protein removal from waste brines generated during ham salting through acidification and centrifugation. Journal of Food Science 2014. Vol. 79, 3, pp. E326-332

[10] “Logistics and Agro-food Trade, a challenge for the Mediterranean Area", Mediterra 2014

[11] Italian technology platform “Food for Life” Strategic Agenda for Research and Innovation (June 2011)

[12] “Innovative food production”, The Knowledge Based Bio-Economy (KBBE) in Europe: Achievements and Challenges Cleverconsult Report (2010)

[13] European Technology platform “Food for Life” Strategic Research and Innovation Agenda (2013-2020 and beyond)

them. Inter-disciplinary research between food and pharmaceutical researchers to develop novel foods with health-giving properties or new delivery systems could also be considered.

New product innovation will also be driven by the development of new flavours and textures, the use of bioactive ingredients and the health requirements of population groups. Consumer studies are needed to underpin this research and to ensure new food products are compatible with high standards of human health and environmental sustainability, and aligned to their needs and behavior. Thus more research into the sensory properties of food and their impact on consumer choice is required to support the development of novel and healthy food products and ingredients.

There is a need for a lot more research into new cutting-edge food production systems and sciences (synthetic food, molecular gastronomy, personalized nutrition, food designer). There could also be more research into the understanding of food structure in order to develop a robust food formulation approach.

In the context of accessing global markets, the complex interactions between ingredients, processing technology/parameters and storage/transport conditions determining the overall structure and physical stability of food systems needs to be investigated.

More research into the changing roles of large retail companies and their relationship with suppliers and the impact on food producers, SMEs, consumers and innovation is required.

Updated and objective profiling of consumer habits and patterns across the EU in different socio-economic strata can be very useful to set up a 'baseline'. This can help with assessing life style associated diseases and finding imbalances with dietary needs, but also for food safety risk assessment relative to exposure.

The role of school education and policies, the impact of gender, the influence of the media, the role and influence of women in children’s food education and in sustainable behaviour are important factors in affecting consumer behaviour from an early age. There is a need for more research into the key influencers of consumer choice to support the dissemination and communication of key messages in relation to nutrition, sustainability, food for health and so on. Food and nutrition anthropological studies can investigate culture, creativity and fashion linked to food innovation, defining the social and cultural meaning and role of food as an identification factor.

While population growth and the question of feeding the world in the future is not really the main food production issue, access to food in general and a more equitable food distribution is. Demographic changes such as a significant increase in elderly populations need to be considered, especially in combination with a significant rise in life-style diseases. There is a grand challenge to change population diets so research should not only focus on increased food production, but should look at ways to create and monitor food demand, and consider/promote territorial value and rural welfare.

Research focused on showing the benefit of Farm-to-Fork surveillance to be seen in a developing One Health context - European success should be documented scientifically, enabling systems to be spread globally, thereby returning a benefit to EU Agricultural systems and to public health in general.

To provide safe food for all there is a need to rapidly trace food safety problems throughout the food supply chain. Therefore, novel technological developments are needed to collect, collate, and analyze information throughout the chain in near real-time, enabling the implementation of the most efficient control measures. Focused research efforts could bridge the gap between conventional detection, control methods and new approaches (applied micro and nanotechnology and other emerging technologies) in food production, food control and food packaging. Likewise novel technologies, notably New Generation DNA-sequencing may provide this research area with a significant boost, and the applied aspects of such development should be elaborated in addition to already defined H2020 calls in the area.

SECTION 5

How the success would look like

European Food production already represents the largest manufacturing sector in the EU in terms of turnover and employment, and continues to be a growing part of the European economy. A repositioning of agriculture in relation to a better understanding of the inter-linkage between production, environmental and health safety and economy will place European food production in a central and competitive position and in addition make Europe a worldwide model of responsible and sustainable food producer. Made in Europe will equate with high quality and safety standards and sustainable production and distribution as well as recognizing regional strengths.

A transparent and fair supply chain will contribute to the availability of safe, affordable, high quality foods produced from sustainable and competitive production systems. A healthy, happy and informed consumer will make better choices and improve their own health by making purchasing decisions underpinned by scientific research and sustainable processes.

Sensible science-based policies in Europe may lead to a greener and more sustainable Europe. Targeted research may help reduce waste from the whole food chain, re-think transport, help the organization of multi-actor innovation in the food production chain. This will in turn allow a shift towards long term processes, offering market places for bottom-up innovation, recognizing diversity as a means of resilience and adaptation and opening minds of policy makers to diversify rules enabling innovation acceptance.

Innovative solutions will drive Europe towards a sustainable food production sector that uses fewer by products and re-uses waste products and energy, cutting down on production and increasing the affordability of healthy foods. European food production systems could be at the forefront of waste-free food production, leading to increased sales of European food also at global markets. More energy-efficient practices across the chain from farming to transportation will be supported by innovation in technologies. However, the science-base for such developments could also be used to export experience and systems to the rest of the world, thereby pushing global food production in a sustainable direction.

The trade-offs between agricultural production systems and ecosystem services will be optimized. At the same time solid research results in this area could aid in providing member states with a common – and science-based - understanding of differences and similarities in the impact and implementation of the common agricultural policy between member states.

Integrated Farm-to-Fork surveillance systems and One Health approaches to replace and lower use of antibiotics, both a WHO[14] and an ECDC[15] priority issue, and working towards pathogen free farm animals, will modernize food animal production, make it more sustainable, safer for human health and more attractive on a global market. This will involve big data and integrating European success stories, and could make the European agricultural sector more competitive at a global market that is demanding high levels of food security combined with environmentally sustainable approaches.

New knowledge, innovation and entrepreneurship in food and health will deliver targeted food and novel food products onto the domestic and export markets that will underpin the prevention of lifestyle diseases, and in some cases complement personalized medicine solutions, therefore reducing health care costs and improving the overall wellbeing of consumers. The inclusion of essential nutrients, eg vitamins, in food in novel ways will open up new avenues in health-promoting food.

Changing demographic patterns will lead to foods specifically targeted to the needs of elderly people, ethnic minorities and low socio-economic groups at high risk from the introduction of poor western diets. Successful outcomes have the potential to improve the general health status of consumers, both physically and mentally reducing economic burdens related to food.

Research on and production of innovative foods that promote health may significantly reduce the burden of some food related diseases. Doing this through food has the advantage for consumers that it is an easy way to improve health, and it may take away or reduce the necessity of some of the medical treatments and their inherent side effects. Innovative European food may compete at the global market and find a competitive advantage in a label of being proven healthy.

[14] *WHO, 2011. Tackling antibiotic resistance from a food safety perspective in Europe.* Copenhagen, World Health Organization, regional office for Europe, 2011. *http://www.euro.who.int/__data/assets/pdf_file/0005/136454/e94889.pdf*

[15] ECDC, 2010. Annual Report of the European Antimicrobial Resistance Surveillance Network (EARS-Net). Antimicrobial resistance surveillance in Europe 2009, http://www.ecdc.europa.eu/en/publications/Publications/1011 SUR annual EARS Net 2009.pdf.

2 SUSTAINABLE AGRICULTURE AND FORESTRY

SECTION 1

Priorities selected from the Specific Program

The overall aim is to support Research and Innovation aiming at securing and improving growth, sustainability and competiveness in the agricultural, forestry and livestock production sectors. The tasks are interlinked and mutually supporting. For example, the public recognition of the benefits delivered by public goods and ecosystem services in rural areas will support their empowerment and create better conditions for enhancing the use-efficiency of natural resources.

Increasing efficiency (2.1.1): It is imperative to enhance natural and human resources efficiency, which implies sustainable production systems not only focused on maximizing productivity, but to optimize across a far more complex set of outcomes integrating production, environment, and social justice (Godfray et al., 2010). Adaptive capacity of plants, animals and production systems should be considered to cope with rapidly changing environmental/climatic conditions and increasingly scarce natural resources. This includes new methods for ecological intensification for the benefit of conventional and organic agriculture. Moreover, in the area of animal health, strategies for the eradication or effective management of diseases, including zoonoses, and linked with research on how to avoid antimicrobial resistance will be promoted. Integrated control of disease, parasites and pests with minimum of medicine use will be strengthened, starting from a better understanding of host-pathogen interactions, to surveillance, diagnostics and treatments.

Ecosystem services, public goods through innovative land use and sustainable forestry (2.1.2 and 2.1.4): A better understanding of how diversity in land use and forestry may at the same time provide public goods and increase ecosystem resilience and thus benefit long term production as an insurance for the future. This requires more research and innovation into the management of biological processes needed for sustainable agricultural and forestry production, focusing on the interactions between primary production systems and ecosystem services, and delivery of management solutions and decision-support tools for multiple uses. Agricultural systems rely on ecosystem services provided by natural ecosystems, including pollination, biological pest control, maintenance of soil structure and fertility, nutrient cycling and hydrological services. Preliminary assessments indicate that the value of these ecosystem services to agriculture is enormous and often underappreciated (Power, 2010). A fundamental priority is to enhance and preserve biodiversity as a long term support of food security and sustainable livelihoods (FAO, 2010). Overall, activities in the forestry sector will seek to promote multi-functional forests which deliver a variety of ecological, economic, and social benefits including forest owners' needs and taking into account climate change by the strengthening of forest resilience including tree health.

Empowerment of rural areas (2.1.3): Once agricultural knowledge, science and technology is directed simultaneously toward production, profitability, ecosystem services and food systems, then formal, traditional and local knowledge need to be integrated (IAASTD, 2009). Traditional and local knowledge, which are site-specific and evolving, constitute an extensive realm of accumulated practical knowledge and knowledge-generating capacity that is needed if sustainability and development goals are to be reached. Strengthening their capacity for primary production and delivery of ecosystem services, socio-economic research and studies are needed to ensure cohesion of rural areas and prevent economic and social marginalization.

SECTION 2
Drivers and Trends

These are the key drivers and trends underpinning the development of the priorities selected in the previous section.

- **Increase in global food needs:** The last decade has changed the general view on future food sufficiency from a more optimistic view at the turn of the century to one of concern over declining yields growth rates and threats to the natural resources food production depends on (Cassman, 2012). Population changes and the rapidly developing middle class in middle income countries increase global demands for livestock products (Regmi & Meade, 2013) and – therefore – protein crops for feed, which again puts pressure on land use[16] (Alexandratos & Bruinsma, 2012; Searchinger et al, 2013).

- **Environmental concern over intensive farming:** On the other hand, environmental pressure from intensive farming practices has increasingly become societal issues globally (Nelleman et al, 2009; Searchinger et al, 2013) and in Europe (EEA, 2010; 3rd SCAR foresight) as expressed in the debates over the so-called Greening of the CAP. Large farming areas in Europe have developed into monoculture of annual crops grown with high levels of external input resulting in loss of farmland biodiversity and soil quality (EEA, 2010). As cash crops and reproductive material (for plants and animals) keep expanding, the biodiversity and resilience of agricultural and forestry ecosystems rises in importance (Brussaard et al., 2010). **The environmental degradation has** strong effects on health and on the availability of resources, especially on land, water and biodiversity and biological resources, thereby threatening the resilience of eco-systems and ultimately the capacity to ensure supply of food and other vital services demands for agriculture to provide ecosystem services (MEA, 2005; Mc Intyre et al., 2009; Nelleman et al, 2009). In this light, forestry is increasingly required to develop into forms which positively contribute to preserving ecosystems services. A parallel challenge of intensive livestock systems is the high use of antimicrobial medicine which has implications for the development of resistance towards certain antibiotics in human diseases as well (see for example Wegener, 2012; CDC 2014; Yongfei Hu t al. 2014). Research is needed in clarifying causes-effect links between livestock systems and human health systems including treatment of zoonosis in a One-Health perspective (Wegener, 2012) and understanding significant differences in the use of anti-microbial medicine per animal between different production systems.

- **Globalization**: Most existing assessments project that international trade in agricultural commodities will increase and often predict that developing countries, as an aggregate, will become net importers (Alexandratos and Bruinsma, 2012; see also footnote 1).; However, the financial and economic crisis and the increasing unemployment has pushed other types of trade, much more focused on local and regional products. Europe is a large importer of concentrated feed

[16] For example It is expected that Chinese meat import will increase by 3500 % by 2050: http://www.efeedlink.com/contents/05-21-2014/562d0bf3-9397-44fe-95f1-d4c5ce8c58f2-b531.html

for livestock which indirectly put pressure on land use globally. Therefore, even though the major increase in global food production should preferably take place in regions where the majority of food insecure are such as Africa and South Asia (Alexandratos & Bruinsma, 2012; Searchinger et al, 2013) then – according to some schools – Europe should also increase total food and feed production (3rd SCAR foresight; Underwood et al., 2013).

- **ICT**: Is a strong driver of future change, driving processes of integration, whilst at the same time raising fundamental ethical issues re. registration and control. The combination of robotics, automation, efficient data handling, sattelites and internet will create opportunities for significant changes in organization, management and monitoring of agricultural production, which is well described at the "ICT-AGRI Meta Knowledge Base" (http://ict-agri.eu). Besides the "hard" technological options there is a trend towards increased "soft" use of ICT for communication and knowledge exchange in agriculture. People organize themselves in networks across Europe and globally changing the rules of current organization. The use of social networks, crowd sourcing and new ways of organizing communication and knowledge exchange is increasing and provide important options for learning and innovation (Jespersen et al., 2013).

- **New technologies** have traditionally targeted and resulted in yield increases and/or increases in agricultural labor productivity. Besides ICT mentioned already new technologies relevant for agriculture are mainly in the field of biotechnology, nanotechnology and ecosystems management and some technologies - in particular GMO's - have become the subject of important controversies. This question is linked with basic understandings of how best to cope with the above mentioned challenges of increased food demand vis-à-vis the need to alleviate agriculture's negative impact on natural capital and broader ecosystems services (3rd SCAR foresight; Underwood et al., 2013) and whether the one solution (i.e. strong focus on biotechnological solutions and – possibly GMO – might create further obstacles for the other (ecological intensification based on clever use of biodiversity) (Vanloqueren & Baret, 2009; Jacobsen *et al.,* 2013). The jury is still out on this question and research should assist bringing light on possible synergies between the different approaches.

It is interesting to explore key inter-linkages between the different drivers and resulting changes.

SECTION 3
Bottlenecks, future challenges, gaps, potential threats

- Current socioeconomic situation and unemployment

- **Climate change**: Existing assessments expect agriculture to increasingly be affected by global warming and changes in climate variability. For agriculture, changes in seasonal variability and extreme events are even more important than changes in mean temperature and precipitation. Recent studies, such as presented in the IPCC's Fourth Assessment Report, indicate that negative impacts on agriculture tend to concentrate in low income regions. In temperate regions impacts could result in net positive yields. Developments in Agricultural Knowledge Science and Technology (AKST) will determine the capacity of food systems to respond to the likely climate changes (IAASTD, 2009). Research needs linked to specific challenges for Europe in relation to food, agriculture and climate change is presented in detail by FACCE (https://www.faccejpi.com).
- There seem to be bottlenecks in respect to reacting properly to the challenges mentioned under drivers and trends, especially realizing increased yields in major crops. Thus, a yield gap analysis, and need for more research for yield maintenance and improvement (Ittersum *et al.,* 2013) should be linked with holistic analysis of the production systems (Sossidou, 2002);
- **Farmers meet the Experts and the Industry**: Knowledge from actors should be considered as valuable as scientific ones; future challenges: development of multi-actor/participatory research practices gaps in R&I: evaluation of participatory research activities, funding "innovation based research projects" initiated by actors who are not officially researchers; potential threats: lack of means for actors to access to project funding and to sustain their actions for a long time.
- **Rules are mainly developed for global markets**; future challenges: policy-makers awareness; gaps in R&I: transdisciplinarity, linking social and agronomical sciences; potential threats: Insufficient methods and means to valorise farmer innovations and secure multiplication and out-scaling of such case based innovations based on evidence;
- **Socio-economic sciences and humanities are very often not connected to "technical/biological" sciences in a pro-active approach.** Implementing a range of results from natural science in agronomy/livestock/forestry requires new management approaches and –sometimes- collective organization (e.g. improved coordination of land use, crop varieties, biodiversity preservation, farmer field schools and stable schools for reduction of antibiotics use) which again requires involvement of expertise from humanities, which however is not always geared to be involved in proactive – rather than merely descriptive – modus operandi. ;
- **«Technologies" are individually dealing with narrow aspects of the global challenge**; future challenges: development of holistic approaches which evaluate the impacts of technologies compared to social innovations to cope with planet survival; gaps in R&I: to enlarge the science culture of global and ecological challenges; potential threats: education, policy maker awareness and researchers training/formation.
- Existing assessments project a combination of intensification of agricultural production and expansion of cultivated land to meet increasing demands for food, feed, fiber and fuel. A major uncertainty in the scenarios presented in these assessments results from **the degree of extensification versus intensification in agricultural production**.

- Assessments indicate **an increased demand for water from non-agricultural sectors**, which could further exacerbate water limitations already felt by farmers in developing countries. Increasing rates of land degradation in many regions may limit the ability of agriculture systems to provide food security. Business-as-usual scenarios indicate a further increase in the already substantial negative contribution of agriculture in global environmental change. However, alternative scenarios highlight that there are also many opportunities to enhance the positive role of agriculture in providing ecosystem services and minimizing its environmental impacts (IAASTD, 2009).
- Trends observed over the last decade show that **the share of employment in agriculture is declining** and this emerging trend is expected to continue. The expected increase in urbanization and international labour migration as well as better working conditions in other sectors will catalyse a labour shift away from agriculture to other sectors. Agricultural labour productivity is expected to increase as a result of improved mechanisation and developments in AKST that are responsive to emerging agricultural and food systems.
- There is **a trend in many regions to reduce investment in traditional agricultural disciplines** in favour of emerging research areas such as plant and microbial molecular biology, information technology and nanotechnology. Investment in AKST is increasingly less driven by the needs of agriculture per se, but is a spin-off of other research priorities such as human health and food security. These investments mainly occur in industrialized countries and advanced developing countries and the resulting products and services may not be easily accessible to and applicable by least developing countries. Knowledge generated in the traditional agricultural disciplines is required to effectively apply advances in the emerging research areas to diverse agriculture systems. The effect of the shift in investments on AKST is not fully explored.
- In forest production one overall challenge is finding the right balance between the potentially increased role of bioenergy provider vs acting as carbon sink and at the same time providing other ecosystems services such as biodiversity protection. Major challenges are that given the uncertainty of future carbon and energy prices, renewable energy sources (RES) policies help to promote new investments. However, they can also cause new problems. Subsidies directed to one sector may harm other sectors, and can also increase the costs of mitigating climate change. For example, research has found that if subsidies are given for biodiesel production, this tends to increase the forest biomass price, which in turn may decrease the production of wood-based heat and power. In some cases, it could also decrease pulp and panel production. Policy makers need to be better informed about the many impacts that policies may have.
- Although lost forests are often offset by afforestation elsewhere, it takes decades for a hectare of new forest — which sequesters 1–2 tonnes of carbon per hectare — to compensate for the carbon lost through deforestation. For Europe, the deforestation causes an upfront loss of 25.7 Mt CO_2 yr^{-1} in total, roughly 6% of the sink in the remaining forest. In terms of biodiversity, a hectare of lost (old) forest can in no way be compensated for by a hectare of planted seedlings on former agricultural land elsewhere. Development of options for partially reduced deforestation, increased shelter wood cuttings/restocking modalities and other means for balancing the different objectives are needed.
- The potential annual harvest of biomass from forests for energy in the EU is about 200 million m^3. There is also still plenty of potential and need to strengthen the utilization of industrial wood

residues (e.g. sawdust and chips) and post consumer wood (e.g. packaging materials, demolition wood, timber from building sites). It is estimated that the EU would need around 40,000 person-years in labour input to mobilize the full potential of harvested forest biomass for innovative production of renewable items and subsequently energy − eight-times the number who work in forest energy supply today. To meet this likely shortfall in labour, novel technologies are needed to improve efficiency in forest biomass harvesting, logging, processing and transport.

SECTION 4

Key priority orientations and strategic recommendations related to research and innovation

The key areas for research and innovation for contributing to a social, environmental and economic growth of Agriculture, Livestock and Forestry in a sustainable, climate smart and competitive Europe are identified as follows:

Improve resource efficiency in crop and livestock farming systems

- Since the structure and functioning of the world's ecosystems changed more rapidly in the second half of the twentieth century than at any time in human history. Water withdrawals from rivers and lakes doubled since 1960; most water use (70% worldwide) is for agriculture. More land was converted to cropland in the 30 years after 1950 than in the 150 years between 1700 and 1850. Thus, it is imperative to improve efficiency in the use of water and other resources and to enhance biodiversity. Therefore, the priority today is "sustainability" (MEA, 2013) and promoting agricultural systems which builds on and enhance ecosystems services, so called eco-functional intensification (**Buckwell A. *et al.*;** 2014).
- Agricultural (including livestock) and Forestry Production Systems with increased technical/biological and economic resource efficiency is needed based on combinations of efficient use of limited resources such as water, Phosphorous, fossil based energy and land, improved recycling of nutrients and reduction of waste and emissions. This is linked with innovations to minimize environmental impact of animal production while improving animal health and welfare.
- New R&I models to achieving integration of knowledge for monitoring and management of diseases, nutrient use and use of organic by-products are expected to significantly contribute to the resource efficiency in the production systems. This work should combine classical "genotype by environment interaction" studies and breeding but integrated at systems level following principles from agroecology (Gliessman, 1998; Wezel et al. , 2014).
- Research should focus on using limited resources by robust and efficient production systems also in Livestock. Increased resource efficiency in the livestock sector depends on new innovative management systems at farm level (complementary to implementing already existing knowledge in all farms) as well as at the level of the individual animals (Animal Task Force, 2013). More robust, healthy and efficient animals (ruminants as well as monogastrics) should be developed using combinations of modern genetic methods and thorough phenotypic studies in actual farming systems (using feedback of information from private farms) and tailored to the different livestock systems with market potential including alternative, organic and free range systems. Efficiency is linked with feed utilization including of non-concentrates.
- Moreover, high reproduction and reducing losses due to health problems are key to robust livestock systems, monitoring clinical and sub-clinical diseases, metabolic disorders and production diseases that incorporate Public Health with Animal/Plant Health and Animal Welfare, see below.

- Research and innovation should be driven towards the development of viable systems with alternative protein resources and reducing protein imports into Europe, and reduce competition between feed and food production.
- An integrative approach is needed to improve pasture and grassland management in the livestock sector in a cost-effective, environmentally sound and manageable way that also incorporates animal health and welfare as well as ecosystem services.
- Explore better use of organic re-cycled products, using alternative feed resources for animal feeding and recycling industrial by-products to produce functional food while improving feed chains.

Understand and improve agriculture's role vis-a-vis climate change

- Develop tools to accurately assess the role of agriculture and forestry systems in climate change mitigation and adaptation (FACCE, 2012).
- To support the concept known as 'climate-smart agriculture', studies should be undertaken to assess the risks of climate change for all agricultural and forestry systems and to conclude with simulation models of climate smart, low-emitting, productive, resilient and robust production systems. Particularly new Agricultural Knowledge Science and Technology (AKST) options need to be developed for the reduction of net emissions of carbon dioxide, methane and nitrous oxide.
- Food systems are not only at great risk from climate change; as noted above, they also are a major contributor to greenhouse gas (GHG) emissions that are responsible for such changes. Research and Innovation is thus needed in order to develop GHG mitigation options for food and farming systems including livestock (FACCE, 2012).
- Improve knowledge of how forest ecosystems and the forest-based sector can contribute to reducing carbon emissions and how forests can be adapted to a changed climate as well as to mitigate climate change is needed.

Balance growth and environmental protection through Eco-functional Intensification

- As a response to the drivers and trends re. increased focus on environmental aspects of European agriculture and the need to improve its protection and enhancement of ecosystem services while at the same time provide consistent high output, the terms sustainable intensification or eco-functional intensification are receiving increasing interest and interpretation. This is one major reason why a shift to agro-ecological modes of production is urgently called for (De Schutter, 2014). As a way to improve the resilience and sustainability of food systems, agroecology is now supported by an increasingly broad part of the scientific community (Wezel *et al.,* 2009; 2014). There is a need to study the opportunities for enhancing the positive role of agriculture in providing ecosystem services and minimizing its environmental impacts.

- There is a need to further develop farming practices in crop and livestock production which enhances and benefits from ecosystem services, in the sense of the term "eco-functional intensification" which is parallel to some interpretations of "sustainable intensification". As discussed in a report by the RISE foundation, the term "sustainable intensification when applied to the EU must place most emphasis on the first word", because food production in Europe is already very intensive. This means that focus should be on the intensification in the production of ecosystems services in the wider sense (more environmental elements but including food and feed production) and this must in the future take the form of added knowledge and improved management rather than added physical input (**Buckwell A. *et al.*,** 2014; 3rd Scar Foresight). Thus, there is a need to support the development of eco-functional intensification methods through exploring and supporting a range of possible pathways including low-tillage systems, integrated agro-forestry and crop-livestock systems and organic agriculture. The idea should be to support the development of such different approaches in their own right and for suitable conditions – rather than focusing on experimental systems comparisons. This again requires a research strategy which is open for dedicated actions focusing on specific systems and approaches with a view to the mutual learning options for a wider use of methods developed.

- Within each approach there are a multitude of research and innovation needs for proper management of the bio-physical systems including management of pests, diseases and crop nutrient supply at field and farming systems scales. The objectives are to achieve sufficient yields and quality by proper management practices such as soil use, crop rotation, catch crops and intercropping and integration of perennials and livestock in combination with new tools within ICT and robotics for observation and crop management.
- "Big data" (The Economist, 2014) can be applied to research on good agricultural practices. Big data already exists: regional extension services, private companies related to selection of varieties, or seed production, fertilizers, and pesticides recommendations have also accumulated data on farms. Furthermore, insurance companies have detailed information derived from in-field evaluation and years of explicit monitoring techniques. 'Prescriptive planting' is already a query in economic journals, including links to 'precision farming'.
- While some research has addressed the challenges of sustainable intensification (e.g. IPM methods, inclusion of legumes in crop rotations) there is still a need to further develop and implement agro-ecological practices (including organic agriculture, Action plan, 2014)) for the benefit of soil and biodiversity. It is a challenge that these practices are highly context-dependent and knowledge-intensive and therefore actions should integrate research and innovation by including scientists, industry (advisers, farmers, SMEs) and other relevant stakeholders – when relevant also in landscape and or value chain approaches.
- This work should be linked with innovation into strategies for responses to market opportunities and quality management and social innovations necessary for improved collective management of diversified and multifunctional land-use across landscapes with several farms and stakeholders.
- Research in eco-functional intensification would benefit from collaboration with countries outside the EC. Most notably North America (USA, Canada), Brazil and China where complementary research activities and communities in University and sector research are strong and would supplement the EC research base. Moreover, a wider interest and need for such approaches to agricultural development are also interesting in areas of Asia and Africa with less research capacity which could benefit from joint programs with the EC.

Adapting communities to change

- Research should also focus on re-designing Agriculture, Livestock and Forestry systems on the basis of discussions with society to integrate a regional and economic context and give social and ethical value to the people working with and in these systems and value to the individual animal and plant species living in these systems.

- To redesign the systems, sound analysis of the current situation and future options for production is needed to define the specificities of EU systems, the society expectations, the socio-geographic and demographic changes to be made, the regional differences, etc (Connor D.J. and Minguez, M.I. 2013).
- This requires the development of an integrated approach for the assessment of current systems and their efficiency by developing multi-criteria assessment tools of the systems and food chains. In these analyses broad and extensive coverage to all agricultural and livestock production enterprises should be considered.
- Assessing trade-offs or synergies of agricultural and livestock systems over time. The motivation for green growth is that long-term growth is maximized by paying attention now to resource limits and constraints. This raises questions of trade-offs (or synergies) over time as it implies in many cases that changes in resource use that could have negative short-term impacts on economic growth will enable improved progress in the long term.
- Assessing the impact of coherent policy packages in the achievement of green growth based on the agricultural, livestock and forestry sectors. Achieving green growth is about taking a broader view—both exploring the cost effectiveness of different policy measures in meeting a range of objectives, and identifying the synergies between policies taking into account both the whole food supply chain (vertical connections) and the linkages outside the food chain (horizontal connections); and avoid as far as possible unintended consequences.
- Enhancement of foresight techniques to assess the impact of direct and indirect drivers on agricultural, livestock and forestry systems considering new insights in key drivers.

Improve animal, farmer and consumer welfare by Preventing Animal Diseases

- Prevention, control and eradication of animal diseases should be one of the top research priorities with a strong regard to reducing the use of antibiotics and eliminating agriculture's role in the development of antimicrobial resistance. The ultimate purpose is to reduce the incidence and severity of endemic and emerging diseases, taking into account the characteristics of the pathogens, the species, the farms, the environment and with the objective of improving well-being of animals, farmers and consumers and the economy of the production systems.
- Bio-security, vaccines, rapid and precise diagnostics, disease-resistant genotypes, feeding systems etc., together with cost-effective approaches, are required to combine all system elements into integrated systems for disease control. Immune competence in species should be studied to lead to the development of more robust animals and improved management systems.
- Genetic approaches based on phenotypic markers and use of new tools –'omics' etc. should be developed to provide genotypes with enhanced disease resistance or disease tolerance suited for different housing, management and feeding systems.
- Improved, innovative livestock management practices should be developed interactively with farmer groups to improve preventive routines against diseases and reduce the use of antibiotics. Comparative studies benefitting from knowledge in alternative systems with evidence of very limited use of medicine could be part of research and innovation program. This priority orientation will be informed by the up-coming report from the EC EIP EIP focus group on animal husbandry

focusing on "reduction of anti-biotic use in the pig sector" (http://ec.europa.eu/agriculture/eip/focus-groups/animal-husbandry/index_en.htm) .

- Studies for understanding the interaction between nutritional composition of feed and genetics should be promoted to assess the impact of new feed (re)sources on the nutritional value of livestock products.
- Assess all phases of production to set up good practices at farm level, during animal transportation and at slaughterhouses.
- Studies are required to disentangle the non-welfare concepts from the welfare concepts.
- Research should provide agriculture and society with scientifically sound and practical welfare monitoring tools and methods to improve welfare in an integrated holistic way **(**Sossidou and Szücs, 2007, Sossidou; Sossidou, Szücs and Konrád, 2013).

Further develop Forests and their management and use

The overall aim is achieving increased, sustainable and industrially integrated supply of forest biomass for efficient and value added production of traditional and new, innovative renewable goods and bioenergy by the bio-based industries and forestry in cooperation.

Weather conditions are changing rapidly across Europe. Especially extreme events, such as drought and flooding strongly affect the growth and mortality of European tree species, altering and undermining sustainable forest management and provision of goods and services. Yet, the mechanisms behind the tree response to extreme events are poorly understood although this is essential to come up with accurate estimates of wood production and quality as carbon-storage capacity in different European forest ecosystems under different climate-change scenario's.

Dendrochronology provides high-precision data on growth and climate-growth response functions assessed for forest stands across Europe. Integration with information gained from national forest inventory and remotely sensed data allows to sharpen existing models for calculation of biomass-production and storage capacity as well as stability forest ecosystems under future climate change scenario's; a prerequisite to formulate management tools to enhance the resilience of European forests.

Development of tools for assessing the impact of policy integration between sectors and levels on European forests. Different policy sectors (e.g. forest, climate, energy, nature conservation) have different priorities for forests and their management. This results in distinct forest-related policy problem perceptions (e.g. the need to better protect forests versus the need to mobilize more wood) and related solution strategies (protection versus intensified management). These contradicting views are reinforced by competing actor networks and institutional arrangements (e.g. policy strategies and law). (based on Natura 2000 and Europe's forests. Biodiversity ERA-Net (2014)."

- Efficient forest management, operations and planning should include a strong ability to deliver other requested ecosystem services. Research and innovation in programmes for tree breeding, models for forest regeneration and management and efficient resource planning with respect of bio-production, biodiversity and social benefits is needed.

- Studies to synthesize the best scientific knowledge about carbon neutrality, and point out the inter-linkages between bioenergy and climate policies, and the implications for policy (Address the hidden impacts of policies and trade-offs).
- Development of tools to monitor the forest biomass-based bioenergy production supported by subsidies or other policy means in the EU and assess whether this has an environmentally and economically sustainable basis. This includes assessing the trade-offs and synergies between timber production and nature conservation, particularly in managed Natura 2000 sites.

Increasing plant health / controlling diseases

- Uncertainty in models of plant disease (Pautasso *et al.*, 2013) development under climate change calls for a diversity of management strategies, from more participatory approaches to interdisciplinary science. Involvement of stakeholders and scientists from outside plant pathology disciplines shows the importance of trade-offs, for example in the land-sharing vs. sparing debate.
- Instead of considering the concept of disease, the notion of plant health has so far remained conceptually underdeveloped (Doring, et *al.*, 2011). Despite the importance and high profile of health for agriculture, forestry and conservation biology, plant protection needs to be re-integrated with agronomy, food quality science and ecology, and true primary goals, such as yield, food quality and biodiversity need to be prioritized.
- Plant-associated microorganisms fulfill important functions for plant growth and health (Berg, 2009). Unfortunately, the beneficial plant–microbe interaction was often ignored in breeding strategies although plant-associated microorganisms fulfill important ecosystem functions for plants and soils (Smith *et al*. 1999). The development of agronomy development and plant breeding, including an improved knowledge of the effects of plant-associated microorganisms on plant health and growth, could be relevant to enhance sustainability with less pesticides; they enhance stress tolerance, provide disease resistance, aid nutrient availability and uptake and promote biodiversity (Morrissey *et al*. 2004). Since plant-associated microbial communities show, due to specific secondary metabolism and morphology, a certain degree of specificity for each plant species (Berg and Smalla, 2009), participatory and on-farm research should be promoted.

Increasing crop performance and quality

- The key to resilience, as Charles Darwin made so clear in 'On the Origin of Species', is variation. Above all we need diversity of crop and livestock species; and within each breed of crop and livestock we need as much genetic diversity as possible. Diversity is already explored in plant breeding (Wolfe, 2000) and should be emphasized. Breeding effort for homogeneity, coupled to the increasing convenience of monoculture, now dominates modern farming but some people question the value of this approach to farming and breeding mainly for sustainability. Using landraces and improved heterogeneous varieties become more apparent to achieve greater sustainability. Legislation changes are being made to facilitate this trade too. However, some seed regulation evolutions are needed to promote the exploitation of diversity in landraces and encourage their use (Newton *at al*., 2010; Bocci *et al*., 2011; Louwaars *et al.,* 2012; Lammerts van Bueren and Myers (Eds), 2012).
- Rapid adaptation to climate change and a diversified environment can be rapidly obtained in crop in the framework of participatory research (Goldringer et al., 2006). For example, participatory

plant breeding (PPB) is now adopted in many areas in the world and mainly for organic agriculture in Europe. These breeding organisations take advantage of the specific knowledge of farmers (Chable *et al.*, 2012).

Widening research methodologies; Participatory and trans-disciplinary research

- For innovations and technological developments to be successful, it is important that these are developed together with the farmers and industry since their knowledge greatly contributes to implement scientific findings in practice.
- Previous strategies of agriculture development were to improve agricultural professionals achieving sustainable implementation of research results. Now, stakeholders' expertise can thus help us to prioritize research options in order to simultaneously fill scientific gaps and produce knowledge relevant to practice (Lugnot and Martin, 2013). To encourage farmers' experiments, it is important to develop conditions that support farmers in their experimenting role (Kummer et al., 2012) much in line with ideas of the European Innovation Partnership on 'Agricultural Productivity and Sustainability' (http://ec.europa.eu/agriculture/eip/index_en.htm) .
- A reorientation towards more holistic approaches, including agroecology, has recently been backed by a global international assessment of agriculture S&T for development (IAASTD, 2009). Nevertheless, most of the research organizations and institutions are founded on discipline excellence. First, reorientation will need to understand the past and current trends of agricultural science (Vanloqueren and Baret, 2009) to be able to implement such recommendations. Adopting a social-ecological systems (SES) concept to consider the systemic inter-dependencies among natural and socio-economic processes occurring in particular territories and sectors. Social-ecological systems are linked systems of people and nature, emphasising that humans must be seen as a part of, not apart from, nature (Berkes and Folke, 1998).
- Some approaches tend to exclusively apply agro-ecology as a framework to reinforce, expand or develop scientific research. This is dominant in Europe and the natural sciences (Wezel *et al.* 2009; Wezel and Soldat 2009). However, although this approach may seek to impact broader agro-food systems, it remains mainly grounded in natural science research with analyses at different scales (i.e., farm, landscape, and region) of the agricultural production process, not of the whole agro-food system. To reach the objective of sustainability, we need to include social and cultural issues and to engage the wider social science research (Méndez *et al.*, 2013). We need to support an agroecological approach developed from firm roots in the sciences of ecology and agronomy into a framework that seeks to integrate transdisciplinary, participatory and action-oriented approaches, as well as to discuss political-economic issues that affect agro-food systems (Gliessman 2007; Méndez 2010). We consider transdisciplinary approaches as those that value and integrate different types of knowledge systems, which can include scientific or academic disciplines, as well as different types of knowledge systems (i.e., experiential, local, indigenous, etc.), as well as adopt a problem-based focus (Dawson *et al*., 2013; Pimbert , 2011).
- Following the above rationale an important option is to evaluate traditional knowledge ('prema-culture') existing in some areas such as sheep and goat farming in less favored areas of some European countries in relation to the local communities and economies and the production of high quality products (cheese, yogurt, etc.) (Ligda *et al*, 2013; Tzouramani *et al.*2013).

- Research and innovation should be driven towards improved knowledge exchange with farmers and industry. This is the aim of the agricultural European Innovation Partnership (EIP-AGRI), which works "to foster competitive and sustainable farming and forestry that 'achieves more and better from less'. It contributes to ensuring a steady supply of food, feed and biomaterials, developing its work in harmony with the essential natural resources on which farming depends". Europe will favor the creation of an 'interactive innovation model' instead of the 'linear innovation model'. The EIP-AGRI adheres to the 'interactive innovation model' which focuses on forming partnerships - using bottom-up approaches and linking farmers, advisors, researchers, businesses, and other actors in Operational Groups. Such an approach to research and innovation for a sustainable agriculture will stimulate innovation from all sides: technological, non-technological, organizational and social and based on new or traditional practices. This can be linked with developments in use of ICT and web based social networks for knowledge exchange, see above.
- It is a general aim of H2020 to include and demand collaboration with SME's as part of research and innovation. This is important also for the above Key priority orientations. However, in many cases this would include farmers or advisory/extension organisations rather than commercial companies. For example, innovations in eco-functional intensification does not necessarily involve the development and use of new marketable input items, rather improvement in the organisation and use of knowledge. In areas of organic and low input agriculture the range of SME's involved in selling inputs to farmers is limited. On the other hand, collaboration might include SME's involved in the processing or marketing of farm products or in the development of tools for automation and monotoring.
- A number of research areas would benefit for international collaboration outside the EC.

SECTION 5

What success would look like

A successful implementation would help developing new concepts of **Good agricultural practices, integrating better** agroecological practices as guideline for Code of conduct to farmers. This in combination with more efficient use of resources could improve profitability for the farmer and diminish environmental impacts of the intensification of cropping and livestock systems. The idea that growth in the agricultural sector may in fact be combined with improved preservation of natural capital through eco-functional intensification needs verification but if successful could secure multiple goals in Europe including:

- More jobs and a reduction of depopulation of rural areas
- Increased food/feed security also in light of climate change and reduced dependence on feed imports
- Improved environment and securing ecosystems services in a wider sense for the benefit of agriculture and Europe's population in general including recreational purposes
- Increased multi-functionality of agriculture and forestry on the one hand, and better use of land in Europe on the other hand.
- A more robust agriculture vis-à-vis economic and environmental/climate changes
- Improving health care management in livestock would improve animal and farmer welfare improve robustnes and lead to reduce impact of agriculture on antimicrobial resistance and provide better quality for consumers.
- Decrease indirect impacts of land use in other continents.

- Innovation and implementation of tools for precision (livestock) farming and forestry
- A change in the mind set on integrated land-use management is needed to achieve effective carbon mitigation: forests should be valued for all of the environmental services they provide. When management schedules are being revised, the trade-offs with other forest goods and services should be carefully considered. Manifesting the multifunctionality of forest, including its carbon sink capacity, goes beyond the boundaries of the forest sector. Integrated land-use is necessary to achieve an overall balance of functions, incorporating carbon sequestration, both within and outside forests.
- Tackling the challenges outlined above will require better coordination of the policies that affect forest and forest management at the national, EU and pan-European levels (for example, on energy, biodiversity and rural development, as well as the new Common Agricultural Policy, the Forest Strategy and Forest Europe policies). Only then will the multifaceted carbon mitigation functions of forests be fully exploited.

References

Alexandratos, N & Bruinsma, J; 2012: World Agriculture towards 2030/2050. FAO.

Action Plan for the future of Organic Production in the European Union, EC, COM (2014) 179 final

Animal Task Force White Paper (2013), Research and Innovation for a sustainable livestock sector in Europe, April 2013

Berkes F and Folke C (1998) Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience, Cambridge University Press, New York

Berg G, Smalla K (2009) Plant species and soil type cooperatively shape the structure and function of microbial communities in the rhizosphere. FEMS Microbiol Ecol 68:1–13

Berg, G. (2009) Appl Microbiol Biotechnol 84:11–18 DOI 10.1007/s00253-009-2092-7

Bocci R, Chable V, Kastler G, Louwaars N (2011) Farm Seed opportunities, recommendations for on farm conservation in Europe. In Agrobiodiversity Conservation: Securing the Diversity of Crop Wild Relatives and Landraces, Eds Nigel Maxted , Ehsan Dulloo, Brian V. Ford-Lloyd, Jose M. Iriondo, M. A. A. Pinheiro de Carvalho, CABI Publishing, 400p

Brussaard, L., Caron, P., Campbell, B., Lipper, L., Mainka, S.,
Rabbinge, R., Babin, D. and Pulleman, M. 2010. Reconciling
biodiversity conservation and food security: scientific challenges
for a new agriculture. Curr. Opin. Environ. Sustain. 2: 1_9.

Buckwell A. *et al.* (2014) Sustainable Intensification of European Agriculture. A review sponsored by the RISE foundation. 96 pp

Cassman, K.G. 2012. Editorial, What do we know about global food security? Global Food Security (1), 81-82

CDC, 2014: Antibiotic Use in Food-Producing Animals. Tracking and Reducing the Public Health Impact. Centers for Disease Control and Prevention. http://www.cdc.gov/narms/animals.html

Chable V, Louwaars N, Hubbard K, Baker B, Bocci R (2012) Plant Breeding, Variety Release and Seed Commercialisation: Laws and Policies of Concern to the Organic Sector. E.T. Lammerts van Bueren & J.R. Myers (Eds), 2012. Organic Crop Breeding. Wiley-Blackwell, Hoboken, NY, USA ISBN: 978-0-470-95858-2

Connor , DJ and Mínguez MI. 2012. Evolution not revolution of farming systems will best feed and green the world. Global Food Security 1: 106–113.

De Schutter O (2014) Report of the Special Rapporteur on the right to food, Final report: The transformative potential of the right to food (http://www.srfood.org/en/final-report-to-un-human-rights-council

Dawson JC, Rivière P, Berthellot JF, Mercier F, de Kochko P, Galic N, Pin S, Serpolay E, Thomas M, Giuliano S & I Goldringer (2011) Collaborative Plant Breeding for Organic Agricultural Systems in Developed Countries. Sustainability 3(8): 1206-1223; DOI:10.3390/su3081206 Dore´ , T., Makowski, D., Male´zieux, E., Munier-Jolain, N., Tchamitchian, M. and Tittonell, P. 2011. Facing up to the paradigm of ecological intensification in agronomy: Revisiting methods, concepts and knowledge. Eur. J. Agron. 34: 197_210.

Doring TF, Pautasso, M, Finckh MR, Wolfe MS (2011) Concepts of plant health - reviewing and challenging the foundations of plant protection.Plant Pathology 61(1):1-15 DOI: 10.1111/j.1365-3059.2011.02501.x

EC, COM (2014) Action Plan for the future of Organic Production in the European Union, 179 final

European Environmental Agency, 2010. The European environment – State and Outlook 2010. Available on-line: http://www.eea.europa.eu/soer/synthesis/synthesis

FACCE, 2012: The Strategic Research Agenda of the Joint Programming Initiative on Agriculture, Food Security and Climate Change (FACCE – JPI). **https://www.faccejpi.com/faccejpi/Strategic-Research-Agenda**

FAO (2010) Biodiversity for Food and Agriculture: Contributing to food security and sustainability in a changing world, Expert Workshop by FAO and the Platform on Agrobiodiversity Research, 14-16 April, Rome, Italy

Gliessman SR (2007), Agroecology: The ecology of sustainable food systems (2nd ed.)

Gliessman, SR. (1998) Agroecology: Ecological Processes in Sustainable Agriculture, Ann Arbor Press, Chelsea, MI

Godfray HC, Beddington JR, Crute IR, Haddad L., Lawrence D. , Muir JF, Pretty J., Robinson S., Thomas SM, Toulmin C (2010) People Food Security: The Challenge of Feeding 9 Billion Science 327, 812 (DOI: 10.1126/science.1185383)

Goldringer I, Prouin C, Rousset M, Galic N and Bonnin I (2006) Rapid Differentiation of Experimental Populations of Wheat for Heading Time in Response to Local Climatic Conditions, Annals of Botany 98: 805–817doi:10.1093/aob/mcl160

IAASTD (2009) Agriculture at a Crossroads, Sythesis Report

Ittersum M, Cassman KG, Grassini P, Wolf J, Tittonell P, Hochman Z (2013) Yield gap analysis with local to global relevance—A review. Field Crops Research 143:4–17

Jacobsen, S E, Sorensen M, Weiner J (2013) Agronomy for Sustainable Development, Volume: 33 , Issue: 4, 651-662.

Jespersen, L. Melby, Jens Peter Hansen, Gianluca Brunori, Allan Leck Jensen, Kirsten Holst, Camilla Mathiesen, Niels Halberg and Ilse Ankjær Rasmussen, 2013. ICT and social media as drivers of multi-actor innovation in agriculture – barriers, recommendations and potentials. In : "

AGRICULTURAL KNOWLEDGE AND INNOVATION SYSTEMS TOWARDS 2020. SCAR-Collaborative Working Group AKIS-2, Brussels.

Kummer S, Milestad R, Leitgeb F and Vogl CR (2012) Sustainable Agriculture Research; Vol. 1, No. 2 Building Resilience through Farmers' Experiments in Organic Agriculture: Examples from Eastern Austria, Vol. 1, No. 2, ISSN 1927-050X E-ISSN 1927-0518

Ligda C Sossidou E , Araba A , Lauvie, A, Hadjipavlou G. (2013), The role of sheep and goat breeds' value chains in the rural development in the Mediterranean Region (Invited presentation in session 20b: S&G Economics and marketing) Coordination of the Agricultural Research in the Mediterranean Area, Proceedings of the 10th International Conference on Modern Aspects on Livestock Production, 2-4 October 2013, Belgrade

Lugnot, G. Martin (2013) Reg Environ Change 13:1145–1155 DOI 10.1007/s10113-013-0426-6 Susanne McIntyre, B., Herren, H. R., Wakhungu, J. and Watson, R. T. (eds.) 2009. Agriculture at a crossroads. Synthesis Report and Global Summary for Decision makers, IAASTD. [Online] Available: www.agassessment.org/reports/IAASTD/EN/Agri culture%20at%20a%20Crossroads_Synthesis%20Report%20 (English).pdf [2011 Dec. 04].

Méndez VE (2010), Agroecology. In Encyclopedia of geography, ed. B. Warf, 55–59. Thousand Oaks, CA: Sage

MEA; 2005: Millenium Ecosystems Assessment. Ecosystems and human wellbeing: Biodiversity, synthesis. World Resources Institute, Washington, DC. [Online] Available: www.maweb.org/en/Synthesis.aspx [2011 Dec. 04].

Morrissey JP, Dow JM, Mark L, O'Gara F (2004) Are microbes at the root of a solution to world food production? EMBO Rep 5:922–926

Nelleman, C., MacDevette, M., Manders, T., Eickhout, B., Sivhus, B., Prins, A. G. and Kaltenborgn, B. P. (eds.) 2009. The environmental food crisis _ The environment's role in averting future food crises. A UNEP rapid response assessment, United Nations Environment Programme, GRID-Arendal. [Online] Available: www.grida.no [2011 Dec. 04].

Newton AC, Akar T, Baresel JP (2010) Cereal landraces for sustainable agriculture. A review. Agronomy for Sustainable Development, Volume: 30 Issue: 2 Pages: 237-269

Pautasso M, Döring TF, Garbelotto M, Pellis L, Jeger MJ (2013), Eur J Plant Pathol, Impacts of climate change on plant diseases—opinionsand trends, DOI 10.1007/s10658-012-9936-1

Pimbert M (2011) Participatory Research and On-Farm Management of Agricultural Biodiversity in Europe. IIED, London

Power AG (2010) Ecosystems services and agriculture:tradeoffs and synergies, Phil. Trans. R. Soc. B 27 September 2010, vol 365 no. 1554, 2959-2971.

Regmi, A. & Meade, B., 2013. Demand side drivers of global food security. Global food security (2), 166-171.

Smith KP, Handelsman J, Godman RM (1999) Genetic basis in plants for interactions with disease-suppressive bacteria. Proc Natl Acad Sci USA 9:4786–4790

Sossidou, E N (2002) Statistical modeling of livestock production systems to support sustainable management of physical resources" (2002) In: Book of Proceedings, International Conference "Agricultural Statistics in the new Millennium: The Challenge of agri-environmental indicators as a tool for the planning of sustainable development for agriculture", 13-15 November, Chania, Greece : 209-215

Sossidou E and Szücs E (2007), Farm Animal Welfare, Environment and Food Quality Interaction Studies, ISBN 978-960-89849-0-5

Sossidou E, Szücs E and Konrad S (2007), Farm Animal Welfare and Product Quality, ISBN 978-960-98079-1-3

The Economist (2014), Digital disruption in the farm

The Millennium Ecosystem Assessment Series (2013) http://www.unep.org/maweb/en/index.aspx Ecosystems and human well-being: synthesis ISBN 1-59726-040-1

Tzouramani,I., Sossidou E., Casabianca F., Hadjipavlou G., Araba A. and Ligda C. (2013), Mediterranean biodiversity as a tool for the sustainable development of the small ruminant sector (Poster in session 22b: S&G), EAAP meeting, Nantes, August 2013,

Underwood, E et al., 2013. Options for sustainable food and agriculture in the EU. Synthesis report of the STOA Project 'Technology Options for Feeding 10 Billion People'. Institute for European Environmental Policy, European Parliament. London/Brussels. Available on-line: http://www.europarl.europa.eu/RegData/etudes/etudes/join/2013/513539/IPOL-JOIN_ET%282013%29513539%28SUM01%29_EN.pdf

Wegener, H. C., 2012: ANTIBIOTIC RESISTANCE—LINKING HUMAN AND ANIMAL HEALTH. In: Improving Food Safety Through a One Health Approach: Workshop Summary. Institute of Medicine (US). Washington (DC): National Academies Press (US); Available at: http://www.ncbi.nlm.nih.gov/books/NBK114485/#_ncbi_dlg_citbx_NBK114485

Wezel A., Bellon S, Dore T, Francis C, Vallod D, and David C (2009) Agroecology as a science, a movement and a practice. A review.Agronomy for Sustainable Development 29: 503–515. DOI:10.1051/agro/2009004

Wezel A. and Soldat V (2009) A quantitative and qualitative historical analysis of the scientific discipline of agroecology, International Journal of Agricultural Sustainability, vol. 7, No. 1, pp. 3–18. **Wezel A, Casagrande M. Celette F, Vian, JF, Ferrer A, Peigne J** (2014) Agroecological practices for sustainable agriculture. A review. Agronomy for Sustainable Development, Volume: 34 Issue: 1 Pages: 1-20, DOI: 10.1007/s13593-013-0180-7

Wolfe MS (2000) Crop strength through diversity Nature 406, 681-682 (17 August 2000) | doi:10.1038/35021152

Vanloqueren G, Baret PV (2009) How agricultural research systems shape a technological regime that develops genetic engineering but locks out agroecological innovations Research Policy 38 (2009) 971–983

Yongfei Hu, Xi Yang, Na Lu, Baoli Zhu, 2014:
The abundance of antibiotic resistance genes in human guts has correlation to the consumption of antibiotics in animal. Gut Microbes.; 5(2): 245–249. Published online 2014 January 31. doi: 10.4161/gmic.27916

3 GREEN BIOMASS FOR SYNERGY IN AGRO-ECOLOGICAL LAND USE, FOOD and NON-FOOD PRODUCTION

SECTION 1

Priorities selected from the Specific Program

In reference to the introduction to section 2.1 in the Specific Programme, Sustainable agriculture and forestry there is a need to intensify land use and crop production for food use and alternative uses of biomass including reducing European protein import and - at the same time - deliver ecosystems services and improve agricultural resilience. This calls for ecological intensification for the benefit of conventional and organic agriculture (2.1.1) which again means looking for synergies in the development of integrated and diverse production systems with increased adaptive capacity. This is linked (across thematic areas) to the goal of finding non-food competitive biomass (2.4.1) through sustainable land use systems. Agriculture is moreover expected to deliver important ecological services (2.1.2). It is a controversial hypothesis whether such synergies (between increased production and economic output and improvement of agriculture's environmental sustainability) may in fact be found and delivered and this will require new innovations at different levels of scale, from crop, field and forest level to farming and forestry systems and landscape planning in combination with bio refinery techniques and market development as well as social and organizational innovations.

SECTION 2

Drivers and Trends

(this section is to be seen in continuation of the section two in chapter 2)

Drivers:

The last decade has changed the general view on future food sufficiency from a more optimistic view at the turn of the century to one of concern over declining yields growth rates and threats to the natural resources food production depends on[17].

Population changes and the rapidly developing middle class in middle income countries increase global demands for livestock products and – therefore – protein crops for feed, which again puts pressure on land use[18]. Currently the increasing global demand for animal based food products combined with abolition of e.g. milk quotas is beginning to stimulate European entrepreneurial farmers to increase production. Also, the wish to replace fossil based energy and chemicals with biomass reinforces the trend to focus more on increasing crop yields per ha. On the other hand environmental pressure from intensive farming practices has increasingly become societal issues[19+20] as expressed in the debates over the so-called Greening of the CAP. Large farming areas in Europe have developed into monoculture of annual crops grown with high

[17] Cassman, K.G. 2012. Editorial, What do we know about global food security? Global Food Security (1), 81-82

[18] For example It is expected that Chinese meat import will increase by 3500 % by 2050: http://www.efeedlink.com/contents/05-21-2014/562d0bf3-9397-44fe-95f1-d4c5ce8c58f2-b531.html

[19] European Environmental Agency, 2010. The European environment – State and Outlook 2010. Available on-line: http://www.eea.europa.eu/soer/synthesis/synthesis

[20] Underwood, E et al., 2013. Options for sustainable food and agriculture in the EU. Synthesis report of the STOA Project 'Technology Options for Feeding 10 Billion People'. Institute for European Environmental Policy, European Parliament. London/Brussels. Available on-line: http://www.europarl.europa.eu/RegData/etudes/etudes/join/2013/513539/IPOL-JOIN_ET%282013%29513539%28SUM01%29_EN.pdf

levels of external input resulting in loss of farmland biodiversity and soil quality[21+2]. According to some schools this reduces the agricultural sector's ability to withstand the changing climate, thus its resilience and sustainability. New scientific forecasts project that European wheat production will suffer dramatically from changing weather[22] and that there is a strong need for development of adaptation strategies. The scarcities foreseen in resources such as soil fertility, Phosphorus, biodiversity and water will affect agricultural development (see foot note 3). This is why a trend is growing to suggest that the development of an integrated approach to agricultural development building on agro-ecological practices[23] and combinations of food and non-food production with increased use of perennial crops[8)] could reduce vulnerability by improving resilience at farm, landscape and societal levels against climate change and fluctuations in yields and food prices. This, in combination with increasing consumer demand for organic and other environmentally friendly products calls for further development and documentation of such methods[8)].

The necessary focus on global and European food security means that biomass used for non-food products should come from non-food competitive biomass sources. Thus, attempts to develop the bioindustry based on biorefinery technologies aiming at non-food markets should be assessed at their capacity to satisfy food and feed demand complementary to the use of biomass for non-food products. Relatively well established sources of biomass includes waste from food industry, livestock manure and the so-called *yellow biomass* which includes straw and other dry and/or lignified crop residues. The following ideas will focus on green types of biomass such as sugar beets, alfalfa and grass-legume mixtures or other perennials suitable for combined food, feed and bio refinery production. ("green" is thus referring to the crop type and its harvest time and use only, not as an environmental branding). These partly perennial crops often have higher yields per hectare compared with cereals and other annual crops and might be used fresh or after conservation for example by drying or ensiling. They also in most cases have higher yields of dry matter per hectare compared with cereals, annual legumes and oil seeds, so potentially they could provide material for non-food use without compromising the supply of feed to livestock. This is a hypothesis worth testing.

The hypothesis is that land use should move from single purpose monoculture to more diversified cropping systems including use of perennials and this might - at the same time - reduce environmental pressure, improve ecosystems services and increase the total biomass production for food and non-food purposes[24],[25]. Moreover, marginal lands and perennial grasslands are underused in Europe, due to intensification of ruminant production leaving a potential resource underused and threatening high value nature landscapes including agro-forestry landscapes. This is a second type of possible supply of green biomass for bio refineries which does not reduce food production.

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[21] 3rd SCAR Foresight Exercise – Sustainable food consumption and production in a resource-constrained world. February 2011

[22] Trnka, M. Et al, 2014: Adverse weather conditions for European wheat production will become more frequent with climate change, Nature Climate Change (2014) doi:10.1038/nclimate2242

[23] Wezel at al., 2014: Agroecological practices for sustainable agriculture. A review. Agronomy for Sustainable Development, 34: 1-20.

[24] Asbjornsen, H. Et al. 2014: Targeting perennial vegetation in agricultural landscapes for enhancing ecosystems services. Renewable Agric. And Food systems (29) 101-125, (324 references).

[25] Gylling, M. Et al. 2012. The + 10 mio. Tonnes plan – options for increased production of sustainable biomass for biorefineries in Denmark.

A Danish feasibility study demonstrated a potential 300% increase in biomass availability for non-food purposes without compromising food production and with positive environmental impact by shifting app. 20% of the present cereal and rape seed production to higher yielding crops for green biomass in the form of beetroots and grass-legume crops (Figure 1). If app. 10% of this green biomass is converted to livestock feed this would compensate for the reduced feed grain area under the "environmental scenario".

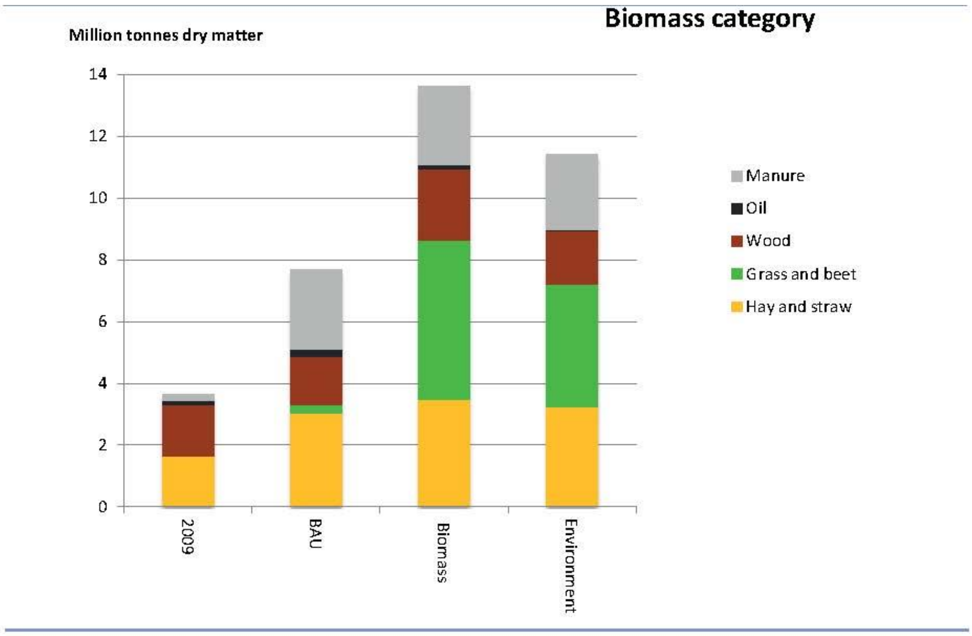

Figure 6. Biomass categories in the scenarios and in 2009. Yellow biomass is hay and straw, Green biomass is grass and beet. Brown biomass is wood. Grey biomass is animal manure. Oil is rapeseed oil.

Thus, using these two resources of green biomass could support an ecological intensification respectively preservation and provide non-food biomass without reducing food production. Moreover, creating a market chain for biorefinery products based on green biomass would allow non-livestock farmers to diversify land use into more grass-clover based cropping systems or otherwise integrating perennials in land use[7)]. This emerging opportunity has the potential to pull the development of European agriculture into a more sustainable and socially accepted development pathway which could solve several challenges for the sector and allow for a balanced, eco-functional intensification taking into account a range of objectives. However, there are challenges for such an approach, not the least in securing a high quality feed for livestock to replace the reduced direct feed production.

SECTION 3

Bottlenecks, future challenges, gaps in R & I, potential threats

Taking long term trends in scarcities into account there is a need and opportunity to support R&I in agro-ecologically[6] based intensification of land use for food, non-food and other ecosystems services in combination with integrated use of the biomass in cascade bio-refineries providing high quality feed and food ingredients, other high value chemicals and ultimately bioenergy[26] . In order to support the pull of agriculture, forestry and bio economy sectors jointly in the suggested direction a joint effort of Research and Innovation is needed in combination with other tools such as market development and policies. The need for developing at the same time 1) value chains for alternative use of biomass and 2) the resilient, environmentally friendly and economic farming and forestry systems and 3) the related processing methods for the green biomass into valuable products presents a triple and interconnected bottleneck. The development of agro-ecologically based intensification (i.e. ecofunctional intensification, see also chapter 1) as a basis for addressing consumer expectations for high quality food including organic[27] faces gaps in R&I and there is a need for innovations in how to integrate higher yielding perennials for green biomas into cash crop rotations and intensively cropped landscapes. Moreover, there is a need for similar feasibility studies - as the cited Danish one - of the potential advantages of perennialization of land use for increasing total biomass production and its dual implications for food, feed and ecosystems services in different European regions[28]. This should be linked with further development of the ILUC methodology for assessing the indirect consequences of such land use changes on countries outside Europe.

Another bottleneck is the technologies themselves for converting green biomass into valuable products in a cascade processing chain including returning waste and nutrients to the land[7)].

It is a risk that the previous focus on 1st generation biofuels – which proved not to be sustainable – could be hampering support and development of second generation bio refineries. Recent developments in fuel prices and fossil fuel reserves slow the demand for renewable energy.

While some research has addressed the challenges of sustainable intensification (e.g. IPM methods, inclusion of legumes in crop rotations, ..) there is still a need to further develop and implement agro-ecological practices including organic agriculture[29] for the benefit of soil and biodiversity. It is a challenge that these practices are highly context dependent and knowledge intensive.
Moreover, in dry regions, especially Mediterranean areas, water may limit severely the biomass production and there can be a difficult tradeoff between biomass harvest vs protection of soil and landscapes and water resources. Thus, research should be sensitive to regional contexts and closely linked with regional and local innovation efforts and should involve advisors and farmers directly in farming systems approaches, such as foreseen in the EIP. Moreover, important solutions will need a coordinated landscape/food catchment ("food shed") approach where methods and practices are developed to secure participatory planning of agricultural production in light of soil, water, pest management, biodiversity and other ecosystem services[30]. This requires a new approach to integrating socio-economic research in a form which supports the pro-active and management oriented focus of agro-ecology.

SECTION 4
Key Priority orientations: Inputs, strategic recommendations related to research and innovation

[26] Bio-based industries, in Innovation for sustainable Growth, A bioeconomy for Europe, EC 2012
[27] Action Plan for the future of Organic Production in the European Union, EC, COM(2014) 179 final
[28] According to the European Bioeconomy observatory there is no recent inventory of actual or potential biomass production for biorefineries, D. Plan, JRC, Brussels, pers. Comm.
[29] Action Plan for the future of Organic Production in the European Union, EC, COM(2014) 179 final
[30] 3rd SCAR Foresight Exercise – Sustainable food consumption and production in a resource-constrained world. February, 2011

The transformation described depends on an integrated approach where research and innovation is backed by support to market development and public regulation in order to realize the potential synergies. Cross-cutting research and innovation efforts are needed to combine 1) technological development within bio-refinery of green biomass into feed, non-food and energy products with 2) developing sustainable land use and cropping systems in a cradle to cradle perspective and 3) with due consideration for a wide understanding of *ecosystem services* and searching for synergies between them.

1) Research in bio-refinery technologies should be seen in light of efforts planned under the BIC (Bio-based Industries Consortium PPP) supporting the BIC strategy and be integrated with product development in cascade organization including the use of biomass fractions for high value livestock feed and possibly non-food uses of biopolymers. Focus under the SC would thus be complementary in terms of more strategic research and development (i.e. lower TRLs) and in focusing on handling and refining green (fresh) biomass complimentary to existing and planned innovations in use of yellow biobas (e.g. straw, forest residues) and waste.
2) Agro-ecological research and innovation into the potential for ecological intensification of land use including agro-forestry and forestry and the relations with land use, thus also including perspectives of scale and spatial localization. This should be combined with innovations in harvest technology and new technologies (precision, robotics and automation technology, ICT, sensor technology and remote sensing for high precision monitoring and measurement systems and decision support systems for operational planning) for rational, competitive and environmentally friendly procurement of food and green biomass from different farming and forestry systems - including organic and other low input systems - and under a variety of European contexts. Specific challenges in the Mediterranean areas with lower rainfall and biomass production and the different impacts of climate change over different regions should be included. New, innovative farming and land use systems demonstrating synergies through combined food and biomass production should be developed and documented, in actor oriented processes linked to EIP.
3) The relation to other *ecosystem services* and the *public goods* delivered from organic and conventional land use systems should be integrated in research and development including impacts on biodiversity, soil quality and water resources.
4) Socio-economic research should be integrated but with a strong focus on applied and pro-active – rather than solely descriptive/analytical – approaches and linked to ecological economics and life cycle assessments of the land use and bio-economy value chains.

A number of pioneering research and innovation platforms pursuing the described objectives of green biomass for bio-refineries exist in some European countries (Austria, Denmark, Germany, Sweden, Netherlands, …?) but should be backed more systematically and with more focus on researching potential synergies between agro-ecological, agro-forestry and forestry land use practices and refining of green biomass including the improved use of ICT tools. A key approach might be the use of pilot farm and landscape sites for comparison of best strategies under different regional conditions (including temperate and Mediterranean conditions) in terms of natural resources and socioeconomic conditions and including aspects of resilience towards future challenges and risk management.

Last but not least, there is an interdependence between developments in diets towards high consumption of meat and high-energy convenience food and a dual relationship with –on the one hand- the increased incidences of food related health challenges and – on the other hand- the intensification of agriculture, livestock production and food systems. Therefore, the concept of "One-Health", which was developed as an answer to the challenges of food borne diseases from livestock, should be seen in the broader sense of interrelationships between developments in diets and agricultural/food systems and such an understanding should guide cross-sectoral research efforts, thus internalizing food demand and diets into the agricultural development pathways.

The R&I efforts will involve industry including SME's and should be aligned with efforts by the EC bio-economy panel and the Bio-economy observatory.

SECTION 5

How the success would look like

A successful implementation would help transforming monoculture annual cropping systems into diversified and resilient landscapes providing more and improved ecosystems services and public goods while producing higher total biomass yields with reduced environmental load. Reversing the negative trends towards improving soil fertility and agri-biodiversity together with diversified and organic farming systems would improve the resilience of ecosystems services including pollination in light of challenges from increased demands for food and biomass and climate change.

This would be linked to the development of locally or regionally based bio refinery processing plants which create high value products such as high quality protein for humans and to replace livestock feed import, Carbohydrates with special characteristics, and bioenergy of residuals in a cascade processing unit. Such an agro-ecological development could benefit organic and conventional farming sectors and would place Europe as part of a global growth scenario for agriculture and provide valuable examples for a similar clever intensification in other global regions. Moreover, this could support the livestock sector in a sustainable development towards European feed self-sufficiency and improved recycling of waste. This is particularly a challenge for the organic sector[8)].

Technical and economic success criteria would be supplemented with social innovation in terms of organization of new business forms and coordinated supply of diverse range of ecosystem services at landscape ("foods scape") levels of scale.

Indicators for positive change would partly be existing agri-environmental indicators (as used currently by European Environmental Agency), indicators for use of renewable energy sources and new indicators for e.g. replacement of fossil dependent chemicals for industrial purposes.

4 BIOBASED INDUSTRY AND NEW GENERATION BIOREFINERIES INTEGRATED WITH THE TERRITORY: Opportunities for sustainable growth of rural and coastal areas

INTRODUCTION:

Europe has a unique potential in terms of research & innovation, besides a cultural and political context that creates the necessary basis for the developing of bioeconomy,[31] biorefineries[32] and the bio-based industries in line with food and feed security and environmental objectives. The achievement of such goal requires a major effort for the harmonization of technological, economic and social innovation, while **modeling, forecasting and monitoring the impact** of the planned innovation.

European bioeconomy can now draw its own route towards the development of new-generations **biorefineries integrated on European specific territories and communities**, capable to **process** their own sustainable **resources**, thus looking beyond the competition with those "first mover Countries" (e.g. US, Brazil and China) that aggressively pushed the development of first-generation industrial biorefineries, mainly investing on massive use of food crops.

The overall R&I objective is to reduce the Union's dependency on fossil fuels and contribute to meeting its energy and climate change policy targets for 2020 (10 % of transport fuels from renewables and a 20 % reduction of greenhouse gas emissions)[33] while creating growth and employment.

Nevertheless, a **balanced development of bioeconomy** is not achievable through the application of solutions having general validity for any regional context, but rather solutions must rise from the **analysis of opportunities and risks associated to the local and regional situation.** Conversely, ad-**hoc criteria for the assessment of impact** of biorefineries at regional level are requested.

SECTION 1

Priorities selected from the specific program

1.1 Rural[34] and coastal areas

Selected priorities:

2.1.3. Empowerment of rural areas, supporting policies and rural development

2.1.1.Increasing production efficiency and coping climate change while ensuring sustainability and resilience

2.5.3. Cross- cutting concepts and technologies enabling maritime growth.

According to Council Regulation (EC) No 1257/9964, less-favoured areas (LFAs) can be classified into three categories, each of which describes a specific cluster of handicaps which threatens the continuation of agricultural land use.

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[31] http://ec.europa.eu/research/bioeconomy/pdf/official-strategy_en.pdf

http://www3.weforum.org/docs/WEF_FutureIndustrialBiorefineries_Report_2010.pdf

http://www.epsoweb.org/file/560

[32] [32] European Biorefinery Joint Strategic Research Roadmap, Star-COLI BRI, 2011

[33] Estimates conclude that a shift to biological raw materials and biological processing methods could save up to 2,5 billion tons of CO 2 equivalent per year by 2030, increasing markets for bio-based raw materials and new consumer products substantially.

[34] The term "rural areas" is used according to the OECD terms and methodology, explained in the EU publication 'Agriculture and the EU: statistical and economic information 2012' (http://ec.europa.eu/agriculture/statistics/rural-development/2012/full-text_en.pdf

- **Mountain areas** (Article 18) are handicapped by a short growing season because of a high altitude, or by steep slopes at a lower altitude, or by a combination of the two.
- 'Other' less favoured areas (Article 19) are **in danger of abandonment of agricultural land**-use where the conservation of the countryside is necessary. They exhibit the following handicaps: land of poor productivity; production which results from low productivity of the natural environment; and a low or dwindling population predominantly dependent on agricultural activity.
- Areas affected by specific handicaps (Article 20) are areas where farming should be continued in order to conserve or improve the environment, maintain the countryside, and preserve the tourist potential of the areas, or in order to **protect the coastline**.

More than half of the agricultural land in the EU-27 is classified as LFA and most of this land is in danger of abandonment.[35] The incidence of the three LFA categories varies among Member States, as shown by the Figure 1.

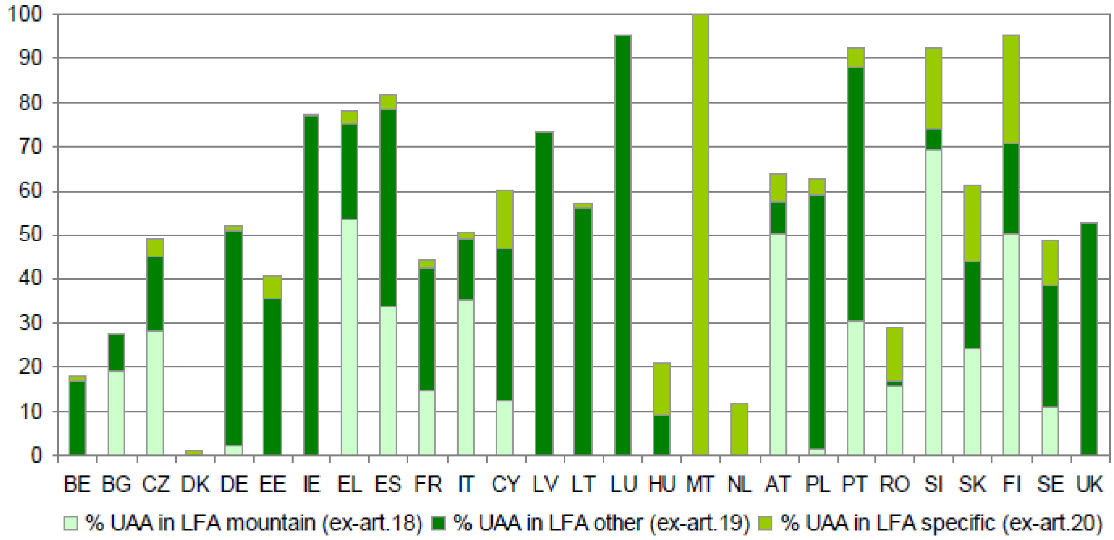

Figure 1: Incidence of LFA categories among Member States (http://ec.europa.eu/agriculture/statistics/rural-development/2012/full-text_en.pdf)

With over 56 % of the EU population living outside of towns and with rural areas accounting for 90% of the territory of the 27 Member States - rural development is a vitally important policy area. **Farming and forestry** remain crucial for the management of natural resources in the EU's rural areas as well as a platform for economic diversification in rural communities.[36]

[35] According to data reported by MSs in 2005 (and from 2007 in case of BG and RO) 65, in the EU-27, more than half of the total UAA (54%) has been classified as LFA. The highest share is taken up by 'other' LFA (34%), followed by mountain areas (16%).

[36] As a result of the economic crisis, the unemployment rate for the EU-27 reached 9.6% in both 2010 and 2011. In terms of number of people, this 9.6% represented around 23 million unemployed persons (6 million more than in 2007). In 2010, 5 million unemployed lived in predominantly rural regions, 8 million in intermediate regions and the highest number, 9.7 million, in predominantly urban regions.

http://enrd.ec.europa.eu/evaluation/en/

A further specific challenge is faced by **coastal areas**, where there is the need to address the problem of preservation of ecosystems through a sustainable management of maritime and coastal activities that must recognize the needs of society to benefit from marine resources and allowing sustainable use of those resources. Currently, more 200 million European citizens live near coastlines, stretching from the North-East Atlantic and the Baltic to the Mediterranean and Black Sea.[37] The Commission launched on 12 March 2013 a **new joint initiative**[38] on integrated coastal management and maritime spatial planning to ensure the sustainability and environmental health of the various uses in marine and coastal areas, maritime spatial planning and coastal management, while employing an approach that respects the limits of ecosystems.[39]This is expected to have economic benefits as natural resources are often an essential basis for activities such as fishing and aquaculture, but tourism[40] as well, which rely on clean seas.[41] Indeed, Maritime and coastal tourism is essentially a cross cutting theme and because the inclusion of tourism as EU competence is relatively recent, there is no specific regulatory framework for it.[42]

1.2 Bioeconomy for the sustainable growth of rural and coastal areas
Selected priorities:
2.3. Unlocking the potential of aquatic living resources
2.3.3. Boosting marine and maritime innovation through biotechnology
2.4. Sustainable and competitive bio-based industries and supporting the developmcnt of a European bioeconomy.
2.4.3. Supporting market development for bio-based products and processes
Globally, 14 % of the population in the EU's predominantly rural regions[43] suffers from unemployment[44] and there are also areas of low per-capita GDP.[45] Much can be done to help create a wider variety of better

[37] http://ec.europa.eu/maritimeaffairs/policy/sea_basins/black_sea/index_en.htm

[38] http://ec.europa.eu/environment/iczm/home.htm

[39] This approach includes the assessment of plans and strategies in accordance with the provisions of Directive 2001/42/EC on strategic environmental assessment of economic activities factors affecting the protection of natural resources at an early stage as well as risks related to climate change and natural hazards to which coastal areas are extremely vulnerable.

[40] In 2010, the tourism industry (including all the related services and investments) represented an average of 10.9% of GDP, making it vitally important to the region's economies (in terms of jobs and its contribution to the external balance of trade in the Mediterranean countries). Without tourism, many Mediterranean countries would be obliged to reduce imports of goods and services drastically in order to restore their balance of trade (in Albania and Montenegro, for example, tourism accounts for over 50% of exports. (http://cor.europa.eu/en/activities/arlem/activities/meetings/Documents/report-sustainable-tourism/EN.pdf).

[41] Coastal and maritime tourism includes beach-based and nautical, cruising or boating tourism and is an essential driver for the economy of many coastal regions and islands in Europe. It employs almost 3.2 million people, generating a total of € 183 billion in gross value added for the EU economy, representing over one third of the maritime economy gross product. Unlocking the potential of coasts and seas would contribute to the wealth and well-being of coastal regions and the EU's economy in general, while ensuring a sustainable and long-term development of all tourism-related activities.
http://ec.europa.eu/enterprise/newsroom/cf/itemdetail.cfm?item_id=7310&lang=en&tpa_id=136&title=Commission-presents-new-European-strategy-to-promote-coastal-and-maritime-tourism

[42] http://ec.europa.eu/maritimeaffairs/documentation/studies/documents/study-maritime-and-coastal-tourism_en.pdf

[43] http://ec.europa.eu/agriculture/policy-perspectives/policy-briefs/05_en.pdf

[44] The unemployment rate is defined as the share of unemployed people in the labour force (composed of both employed and unemployed people)38. An unemployed person, according to the guidelines of the International Labour Organisation, is 15 to 74 years old, currently without work but available and actively looking for a job.

quality jobs and an improved level of overall local development.[46] Bioeconomy and biorefineries represent a major opportunity for rural and coastal areas to mobilize and strengthen their capacity for primary production[47] and delivery of ecosystems services as well as by opening avenues for the production of new and diversified products (including food, feed, materials and energy), which meet the increasing demand for low-carbon short-chain delivery systems.[48]

Bioeconomy innovation[49] and value chains are expected to provide economic growth and employment through different routes:

- The availability of sufficient and constant amounts of **biomasses to supply biorefineries** is nowadays an increasing need that also causes the competition for the land use. In that context, a number of research activities and technological innovations should be undertaken to **enlarge the potential of rural and coastal areas to deliver raw materials through sustainable value chains** (see more details in Section 4). **Farming, forestry and other rural sectors** can supply essential **raw materials** for use in the bio-economy with the sustainable production of energy, materials and chemicals.[50] That would be in line with Europe 2020 and the overall CAP objectives.[51] Three long-term strategic objectives can be

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[45] Gross Domestic Product per capita (GDP per capita) in the EU-27 reached 24 500 Purchasing Power Standards (PPS) on average for the years 2007, 2008 and 2009. Predominantly rural regions had the lowest level (70% of the EU-27 average), followed by intermediate regions (88%). Predominantly urban regions had the highest rate (125% of the EU average). Over the last years, the gap between the three types of regions at EU-27 level has remained stable. PPS is the technical term used by Eurostat for the common currency in which national accounts aggregates are expressed when adjusted for price level differences using PPPs. Thus, PPPs can be interpreted as the exchange rate of the PPS against the euro

[46] The turnover and employment of the European primary and processing biobased sectors is expected to increase by at least 10%, resulting in 3 million extra jobs and an €80 bn increase in turnover. (http://www.biobasedeconomy.nl/wp-content/uploads/2012/07/Bio-Based-Industries-PPP-Vision-doc.pdf)

[47] http://enrd.ec.europa.eu/policy-in-action/cap-towards-2020/rdp-programming-2014-2020/en/rdp-programming-2014-2020_en.cfm

[48] Biobased Industry Objectives for 2030,
• Diversify farmer's income and provide them with additional margins by up to 40% by using available residues;
• Enable 30% of overall chemical production to become biobased. For high addedvalue chemicals and polymers (specialties and fi ne chemicals), the proportion is more than 50%, while less than 10% of bulk commodity chemicals are derived from renewable feedstocks;
• Supply 25% of Europe's transport energy needs by sustainable advanced biofuels;
• Support the European market for biobased fi bre and polymers such as viscose, carbon fi bres, nano-cellulose derivatives and bioplastics to grow rapidly. Traditional fibre products such as paper remain 100% biobased to create more value out of the same resources;
• Realise a new generation of biobased materials and composites produced in biorefineries, allowing the production of better-performing components for industries including automotive, construction and packaging.
Data taken from:
http://www.biobasedeconomy.nl/wp-content/uploads/2012/07/Bio-Based-Industries-PPP-Vision-doc.pdf

[49] www.star-colibri.eu/fi les/fi les/vision-web.pdhttp://ec.europa.eu/research/bioeconomy/pdf/official-strategy_en.pdf

http://www3.weforum.org/docs/WEF_FutureIndustrialBiorefineries_Report_2010.pdf

http://www.epsoweb.org/file/560

[50] According to BNEF, using only 17.5% of the EU27 residue resource for producing advanced biofuels has the potential to diversify farmers' revenue and provide them with additional margins by up to 40%. BNEF also claims that using only 17.5% of the EU 27 residue resource for producing advanced biofuels has the potential to displace between 52% to 62% of the EU27's forecast fossil gasoline consumption by 2020, reducing the bill of EU oil imports by some €20 bn to €24 bn. (Bloomberg New Energy Finance, "Bioproducts: diversifying farmers income", 2011)

[51] See the: European Commission Communication on the CAP towards 2020; http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0672:FIN:en:PDF)

identified for EU rural development policy in the 2014-2020 period: a) improving the competitiveness of agriculture; b) the sustainable management of natural resources and climate action; and c) a balanced territorial development of rural areas.

- These technological and social innovations will leverage the **European leadership in biotechnology and chemistry** both at industrial and R&D levels. Industrial Biotechnology plays a significant role in realizing the biobased economy through biorefineries, but also through novel IB processes for **the transformation of biomass into valuable substances** (chemicals, surfactants, fuels etc.) through e.g. cell-factories, direct enzymatic transformation as well as **using novel feedstock** streams. Although major technological breakthrough are still xpected to fill some gaps (see Section 3), in some cases, technological advances are already available and these innovations have effective potential to **reach the market in less than 7 years**.[52] However, that depends on the realization of an effective **integration of scientific advances** within local regional context and the **definition of clear policy for the support of bio-based industries and biorefinerie.** These issues are also clear priorities of KETs program as well as of the PPP initiative for Bio-based industry, and they will be discussed in detail in Sections 3 and 4.

1.3 Need of ad-hoc criteria for the assessment of impact of bioeconomy and biorefineries at regional level

Due to the intersectorial and muldisciplinary nature of bioeconomy, tackling the above mentioned priorities will necessarily embrace different Societal Challenges priorities (besides SC2), as the ones listed here below:

5.2. Protecting the environment, sustainably managing natural resources, water, biodiversity and ecosystems

5.2.1. Furthering our understanding of biodiversity and the functioning of ecosystems, their interaction with social systems and their role in sustaining the economy and human well-being

5.2.3. Providing knowledge and tools for effective decision making and public engagement)

5.3.3. Finding alternatives for critical raw material

5.4. Enabling the transition towards a green economy and society through eco-innovation

5.4.2. Supporting innovative policies and societal changes)

6.3. Reflective societies - Cultural heritage and European identity)

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[52] Integrated green algal technology for bioremediation and biofuel, Bioresource Technology 107 (2012) 1–9. doi:10.1016/j.biortech.2011.12.091.

Algal Bioremediation of Waste Waters from Land-Based Aquaculture Using Ulva: Selecting Target Species and Strains. PLoS ONE 8(10): e77344. doi:10.1371/journal.pone.0077344

Chemosphere. 2014 Jun 19;119C:31-36. doi: 10.1016/j.chemosphere.2014.04.114. Ryegrass for the phytoremediation of solutions polluted with terbuthylazine.

Biotechnol Lett. 2014 Jun;36(6):1129-39. doi: 10.1007/s10529-014-1466-9. Epub 2014 Feb 22. Removing environmental organic pollutants with bioremediation and phytoremediation.

Waste Manag. 2011 Jan;31(1):78-84. doi: 10.1016/j.wasman.2010.08.016. Comparative management of offshore posidonia residues: composting vs. energy recovery.

Trends in Biotechnology, 2013, Vol. 31, No. 2. Biobased plastics in a bioeconomy.

Chem. Soc. Rev., 2012, **41**, 1499-1518. **DOI:** 10.1039/C1CS15217C. Derivation and synthesis of renewable surfactants
Chem. Soc. Rev., 2012, **41**, 1538-1558. **DOI:** 10.1039/C1CS15147A. Conversion of biomass to selected chemical products

- A smart, inclusive, sustainable and resource **efficient growth** of rural and coastal areas should **reconcile typical economic activities** (agriculture, forestry, fisheries, tourism, recreation…). Therefore, a balanced development of bioeconomy is not achievable through the application of solutions having general validity for any regional context, but rather solutions must rise from the analysis of opportunities and risks associated to the local situation.
- The political and investor pressure for exploitation of natural resources by biorefineries might overwhelm the case for environmental and social resilience protection, especially in Countries where there is little **political representation on behalf of local communities**. Overall, the argument for 'resources for the benefit of bioeconomy growth' must be properly weighed against competition and level playing field.

SECTION 2

Drivers and Trends

Globalisation and fragmentation, population changes, vulnerabilities are testing our resilience

- Developing bioeconomy and biorefineries in rural and coastal areas will allow meeting **globalisation and trade opportunities** and challenges for joining global value chains and delivering products, services and technologies that **no individual country would be able to produce on its own** while meeting bioeconomy opportunities for sustainable economic growth.

- New consumption and mobility patterns[53], migration and rising inequality in Europe (a picture of European disparities is available at http://ec.europa.eu/regional_policy/what/index_en.cfm) are testing the resiliency of European rural communities.

- Furthermore, environment degradation exposes rural and coastal areas in special way because their economic activities (e.g. forestry, fisheries, tourism, and typical regional agriculture) are endangered.[54] Tackling the problem of sustainable development and environmental integrity of coastal areas is also challenging because it depends on the harmonization of environmental and economic policies of MS or extra EU Countries facing a common sea or basin.[55]

- Transversality in new technologies and individual empowerment. High expectations from new technologies

[53] The EU issued 3.2 million Schengen visas only to ENP (European Neighbourgh Policy) partners in 2012. (Algeria, Armenia, Azerbaijan, Belarus, Egypt, Georgia, Israel, Jordan, Lebanon, Libya, Moldova, Morocco, Palestine, Syria, Tunisia and Ukraine). http://ec.europa.eu/europeaid/where/neighbourhood/overview/index_en.htm

[54] "Evolving science of marine reserves: New developments and emerging research frontiers". www.pnas.org/cgi/doi/10.1073/pnas.1002098107.

[55] http://ec.europa.eu/maritimeaffairs/policy/sea_basins/index_en.htm

Macroeconomic Scenarios for the Euro-Mediterranean Area. MEDPRO Report No. 7/July 2013.

- Transversality in new technologies (biotechnology, aquaculture, marine biology, ecology, engineering, chemistry, ICT etc.) should be at the basis of solutions for preventing environmental degradation and natural resources deprivation.[56] The **integrated application of biotechnology, marine biotechnology and chemistry** to industrial processing and production of chemicals, materials and fuels has been identified as a key enabling technology with a strategic relevance for future growth[57]. The development of organisms as optimized biotechnological production systems (e.g. through metabolic engineering and system biology[58]) can replace petro-based products and processes, but also lead to new products and processes, for instance through bio-catalysts, which opens up the **market for technology providers** and **SME** establishment. Synergies between different research fields can open **new technological paradigms**. These developments will also lead to **new feedstock demands** and related new technology developments.

- Environmental degradation, food security, scarcities of natural resources and bioeconomy potentials

- The chemical and, more in general, the bio-based industry seeks **feedstock flexibility** to lower costs and make the **transition from the petroleum based products** to more ecological ones. The potential for **biomass supply in Europe is substantial:** in most of the EU-27 member states climate, water and soil conditions are favorable for cultivation and the yields for wheat in Central Europe are some of the highest in the world.[59] However, the European Environment Agency has expressed some concern that at the long-term **competition** for a limited **biomass /land resource** could emerge between biofuels, biomaterials and conventional uses.[60] The necessary focus on global and European food security means that biomass for non-food products should come from non-competitive biomass sources.[61] Europe wants to put strong emphasis on developing the bio-based industries in line with food and feed security and environmental objectives and to move beyond the innovation brought by "first mover" countries that invested in food–crops processing. Such objective can be now achieved through the acceleration of the development of second-generation technologies enabling each European region to process its own sustainable resources.

- More **advanced biotechnological and chemical methods** that allow the conversion of **waste streams** into **valuable products**, such as food, feed, material and energy will positively affect trade-offs between competing demands and allow greater value to be extracted from the same resource in Europe and world-wide. The **potential for innovation is high** because of the wide range of sciences deployed along with several novel enabling and industrial technologies that create much

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[56] Resources Futures; A Chatham House Report, Bernice Lee, Felix Preston, Jaakko Kooroshy, Rob Bailey and Glada Lahn

[57] A European strategy for Key Enabling Technologies – A bridge to growth and jobs, COM(2012) 341

[58] Emerging Policy Issues in Synthetic Biology. OECD Publication.June 2014 .DOI :10.1787/9789264208421-en

[59] Biomass Futures: an integrated approach for estimating the future contribution of biomass value chains to the European energy system and inform future policy formation, In Biofuels, Bioproducts and Biorefining. Panoutsou, C., et al., 2012

[60] Laying the foundations for greener transport, EEA Report 7/2011

[61] http://www.europarl.europa.eu/RegData/etudes/etudes/join/2013/513515/IPOL-JOIN_ET%282013%29513515_EN.pdf

opportunity for **multi-disciplinary breakthroughs**.[62] As a reference, Figure 2 shows an overview of patents of genes of marine organisms concerning different sectors.[63]

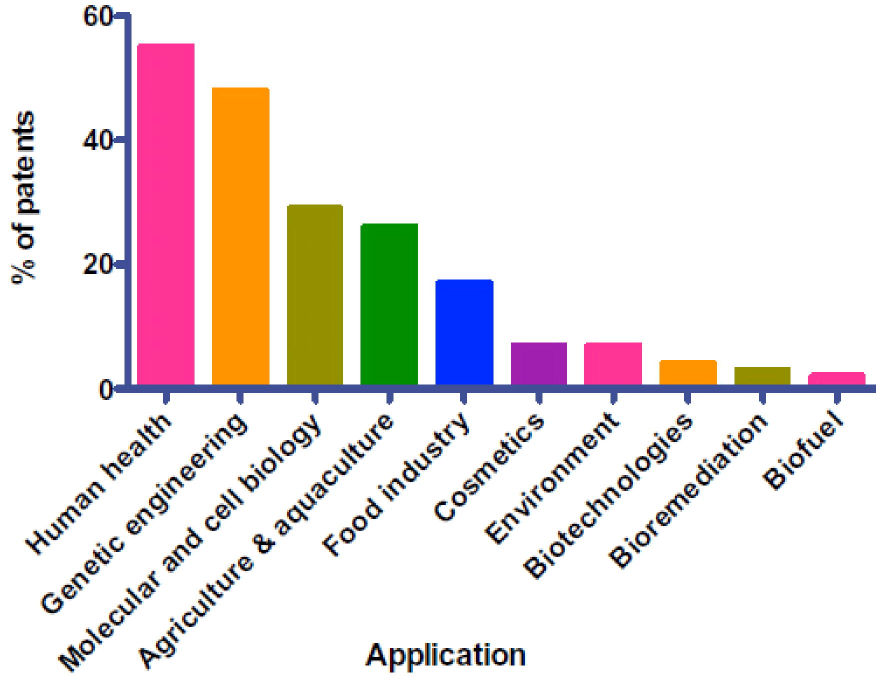

Figure 2: Synthesis of the uses proposed in the claims or description of 460 patents deposited at the International Patent Office and associated with genes isolated in marine organisms. Because each patent claim can belong to several categories, the sum is larger than 100%.

SECTION 3

Bottlenecks, future challenges, gaps in R&I, in market and policy, potential threats

R&I challenges

- **Processes must be integrated into cascade chains**. Second generation biorefineries should rely on integrated chemical and biotechnological innovations for converting typical regional biomass/waste/residues into valuable products in a hierarchical cascade processing chain including returning waste and nutrients to the land. That means that interdisciplinary and multi-sectorial activities must be managed. Since valuable waste streams are already occupied and not disposed as garbage, they could only be taken over by comprehensive innovative solutions able to create higher value added. Such breakthroughs are most likely to surge from the **integration of biotechnology** (metabolic engineering and biocatalysis)**, chemistry** but also **new engineering concepts** prone to

[62] Sustainable Production of Second-Generation Biofuels, OECD/IEA 2010.

Conversion of biomass to selected chemical products. **Chem. Soc. Rev.**, 2012, **41**, 1538-1558. **DOI:** 10.1039/C1CS15147A.

"Marine Biotechnology: Enabling Solutions for Ocean Productivity". OECD (2013),

[63] *"Marine biodiversity and gene patents". Science 25 March 2011: Vol. 331 no. 6024 pp.* 1521-*1522DOI:10.1126/science.1200783*

meet requirements of **new process and products** (rather than adapting old concepts to new productive processes). While lignocellulosic residues value is relatively low as it is used in composting, fertilizer, animal breeding (litter), or biomass burning, non lignocellulosic, residues from food industry are processed to more valuable fodder.

- **Food- and agro-waste streams viability:** The 1.3×10^9 t of food waste generated worldwide per annum constitute a renewable resource for chemical production that at least in terms of capacity should not be neglected taking into account that 3×10^8 t of petroleum per year is required for chemical production.[64] Typical coastal activities, such as fish and crustacean processing, leads to 30 up to 70 % waste, where the fish waste have an oil/fat content of 19% on dry weight basis. These products have an annual market in the EU-27 equal to 5.3×10^6 t. However, improved and low-energy technologies are needed for reduction of water content, extraction of valuable components and transforming food and agricultural waste into raw-material with standardized quality and ready to be processed through fermentation or biotransformation for the production of chemical building blocks (the market value for chemical building blocks in 2030 is expected to reach 9.2 BEUR) bio-based surfactants (market is estimated at nearly 1.3 BEUR) [65] and biopolymers. Furthermore, food processes generate also significant quantities of wastewaters with significant organic loading. Utilization of carbon and nutrient sources from such waste and by-product streams will require restructuring of current treatment or valorisation processes and optimisation of resource utilisation.[66]
- **Making algal production and exploitation economical:**
  The current worldwide microalgae manufacturing infrastructure (producing the equivalent of ~5000 tons of dry algal biomass) is devoted to extraction of high value products (e.g. carotenoids and other antioxidants such as Vitamin C, Vitamin E, BHT; lipids and polyunsaturated fatty acids -PUFA; lectins to be used in medical applications.[67] Production of microalgae for medium – low value products (bulk chemicals and energy) needs to take place on a much larger scale at much lower costs.[68] Despite the recent focus on algal potential also within FP7 (see for instance http://www.biofatproject.eu) the perspective for transforming algae potential into marketable chemical and fuels solutions is still debatable. [69] Analysis indicate that the only way to make algae economical is within the concept of a biorefinery, where "chemicals paid for fuels." Production

[64] Apostolis A. Koutinas et al., Valorization of industrial waste and by-product streams via fermentation for the production of chemicals and biopolymers. *Chem. Soc. Rev.,* 2014, 43, 2587

[65] Bio-Tic technological roadmap.Draft 2. www.industrial-biotechnology.eu

[66] For instance, Olive mill wastewater (OMW) is the main liquid effluent of the olive oil production process. The annual world OMW production is estimated from 10 to over 30 million m^3. OMW is claimed to be one of the most polluting effluents, although it is very rich in phenolic and antioxidant components. Data from: Neda Rahmanian et al., Recovery and Removal of Phenolic Compounds from Olive Mill Wastewater. J Am Oil Chem Soc (2014) 91:1–18. DOI 10.1007/s11746-013-2350-9

[67] Kari Skjånes et al., Potential for green microalgae to produce hydrogen, pharmaceuticals and other high value products in a combined process. *Critical Reviews in Biotechnology*, 2013; 33(2): 172–215

[68] A leap in the development of microalgae technology is required for the production of biofuels and bulk chemicals ; on a practical level, the scale of production needs to increase at least 3 orders of magnitude with a concomitant decrease in the cost of production by a factor 10. In addition a biorefinery infrastructure needs to be established in order to make use of the entire biomass, which is essential to achieve economic viability. Data from: http://www.ieabioenergy.com/wp-content/uploads/2013/10/Task-42-Biobased-Chemicals-value-added-products-from-biorefineries.pdf

[69] http://www.biofatproject.eu/resources/pdf/BIOFAT0614.pdf

efficiency of biomass is the key-factor for financial success in most commercial systems but production of high amounts of secondary metabolites under stress conditions is associated with decreased growth rates and thereby decreased production of total biomass. Overall, algae are an attractive biofactory also for protein cloning and expression. Microalgal biomass also can be processed into other biofuels through biophotolysis to biohydrogen, anaerobic digestion to methane, and via thermochemical processes into bio-oil, syngas, charcoal and electricity. Macroalgal species accumulate significant amounts of sugars that have a low lignin content which can be fermented into bioethanol or butanol amounts of sugars that have a low lignin content which can be fermented into bioethanol or butanol. Integrated algal systems can be used for wastewater treatment (bio-accumulators) and bioremediation to capture carbon, nitrogen and phosphorus from specialty industrial, municipal and agriculture wastes. Technologies need to be developed/improved for both cultivation and biorefinery in order to implement an integrated economical algal production system,[70] also taking into account the problem of accumulation and recovery of hazardous elements.

- **Need of breakthrough technologies for transforming lignin and/or for producing renewable aromatic chemicals and building blocks.** Many key commercial chemicals are aromatic compounds, ultimately derived from petrochemical feedstock. Lignin is the only large-volume renewable feedstock that comprises aromatics. It makes up 25 to 35% of woody biomass [71] Due to its amorphous Despite extensive research, there are very few reports of efficient ways of recovering such aromatic products. The only notable commercial process has been the production of vanillin from lignosulfonates, a by-product of the sulfite pulping industry but the yield of industrial process is not competing with petrochemical routes to vanillin. Currently most lignin (also that derived from second generation biorefineries using lingo-cellulosic biomass) is used as an energy source in the pulping industry, and there are only few examples of routes to valorization beyond the energy route.[72] While there is still no convincing route to single aromatic feedstocks from lignin, there have been important developments in the production of biobased styrene from butadiene produced from bio-ethanol or bio-butanol [73]or even directly by fermentation.[74]
- **Insufficient intersectorial mobility and dialogue**. Closer collaborations between universities SMEs and industries, exchange of personnel, training programs That would facilitate integration and transfer of knowedge/innovation.

Raw material suppliers and sustainability criteria from the regional bioeconomy perspective

- **Multiple suppliers needed**. Bio-industries create new possibilities to support the income of farmers by sale of residues and to contribute thereby to inclusive, innovative and secure societies. Second generation bio-industrial facilities are likely to be large in order to benefit from economies of scale

[70] Integrated green algal technology for bioremediation and biofuel, Bioresource Technology 107 (2012) 1–9. doi:10.1016/j.biortech.2011.12.091

[71] M. Carrier et al., Biomass Bioenergy 35, 298 (2011).

[72] A. G. Sergeev, J. F. Hartwig, Science 332, 439 (2011).

T. D. Matson, K. Barta, A. V. Iretskii, P. C. Ford, J. Am.Chem. Soc. 133, 14090 (2011).

[73] J. van Haveren, E. L. Scott, J. Sanders, Biofuels Bioprod. Bioref. 2, 41 (2008).

[74] www.prnewswire.com/news-releases/global-bioenergiesand-synthos-enter-a-strategic-partnership-on-biologicalbutadiene-a-30bn-market-125808773.html.

and the feedstock requirements will be considerable (up to 600 000 t/yr)[75]. To achieve this will require rigorous quality control and the management of multiple suppliers when the delivery of feedstock cannot be met by a single supplier.

- **Need of ad-hoc criteria for the clear and transparent assessment of impact of biorefineries at regional level.** It is crucial to assure environmental and social resilience protection, especially in Countries where there is little political representation on behalf of local communities. Overall, the argument for 'resources for the benefit of bioeconomy growth' must be properly weighed against the losses involved and .the impact of land-use changes should be assayed.
- **New ecological frontiers.** There is a need of a shift towards analysis and management of natural wealth at "eco-system" level, which might go beyond the national context (e.g. sea basins). That implies the concept of "governance of new ecological frontiers" by applying shared and consistent criteria.
- **Analysis of specific region-centric circumstances.** Assay of locational and climatic differences, which influence primary production systems and value chains, would be necessary in order to provide meaningful and consistent best practice guidance.
- **Logistic challenges.** Collection, transport, pre-processing and inventory management will need to be researched because of its important social science dimension.

Need of policy integration

- **Harmonization of policy within difficult political scenarios.** The challenge of building up new global value chains within an international context requests to tackle the problem of harmonization of environmental and economic policies among MS but also with respect to third Countries. Some of these will be Countries with weaker governance regimes, high rates of poverty and inequality, and greater risks of conflict and or natural disaster. There are uncertain political situations in some neighboring countries facing closed sea Basins (e.g. Black Sea, Energy Community[76], Mediterranean).
- **Need of institutional capacity to manage the new or increased resource investment, operations and revenues effectively and sustainably**. This will not only benefit local populations but also help insure against production disruptions and wider market and macroeconomic instability.[77,78]
- **The bioeconomy is governed by various policies from different sectors.** To ensure a harmonised and efficient future uptake, it is essential to: a) bring stakeholders (industry, science and policy) together in order to stimulate interaction between value chains and co-production of products, and b) to use in a more efficient way side streams; c) remove obstacles through communication, training and capacity building; and d) facilitate the development of integrating policy frameworks

[75] Sustainable Production of Second-Generation Biofuels, OECD/IEA 2010

[76] The Contracting Parties of the Energy Community (www.energycommunity.org comprise Albania, Bosnia and Herzegovina, Kosovo*, fyR of Macedonia, Moldova, Montenegro, Serbia and Ukraine.

[77] In Europe alone, Bloomberg New Energy Finance has estimated that just 17.5% of agricultural residues could support a target of 10% of cellulosic ethanol in gasoline cars by 2030. In this case, the revenues would be €78 bn and 170,000 jobs would be created

Moving towards a next generation ethanol economy, Bloomberg New Energy Finance, 2012

[78] The Final Evaluation of the Lead Market Initiative reports a forecast of €70-80 billion of turnover by 2020 and between 350,000 and 400,000 jobs for all businesses involved in biotechnology and bio-based products

Final Evaluation of the Lead Market Initiative, Centre for Strategy and Evaluation Services, July 2011 linking environment, agriculture and energy. For instance, it has been found that bioplastics sector is a disadvantage compared to some other biobased products, notably biofuels, that often benefit from preferential treatment. At the same tie, greater efforts are needed at the international level as regards standards to avoid creating barriers to international trade in bio-based products.[79]

- **The energy cost in the EU is high compared especially to the US**. This means that raising capital for large scale installations, such as flagship biorefineries, are much more significant. One way to bypass this is by a revision of state aid rules to allow member states to support commercial plants.
- **Access to funding.** Industries and SMEs need to understand different regional mechanisms for access to funding, financing and incentives relevant to bioeconomic development.
- **Reconciling differing legislative barriers.** Currently there are heterogeneous legislations (e.g. for the use of wastes as feedstocks) and there are regional differences relating to tax/levy incentives..
- **Standstill European integration and differences in education/innovation system in MS.** It would be crucial to map and understand differences in innovation systems, structures regarding higher education, research institutes, professional bodies and local governance structures.
- **Need for a coherent long-term and visionary policy making process and framework.** In terms of encouraging investment, there is a lack of certainty and predictability for biobased industries in Europe which is less of an issue elsewhere in the world. In addition, much of industrial biotech's cutting edge technology is increasingly being attracted overseas where framework conditions and support for this technology are more attractive.

Market entry barriers, quality assurance, standardization and certification

- **Clarity in definitions**. It is necessary to work on a set of common definitions and to improve understanding of the different biobased sectors comprising the European bioeconomy
- Supporting market development
- **Standardisation and certification** the establishment of high quality and safety standards, certification of product functionality and biodegradability is also an essential prerequisite for both producer and consumer confidence in the bioeconomy, and hence for the development of biobased products market. [80] However, the analysis of "bioproducts" is difficult and needs expensive equipment and highly skilled personnel that are not available to most SMEs.
- **Bioeconomy in Europe comprises of different market segments**. The fragmented information sources increases potential competition between market segments (food, feed, energy, fuels, non food biobased materials and products, etc.), which also rely on the same primary feedstocks and associated resource inputs (e.g. water, land, etc.), fact. It is therefore important to create a coherent knowledge base and improve transfer of knowledge by conducting systematic market analysis per sector and product to understand the underlying factors (both success and hindering) for the future development and optimal functioning of bioeconomy as a whole in Europe.

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[79] Policies for Bioplastics in the Context of a Bioeconomy. OECD document 28 October 2013. DOI 10.1787/5k3xpf9rrw6d-en

[80] The advisory group support recommendation n the Bioeconomy white paper that transparent, industry-led development and implementation of codes of good practice and standards for each sector are important to ensure continually revision of the standards. In addition we would emphasize that all standards (and standard levels) must be based on independent science. Funding to ensure this should be prioritized in the forthcoming programs

http://www.epsoweb.org/file/560

- **Need to stimulate markets for biobased products**. As an emerging technology - competing against a well-established fossil based infrastructure - supportive measures are needed to stimulate resource efficient biobased products and processes onto the market. Preferences of customers for bio-based products should be based on evidence of performance parameters.
- **Bio-based products have higher costs as compared to traditional ones.** Further research and innovation are requested in some cased to improve economic competitiveness.
- **Development of fully functional financial system supporting industry growth.** Bioeconomy and biorefineries considered as high risk. Biorefinery is a not fully established concept to the chemical/energy sector and considered as high risk, which prevents large CAPEX expenses. Shared multipurpose infrastructures (pilot and demo-facilities accessible to all actors) might reduce the financial risk and attract investors, along with actions aiming at increasing public acceptance of bioeconomy products[81]. Financial support mechanisms (such as government funds or business angels) could help companies to mitigate that risk and associated investments and would weigh favourably in any decision regarding the adoption of bio-based materials.
- **Investment in new technologies is limited at current financial situation in Europe**. The previous focus on 1st generation biofuels proving not sustainable is also hampering support and development of second generation biorefinery. A larger number of start-up companies would accelerate the uptake of innovation.

SECTION 4

Key priority orientations, strategic recommendations related to research and innovation

Acting regionally for joining global value chains

Bio-based processes should be optimized within biorefineries to reach the production of biofuels, materials and fine chemicals from **local biomass** in full compliance with the biodiversity of the territory[82]. Biomass and other raw materials should be delivered while at the same time protecting biodiversity and supporting the development of rural and coastal livelihoods[83]. Conversely, there is the need of **"ad hoc regional" criteria** for assessment of impact based on existing ones but improving, harmonizing, benchmarking[84]. Resources should be prioritized based on their indigenous potential, also developing specific LCA parameters referred to the specific eco-system and social context.[85] Strategic R&I orientations include:

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[81] Science, Technology and Industry Scoreboard 2011, OECD 2011

[82] Bio-based for growth, a public private partnership on biobased industries, http://www.biobasedeconomy.nl/wp-content/uploads/2012/07/Bio-Based-Industries-PPP-Vision-doc.pdf

[83] Possible links to:

5.2. Protecting the environment, sustainably managing natural resources, water, biodiversity and ecosystems
5.2.1. Furthering our understanding of biodiversity and the functioning of ecosystems, their interaction with social systems and their role in sustaining the economy and human well-being
5.2.3. Providing knowledge and tools for effective decision making and public engagement)
5.3.3. Finding alternatives for critical raw material
5.4. Enabling the transition towards a green economy and society through eco-innovation
5.4.2. Supporting innovative policies and societal changes)
6.3. Reflective societies - Cultural heritage and European identity)

[84] PwC, (2011), 'Regional Biotechnology: Establishing a methodology and performance indicators for the assessing bioclusters and bioregions relevant to the KBBE area'.

[85] See link to SC5, priority *5.5. Developing comprehensive and sustained global environmental observation and information systems)*

- Valorization of marginal, contaminated and semiarid lands through regional resilient crops, [86] with high efficiency of resource use and low input requirements. That is achievable only through a better understanding of the role of soil microbial communities,[87] which are responsible of nutrients cycling and therefore of fertility, they determine physical and chemical properties of soil and they protect plants from biotic and abiotic stresses. Moreover, they are involved in bioremediation of contaminated lands and climate change mitigation.
- Phytoremediation algae-remediation of contaminated lands and sea with combined production of unconventional biomass[88, 89]
- Exploitation of aquatic living resources for reduction of sea contaminants and dissolved nutrient loads in aquaculture effluents while producing unconventional biomass.[90,91]

- Supporting the development of rural and coastal livelihoods while protecting biodiversity and livelihood must be funded on adequate decision making in the **management of eco-systems.** There is a need of a shift towards analysis and management of natural wealth at "eco-system" level, which might go beyond the national context (e.g. sea basin). That implies the concept of "**governance of new ecological frontiers**" (beyond administrative borders) by applying shared and consistent criteria. On that respect, specific **international cooperation** activities could be envisaged, also by identifying synergies with macro-regional European policies and initiatives.[92]
- Agroecological and forestry research and innovation is necessary for assessing the potential of ecological **intensification of land use. This should be combined with innovations in harvest and transport technology, operational planning, high precision monitoring** (including remote sensing), measurement systems, **business models** and **ICT** for rational, competitive and environmentally friendly procurement of biomass.

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[86] See link to SC5, priority *5.3.3. Finding alternatives for critical raw materials*

[87] Specificity of plant-microbe interactions in the tree mycorrhizosphere biome and consequences for soil C cycling. Churchland C, Grayston SJ. Front Microbiol. 2014 Jun 3;5:261. doi: 10.3389/fmicb.2014.00261

[88] Chemosphere. 2014 Jun 19; 119C:31-36. doi: 10.1016/j.chemosphere.2014.04.114. Ryegrass for the phytoremediation of solutions polluted with terbuthylazine.

Biotechnol Lett. 2014 Jun;36(6):1129-39. doi: 10.1007/s10529-014-1466-9. Epub 2014 Feb 22. Removing environmental organic pollutants with bioremediation and phytoremediation.

[89] The phytoremediation market is still emerging in Europe, while in the US revenues are likely to exceed $300 million in 2007 (Campos VM, Merino I, Casado R, Pacios LF, Gómez L (2008). Review. Phytoremediation of organic pollutants. Span. J. Agric. Res. 6:38-47)

[90] Integrated green algal technology for bioremediation and biofuel, Bioresource Technology 107 (2012) 1–9. doi:10.1016/j.biortech.2011.12.091.

Algal Bioremediation of Waste Waters from Land-Based Aquaculture Using Ulva: Selecting Target Species and Strains. PLoS ONE 8(10): e77344. doi:10.1371/journal.pone.0077344

Carl C, de Nys R, Paul NA (2014) The Seeding and Cultivation of a Tropical Species of Filamentous *Ulva* for Algal Biomass Production. PLoS ONE 9(6): e98700. doi:10.1371/journal.pone.0098700

[91] The market of algal biomass for biofuel is still small and immature but is expected to growth exponentialy in the next 5-10 year.
[92] (http://www.ai-macroregion.eu/) (http://www.danube-region.eu/) (http://www.balticsea-region-strategy.eu/) (http://ec.europa.eu/maritimeaffairs/policy/sea_basins/atlantic_ocean/index_en.htm)

Integrated biorefineries in the optic of the hierarchical "Cascade value chain" concept.[93]

- Competitive novel generation biorefineries must rely on **integrated solutions** (e.g. **chemistry, biotechnology, marine biotechnology, engineering, computational sciences, etc.)** for efficient transformation of regional resources into **chemicals, materials and fuels.** Innovation should be compliant to a cascade processing chain including **returning waste and nutrients to the land.**[94]
- Attention should be paid at residual and waste streams.[95,96,97] That includes also technologies for the conversion of **Protein Waste to Platform Chemicals, a field that has not been sufficiently explored yet.**[98] Much of this protein is currently processed as animal feed [99] but it would have more value as a feedstock for commodity organic compound production. In the ideal scenario, the essential amino acids contained in this protein waste could be used as animal feed and the nonessential amino acids, with no real value for food or feed, as chemical feedstocks. This would again circumvent the fuel-versusfood issue. Another, potentially enormous source of protein waste that could be exploited in the future will be the by-products from the production of biofuels.
- Chemical and polymer industry would greatly benefit from efficient technologies for **transforming lignin** (also deriving from second generation biorefinery residues) and/or for **bio-production of renewable aromatic chemicals and building blocks.** This would pave the way to the production of a whole class of aromatic chemicals, polymers and plastics. The bioplastics market value is expected to reach approx. 5.2 BEUR in 2030.[100]

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[93] (http://www3.weforum.org/docs/WEF_ENV_TowardsCircularEconomy_Report_2014.pdf)

[94] Derivation and synthesis of renewable surfactants. **Chem. Soc. Rev.**, 2012, **41**, 1499-1518. **DOI:** 10.1039/C1CS15217C.

Conversion of biomass to selected chemical products. **Chem. Soc. Rev.**, 2012, **41**, 1538-1558. **DOI:** 10.1039/C1CS15147A.

Biobased plastics in a bioeconomy. Trends in Biotechnology, 2013, Vol. 31, No. 2.

[95] The largest waste source for carbohydrates and lignin is from lignocellulosic biomass residues, which are estimated to exceed 2 × 1011 t/year worldwide [M. L. Zhang et al., Biomass Bioenergy 31, 250 (2007)]. These residues can be separated into two categories: (i) residues left in the field directly after harvest of crops and (ii) residues separated from the product as it is processed. Although the field residues cannot really be described as waste—because soil quality and crop yield are decreased by their removal—the process residues are waste products that are normally burned and could be converted to small molecules.

On a global scale, the two highest-volume process residues are rice husk and sugarcane bagasse. Rice is a typical crops in many MS and, more specifically, for every 4 t of rice harvested, 1 t of husk is produced, amounting to 120Mt of rice husk per year. Of this, only 20 Mt is currently used, leaving 100 Mt that could be converted into fuels or chemicals [S. Shackley et al., Energy Policy 42, 49 (2012)].

[97] Waste Manag. 2011 Jan;31(1):78-84. doi: 10.1016/j.wasman.2010.08.016. Comparative management of offshore posidonia residues: composting vs. energy recovery.

[98] Substantial amounts of protein-containing waste are generated in the production of foods and beverages. Examples include vinasse (from sugar beet or cane), distiller's grains with solubles (from wheat or maize), press cakes (from oil seeds like palm and rapeseed), fish silage, protein from coffee and tea production, and agricultural residues from various crops. For example, poultry slaughterhouses produce large quantities of feathers with a crude protein content of more than 75% w/w, 65% of which consists of nonessential amino acids. Similarly, the production of shrimp meat generates large amounts of protein-waste together with the carbohydrate chitin.

[99] P. G. Dalev, Bioresour. Technol. 48, 265 (1994). A. Gildberg, E. Stenberg, Process Biochem. 36, 809 (2001).

[100] www.industrial-biotechnology.eu (BIO-TIC – Non-Technological Roadmap)

- Due to the technological complexity of lignin depolymerization, in parallel, more and novel routes for bio-production of **aromatics from nonaromatic biomass sources via fermentation** should be explored and optimized.[101]
- In order to "close the loop" of the integrated cascade processes, efficient and versatile strategies for **extracting** (by enzymatic, chemical and physical methods) and **utilizing components** of **high added values** (e.g. nutraceutical, biosurfactants,[102] cosmetic or bioactive molecules) present in typical regional biomass, residues or by-products[103] (e.g. from fisheries, forestry or agro-food).[104] A strong involvement of agronomy competences will be necessary for systematic assessment of opportunities offered by local natural products/biomass/residues. Besides phenolic compounds (8000 structures) and alkaloids (12 000 structures), terpenes (terpenoids, isoprenoids) represent the largest and most diverse classes of plant secondary metabolites, with over 55 000 members isolated to date. Pharmaceutical, food, agricultural, and chemical industries can benefit from new chemical structures obtained through bio- and chemical selective transformations of these chiral molecules. Turpentine oil, a waste product of paper pulp industry and citrus oil, a co-product of citrus juice production are the major sources of terpenes.[105]
- Implementation of **platforms for data integration and management** will be necessary at local and regional level for accelerating data sharing and the **transfer of knowledge** into industrial innovation.
- Shared multipurpose **infrastructures** (pilot and demo-facilities accessible to all actors) might reduce the **financial risk** and attract investors.[106] That might be accompanied by targeted support to SMEs embedded in the territory and involved in the valorization and processing of local resources

Involving all actors of the knowledge and value chains for cross-sectorial fertilization and education

- Working with partners **across the knowledge and value chain** (agriculture, marine, ecology, forestry, environmental management, computational sciences, chemistry, biotechnology, ICT,

[101] J. van Haveren, E. L. Scott, J. Sanders, Biofuels Bioprod. Bioref. 2, 41 (2008). www.prnewswire.com/news-releases/global-bioenergiesand-synthos-enter-a-strategic-partnership-on-biologicalbutadiene-a-30bn-market-125808773.html.

[102] Biosurfactants are surfactants that are produced extracellularly or as part of the cell membrane by several microorganisms and their applications in the environmental industries are promising due to their biodegradability, low toxicity and effectiveness enhancing biodegradation and solubilization of low solubility compounds. Biosurfactants are a unique class of compounds that have been shown to have a variety of potential applications in the remediation of organic- and metal-contaminated sites, in the enhanced transport of bacteria, in enhanced oil recovery and as cosmetic additives. Biosurfactant-producing microorganisms may play an important role in the accelerated bioremediation of hydrocarbon-contaminated sites. International Research Journal of Public and Environmental Health Vol.1 (2), pp. 19-32, April 2014, http://www.journalissues.org/journals-home.php?id=9

[103] Enzyme-assisted extraction of bioactives from plants. doi:10.1016/j.tibtech.2011.06.014 Trends in Biotechnology, January 2012, Vol. 30, No. 1

[104] The market of algal oil omega-3 ingredients is expected to reach ober USD 480 in 2015 with an annual grouth of over 11%.

Chiitin and chitosan markets are expected to reach 63 and 21.4 USD by 2015 respectively.

Data from: ""Contributing to the bioeconomy: The economic potential of marine biotechnology". DOI:10.1787/9789264194243-5-en

[105] Transformation of terpenes into fine chemicals. DOI: 10.1002/ejlt.201200157. Eur. J. Lipid Sci. Technol. 2013, 115, 3–8

[106] Science, Technology and Industry Scoreboard 2011, OECD 2011

economy etc..) has the potential of **bringing new knowledge to all actors**, thus overcoming the risks of fragmentation. **Multidisciplinary "bioeconomy" centers of excellence** (involving research institutions, large firms and SMEs) might provide the adequate environment for **"cross-sectorial fertilization" and education of a new class of scientists, managers** ready to pick-up the opportunities that a specific region offers for the sustainable development of bioeconomy. [107] Education programs for **mass-media operators** would favor the spreading of sustainability criteria, promote new consumer behavior and increase consumers awareness.

- Support and coordination actions could fertilize the ground, and foster bioeconomy especially in those regions where research and biotechnological innovation in this field is lagging behind.
- Actions aiming at promoting **education and scientific research**[108] should also be directed to facilitate the **integration between chemistry, bio-technologies**, **engineering, computational sciences** by leveraging on i) world class scientists in biotechnology and chemistry; ii) mature substrate of SMEs with high innovation capacity; iii) EU industrial leadership in these fields.[109]
- Cooperation between research and industry and policy (different level of governance) actors that **cover the whole supply and value chain** is crucial[110] **SME**s should be involved as **innovation drivers** and for accelerating technology up-take.
- In order to translate all these actions into effecting growth and employment opportunities, adequate **policy** for market development for bio-based products and processes should be promoted as discussed in section 3.
- All these strategic orientations set also the premises for strong synergies with Part II of Horizon 2020 "'Leadership in Enabling and Industrial Technologies" and the Private and Public Partnership initiative for Bio-based industries.

SECTION 5

How the success would look like

New sustainable economic activities, growth and employment for rural and coastal areas, drawing a novel win-win biorefinery model that goes beyond the food and land competition through the management of inter-sectorial synergies.

- Novel biorefineries integrated with the territories, based on new value chains that valorize the resources and competence of regions, can represent a novel model for converting rural and coastal areas into more prosperous places. That will be made possible thanks to the development and validation of specific criteria for assessment of environmental, social and economic impact of biorefineries at local and macro-regional levels.
- That will make rural and coastal areas more accessible and attractive places for inhabitants, for competent labor force, SMEs, investors but also for tourists, thanks to a combined improvement of sea and land (e.g. decrease of sea pollution coming from agriculture activity or aquaculture). The potential of low productivity/ marginal lands and "low- input" systems (e.g. wastewater irrigation,

[107] See possible link to SC3, priority 3.3. Stimulating innovation by means of cross-fertilisation of knowledge)

[108] See possible link to Excellence Science, 4.1.2: integrating and opening research infrastructures;

[109] See possible link to Excellent Science, priority 3.2. Nurturing excellence by means of cross-border and cross-sector mobility)

[110] http://www.oecd.org/futures/long-termtechnologicalsocietalchallenges/thebioeconomyto2030designingapolicyagenda.htm

etc.) will be tested and regional plans will be drawn for overcoming food-land competition in supplying raw materials to biorefineries.

- Overall, innovation and sustainable growth will make local communities more resilient to future societal disrupters and able to respond to new economic scenarios. Integrated models and tools tested and validated for a better preparedness and support decision making in the management of coastal and rural areas environments will set the basis for long-term systemic effects. That will also create the ground for strengthening European economic integration, while overcoming barriers in the dialogue with Neighboring Countries[111] sharing similar environmental, ecological and social problems.

Advanced technologies for economically competitive biorefineries, which will strengthen the leadership of EU industrial biotechnology and chemistry sectors (both in R&I and in industry), meeting market requests in terms of bio-based products (e.g. biofuels, bio-plastics and bio-materials) while building up new global value chains within an international context

- Efficient biotechnologies for production of building-blocks and chemicals, integrated chemical and biotechnological technologies for valorization of lignin and protein residues, along with innovative extraction processes will allow to close the loop of economically and environmentally sustainable "cascade processing chains" including **returning waste and nutrients to the land**[112]. Recycling and industrial symbiosis (when a residue/ waste from one industry becomes raw material for another) will allow reduction of raw materials usage.
- A wider social awareness and acceptance will lead to **mass adoption of** bio-based, renewable, certified and grounded on clear approved standards, thus replacing petroleum based ones, while coherent policy will support bio-based industries and SMEs throughout EU.
- **Regional hubs** for bioeconomy and biorefinery will assure long-lasting benefits of innovation and fast technology up-take and market access, thanks to a new world-leading class of scientists, managers and mass media operators ready to pick-up the opportunities that each specific region offers in terms of sustainable use of its own resources. Shared facilities and infrastructures will allow all actors and new investors to invest in innovation while decreasing associated risks.

[111] http://ec.europa.eu/europeaid/where/neighbourhood/overview/index_en.htm

[112] Derivation and synthesis of renewable surfactants. **Chem. Soc. Rev.**, 2012, **41**, 1499-1518. **DOI:** 10.1039/C1CS15217C.

Conversion of biomass to selected chemical products. **Chem. Soc. Rev.**, 2012,**41**, 1538-1558. **DOI:** 10.1039/C1CS15147A.

Biobased plastics in a bioeconomy. Trends in Biotechnology, 2013, Vol. 31, No. 2.

Possible scenarios for international cooperation

Activities at international level are important to enhance the competitiveness of European industry bioeconomy by promoting the take-up and trade of novel technologies, for instance through the development of worldwide standards and interoperability guidelines, and by promoting the acceptance and deployment of European solutions outside Europe.

Moreover, some targeted areas of R&I activities appear to offer opportunities for mutual beneficial cooperation with Third Countries that are particularly active not only in research but also in innovation and patenting.

A special attention should be given to cooperation with Neighboring Countries, especially towards the objective of "governance of new ecological frontiers" and policy harmonization.

"Bioeconomy development of rural and coastal areas"

The concept meets numerous objectives of macro-regional European policies and initiatives[113], which involve also Neighboring Countries. Therefore, possible synergies should be sought, as demonstrated by examples and information reported here below:

The **Danube region**[114] covers parts of 9 EU countries (Germany, Austria, Hungary, Czech Republic, Slovak Republic, Slovenia, Bulgaria, Romania and Croatia) and 5 non-EU countries (Serbia, Bosnia and Herzegovina, Montenegro, Ukraine and Moldova).

The region is facing several challenges:

- environmental threats (water pollution, floods, climate change)
- untapped shipping potential and lack of road and rail transport connections
- insufficient energy connections
- uneven socio-economic development
- uncoordinated education, research and innovation systems
- shortcomings in safety and security

Exploitation of forestry resources and marginal/contaminated lands could be considered as areas of investigation for promoting bioeconomy development in the region.

The **Adriatic-Ionian Region** covers 4 EU countries (Croatia, Greece, Italy and Slovenia) and 4 non-EU countries (Albania, Bosnia-Herzegovina, Montenegro, Serbia). The region faces several challenges:

- Shortage on clustering and need for greater interrelation of businesses, research and the public sector
- Uneven socio-economic development
- Shortcomings in transport and energy routes and its interoperability
- Environmental threats, including the preservation of a high diverse marine environment
- Untapped potential on attractiveness of the tourist sector

Potential synergies can be envisaged for promoting initiatives aiming at sustainable growth of coastal areas through valorization of local typical agricultural crops, food-waste streams (e.g. fishery and fish

[113] http://www.danube-region.eu/

[114]:http://www.ai-macroregion.eu/

processing, oil-mill) while mitigating environmental impact of aquaculture through marine-biotechnology.

The European Union Strategy for the **Baltic Sea Region** (EUSBSR) [115]; is the first macro-regional strategy in Europe. The EU Baltic Sea region counts 85 million inhabitants (17 percent of EU population) and eight countries (Sweden, Denmark, Estonia, Finland, Germany, Latvia, Lithuania and Poland) which share common features and challenges. Hence there is a clear need for joining forces and working in cooperation. Against this background, the Strategy intends to increase the levels of environmental sustainability, prosperity, accessibility and attractiveness and safety and security. The Strategy is welcoming cooperation also with EU neighbouring countries (Russia, Norway and Belarus). Due to the Cold War, sealing off most of the coastal strip from intensive residential, industrial and recreational uses gave room to nature and wildlife. Thus, valuable coastal ecosystems and habitats could develop here over decades. After the regime changes in the early 1990s the line of the Iron Curtain was transformed into a Green Belt, a nature conservation zone, through Europe from the Barents to the Black Sea. The idea for a Baltic Green Belt project was proposed in 2008. Economically, the coastline of the Baltic Sea Region is more and more turning into an important tourism, recreational and residential area. A development in the sense of the European Green Belt aims at providing a living for the residents of the Green Belt territory while minimising negative impacts of human activities on the environment. The BSR Strategy builds on four objectives:

1. to improve the environmental state of the Baltic Sea Region and especially of the Sea;
2. to make the Baltic Sea Region a more prosperous place by supporting balanced economic development across the Region;
3. to make the Baltic Sea Region a more accessible and attractive place for both its inhabitants, for competent labor force and for tourists;
4. to make the Baltic Sea Region a safer and more secure place.

As these marine territories are part of the Baltic Green Belt, the European Green Belt environment is directly threatened by poor water quality of the Baltic Sea. The water quality problem is created to the extent of 99% by inland activities, particularly agriculture. The majority of nutrient pollution to the Baltic Sea stems from Polish territories, as agriculture plays a major role for Polish economy.

Cross- cutting concepts of "Technologies enabling maritime growth", also referred to bioeconomy and biorefinery development

More specifically, the concept of "Bioeconomy development for coastal areas" and, conversely, the cross-cutting concepts of "Technologies enabling maritime growth" seem particularly suitable for international cooperation, especially with ENP Countries and within the numerous Marine and maritime-related EU-policy areas.[116] Cross- cutting initiatives could be promoted towards sustainable marine and maritime Union policies**, EU Coastal** and Marine Policy[117] and within the frame of EU **sea basin strategies to ensure**

[115] (http://www.balticsea-region-strategy.eu/

[116] http://ec.europa.eu/maritimeaffairs/policy/sea_basins/index_en.htm

[117] http://ec.europa.eu/maritimeaffairs/policy/blue_growth/

tailor-made measures and to foster cooperation between countries[118, 119] , as reported in the information here below.

EEAS(European External Action Services) has launched the Black Sea Synergy for regional cooperation with and between the countries surrounding the Black Sea.[120] It was designed as a flexible framework to ensure greater coherence and policy guidance while also inviting a more integrated approach.. The Black Sea is bordered by 6 countries - including EU members Bulgaria and Romania. By encouraging cooperation between the countries surrounding the Black Sea, the synergy offers a forum for tackling common problems while encouraging political and economic reform as:

- stimulate democratic and economic reforms
- support stability and promote development
- facilitate practical projects in areas of common concern
- open up opportunities and challenges through coordinated action in a regional framework
- encourage the peaceful resolution of conflicts in the region

Specific Black Sea Synergy sector partnerships will address transport, energy and the environment. Additional initiatives may follow on higher education, public health and the fight against organised crime. Activities are already underway in the fields of civil society, research and information society.

The EU has also established a new cross-border cooperation programme for local authorities in the Black Sea area and that also provides support to civil society organisations. The Black Sea Environmental Partnership was launched in March 2010. Further measures are now needed on biodiversity conservation as well as integrated coastal zone and river basin management. Other priorities include tackling pollution and promoting environmental integration, monitoring, research and eco-innovation.

The **Mediterranean region** is bordered by over twenty countries and a large part of the Mediterranean Sea remains outside national jurisdiction. As a result, cooperation is needed to manage maritime activities, protect the marine environment and maritime heritage, prevent and fight pollution in the Mediterranean Sea region, or ensure a safer and more secure maritime space.

Managing water resources, pollution and waste and combating soil erosion are some of the main challenges, as illustrated by the fact that, in 2007, the Mediterranean region used its natural resources 2.6

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http://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/index_en.htm

118 http://ec.europa.eu/maritimeaffairs/policy/sea_basins/adriatic_ionian/index_en.htm

http://ec.europa.eu/maritimeaffairs/policy/sea_basins/atlantic_ocean/index_en.htm

http://ec.europa.eu/maritimeaffairs/policy/sea_basins/baltic_sea/index_en.htm

http://ec.europa.eu/maritimeaffairs/policy/sea_basins/black_sea/index_en.htm

http://ec.europa.eu/maritimeaffairs/policy/sea_basins/mediterranean_sea/index_en.htm

http://ec.europa.eu/maritimeaffairs/policy/sea_basins/north_sea/index_en.htm

http://ec.europa.eu/maritimeaffairs/policy/sea_basins/arctic_ocean/index_en.htm

119 Macroeconomic Scenarios for the Euro-Mediterranean Area. MEDPRO Report No. 7/July 2013.

120 http://eeas.europa.eu/blacksea/index_en.htm

times faster than it replenished them (compared to the rate of 1.5 times faster for the planet as a whole). [121]

Pressure from human activities and pollution by pathogens, toxic waste (also enter the food chain) can negatively influence human as well as economic activities. Despite the long-standing Convention (1972) and Protocol (1996) on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter,[122] such activities continue to be problematic. As an example EEA (European Environment Agency) estimated that tourism accounted for 7% of all the pollution in the Mediterranean Sea.[123]

EU relations with the countries of the Southern Mediterranean and the Middle East have been developing through the Euro-Mediterranean Partnership, which was established by the Barcelona Declaration in 1995. More recently, the European Neighborhood Policy (ENP) has begun to map out relations between the EU and these regions. The Euro-Mediterranean Partnership – also known as the Barcelona Process – is a regional forum for political, economic and social co-operation, which sits alongside bilateral Association Agreements and ENP Action Plans. The creation of the Union for the Mediterranean (UfM),[124] in 2008, marked the re-launch of the process. The Union for the Mediterranean promotes economic integration and democratic reform across 16 neighbors to the EU's south in North Africa and the Middle East. More concrete and more visible with the initiation.

Along with the 28 EU member states, 15 Southern Mediterranean, African and Middle Eastern countries are members of the UfM: Albania, Algeria, Bosnia and Herzegovina, Egypt, Israel, Jordan, Lebanon, Mauritania, Monaco, Montenegro, Morocco, Palestine, Syria (suspended), Tunisia and Turkey.
The Mediterranean dimension of the integrated maritime policy[125] is currently facilitated by the following actions:

- A Project on Integrated Maritime Policy for the Mediterranean (IMP-MED)[126] that seeks to provide opportunities to the European Neighborhood Policy countries of the Mediterranean for engaging in and to obtaining assistance for maritime-policy development and cooperation.
- The MAritime REgions cooperation for the MEDiterranean (MAREMED)[127] project, falling under the European Territorial Cooperation Programme Med for 2007-2013), that seeks to encourage the integrated maritime management and the sustainable development of coastal zones for the different levels of coastal governance.

[121] Robert Lanquar (2011): Tourism in the MED 11 countries, CASE Network Reports, No. 98/2011, CASE - Center for Social and Economic Research, Warsaw (http://www.case-research.eu/upload/publikacja_plik/34467842_CNR_2011_98.pdf, 18/1/2013).

[122] Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter

Adoption: 13 November 1972; Entry into force: 30 August 1975; 1996 Protocol: Adoption: 7 November 1996; Entry into force: 24 March 2006

[123] What's more, with tourism only marginally affected by the crisis and the downturn caused by the Arab Spring unlikely to be long-lasting, the situation is expected to worsen, with rising numbers of tourists (over the past two decades, the Mediterranean region has recorded the highest growth in inbound tourism in the world) likely to have a worrying impact on the environment. http://cor.europa.eu/en/activities/arlem/activities/meetings/Documents/report-sustainable-tourism/EN.pdf

[124] http://ufmsecretariat.org/
[125] "Towards an EU Integrated Maritime Policy and better maritime governance in the Mediterranean" (COM (2009) 466)

"Partnership for Democracy and Shared Prosperity with the Southern Mediterranean" (COM(2011) 200).

[126] http://www.imp-med.eu/En/home_4_index
[127] http://www.maremed.eu/

“Boosting marine and maritime innovation through biotechnology”

The production of “unconventional” biomass, also through the exploitation of aquatic living resources, is an area of possible international cooperation with Third Countries that are experimenting biotechnology solutions in similar environmental contexts for reduction of sea contaminants and dissolved nutrient loads in aquaculture and agriculture effluents. It might be useful to underline that *29% of marine biotechnology patents are from US and 19% are from Japan.* Environmental technology patent application in Asia dramatically increase and South Korea and Japan lead globally on environment-related technologies (PCT patent applications per Billion GDP) follow up by EC and US in 2000-2014. [128] As a consequence, “Going Global” is a major challenge and opportunity for European research and Innovation[129].

Cooperation with US[130] could be envisaged also within the US-EU Task Force on Biotechnology Research.

Resources from marginal and arid lands: turning creativity into innovation also by exploiting traditional and local know-how

International cooperation activities could bring mutual benefit from the sharing of different local traditional know-how and enlarging specific scientific expertise in the study of resilient plants and crops adaptable in marginal, polluted and arid lands. These cooperation activities could be envisaged within the EU-Africa dialogue on research and innovation[131] and also involving ENP Countries. It might be useful to underline that North Africa and the Middle East natural capital constitutes 36 percent of total wealth, and 24 percent of total wealth in sub-Saharan Africa. This is greater than the share of produced capital.[132]

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[128] http://www.oecd.org/sti/inno/oecdpatentdatabases.htm

[129] European Commission: Placing excellence at the centre of research and innovation policy. Draft Publication of the European Research and Innovation Board (ERIAB). February 2014. pp. 24-26

[130] *Data from:*

“Marine biodiversity and gene patents”. Science 25 March 2011: Vol. 331 no. 6024 pp. 1521-*1522DOI:10.1126/science.1200783*

“Marine Biotechnology: Enabling Solutions for Ocean Productivity”. OECD (2013),

“What lies underneath: Conserving the oceans’ genetic resources. www.pnas.org/cgi/doi/10.1073/pnas.0911897107 PNAS Early

[131] http://hrst.au.int/en/content/eu-africa-high-level-policy-dialogue-science-technology-and-innovation-brussels-belgium

[132] Africa in 50 Years’ Time, The Road Towards Inclusive Growth, African Development Bank, Tunis, Tunisia, September 2011.

5 STRATEGIC NARRATIVE of SUB-GROUP MARINE and MARITIME RESEARCH: Fisheries, Aquaculture, Biodiversity and Society

SECTION 1

Priorities selected from the Specific Program

Four research areas are addressed here that are interlinked and build a complex in support of the Blue Growth as well as the new Common Fishery Policy and the Marine Strategy Framework Directive:

- Advanced offshore and sustainable aquaculture,
- Smart fisheries technologies,
- Development of regionalized management concepts,
- Fish migration and distribution under climate change,
- Zooplankton dynamics and productivity, and
- Ocean (or sea) literacy.

These six topics are deeply connected and partly interlinked. They are of great cross-cutting nature and partly deeply embedded in the transatlantic cooperation. The topics need to be seen as an entity even though they address different parts in the Specific Programme:

Advanced offshore and sustainable aquaculture contributes directly to the European flagship initiative "Innovation Union", refers to the General Provisions (Article 2 a,b,c,e) and addresses PART II, “Industrial Leadership” and in particular § 1.3 *Advanced materials* and meets as well the **Specific Objectives** in Part 2 "Industrial leadership", a (iii) advanced materials, 2a (v) advanced manufacturing and processing, as well as 2c: Increasing innovation in SMEs". More specifically, in PART II, § 2.3. *Unlocking the potential of aquatic living resources*. Furthermore, it contributes directly to the European flagship initiative "Innovation Union".

The overall goal of developing **smart fisheries and aquaculture** is to meet PART III, Societal Challenge § 2.3.1 to *Develop sustainable and environmentally friendly fisheries*. This initiative is pushing the frontiers of technology and matches the Specific Objective of the General Provisions Art. 3, part 1 (b) and in PART I “Excellent Science” by *strengthening research in future emerging technologies* (FET), as well as PART II “Industrial Leadership” by advancing the technology and building-up world leading scientific and technological expertise in development of smart fishing gear and intelligent coupling of production systems and thus establishing the next generation of marine food production. Primarily this addresses PART III “Social Challenges” § 2.3 *Unlocking the potential of aquatic living resources* by boosting the maritime technology, and even more specifically § 2.3.1 *Developing sustainable and environmentally friendly fisheries*.

Regionalized management concepts support the implementation of the Common Fisheries Policy and the Marine Strategy Framework Directive within the Europe 2020 and the flagship initiative “Innovation Union”.

Fish migration and distribution under climate change as well as **zooplankton dynamics and productivity** address also directly § 2.3.1 and refer directly to the Specific Programme Part III, § 2.5.1 *Climate change impact on marine ecosystems and maritime economy*.

Though being part of the current BG-13 call developing **ocean literacy** is a long-term goal and focuses at Part V "Science with and for Society" ("d" and "h") and to Part III Social Challenges § 2.5.1 *Climate change impact on marine ecosystems and maritime economy*.

Background

Both, fisheries and aquaculture are high on the list of the European Maritime Strategy for the Atlantic Ocean Area[133] and are a part of the overall Challenge and Opportunity (2.1: Implementing the Ecosystem Approach) (see Fig.1), and is implemented through the European Action Plan[134], and further corroborated by the specifics of the scientific working group to the Galway Statement[135]. Furthermore it addresses directly the plea of the FAO for concrete actions to improve ocean health and to secure food for the population as requested by the Global Oceans Action Summit on Food Security and Blue Growth[136].

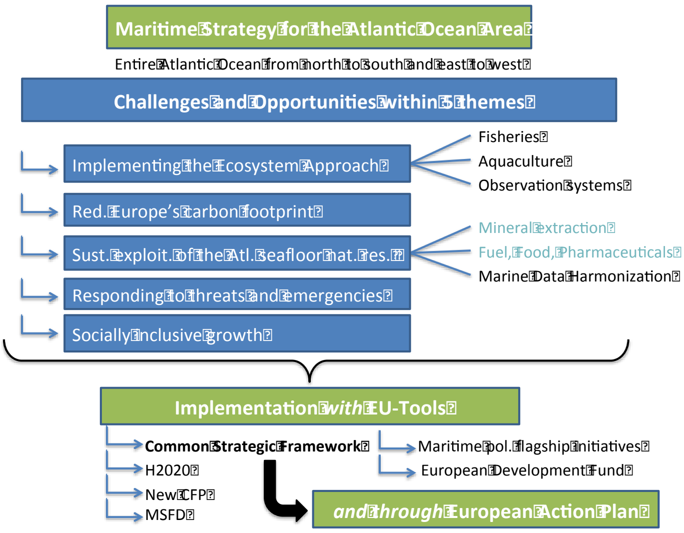

Fig.1, Position of Fisheries and Aquaculture research in the Maritime Strategy for the Atlantic Ocean Area[137], based on COM(2011) 782.

Both as single topics as well as functional complexes these themes gain from pan-European and/or transatlantic cooperation. It is evident that aquaculture as such and fisheries techniques as well have been and are subject to on-going and previous research programmes of the COM. However, offshore aquaculture and smart fisheries techniques together with the integrated regional management concepts go

133 Communication from the Commission tot he European Pariament, the Council, the European Economic and Social Committee and the Committee oft he regions: Developing a Maritime Strategy fort he Atlantic Ocean Area. COM(2011) 782.

134 Action Plan for a Maritime Strategy in the Atlantic Area COM(2013) 279.

135 Galway_2013_scientific_workshop_report.pdf: https://www.google.de/search?q=galway_2013_scientific_workshop_report.pdf&ie=utf-8&oe=utf-8&aq=t&rls=org.mozilla:de:official&client=firefox-a&channel=np&source=hp&gfe_rd=cr&ei=L7qpU6uQIcaK8QfSzoCYBA

136 http://www.fao.org/news/story/en/item/230743/icode/

137 Report oft he ICES Council Working Group on Maritime Transatlantic Cooperation (2014) with permission.

beyond the horizon of the current programmes, as Jones et al. (2014) have underlined most recently[138]. Viable alternatives to wild fish-based aquaculture feeds, resource constraints that will potentially limit expansion of aquaculture, sustainable offshore aquaculture and the treatment of sea lice are no new research topics and issues. However, they have not been solved yet and are still high on the priority list[139].

SECTION 2

Drivers and Trends

Since 2012 the fish and seafood production of the world increased by 10 mill. t. In view of the employment this sector has been growing faster than the world's population[140] since 1990. Still, a great need exists to continue along this line and seems possible since there is still huge potential in the European seas, the aquaculture and fishery technologies. However, success will not be in linear progression of what is currently done. The seas and oceans change and with it it's ecology. The challenge is therefore **firstly** to identify the specific technological potentials, the potentials in seas and oceans that presently undergo climate change, **secondly** to unlock and develop these potentials and **thirdly** to make society a part of this process, since to support this society needs to understand both the change as such, as well as the potentials of development and at the same time the threats.

The potentials and challenges lie in different sectors: (1) technological development in aquaculture systems (i.e. aquaculture in its widest sense including shellfish culture, algae culture etc.), (2) technological development in the techniques of capture fisheries, (3) development of new progressive and integrative management systems for the living resources of the seas, and (4) development of integrated coastal seas and ocean concepts of resource use (biogenic geological and physical resources as well as space).

The Growth of the world population, its demographic changes due to migration caused by civil wars, and/or climate change and desertification as well as world-wide economic crisis ask for real answers and constitute the main drivers. Blue growth can partially be the answer and is already the trend: Making more of the space by going offshore with aquaculture, developing fishery technologies, redesigning the fisheries management and educate people better about the developments, opportunities and threats, i.e. making them a part of it and are integral parts of the international megatrends.

After a preparation phase of nearly 10 years the new Common Fisheries Policy (CFP) and its environmental extension the Marine Strategy Framework Directive (MSFD) have come into force. They are however not yet fully implemented and it is likely that this implementation will take 5 to 10 years. A number of specifics are however not yet fully defined, e.g. environmental descriptors[141] or how to implement and control a discard ban in a mixed fishery. It is imperative that the H2020 research programme supports both, the Specific Programme as well as the implementation of the CFP and the MSFD.

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138 Jones, A.C. et al. (2014) Prioritization of knowledge needs for sustainable aquaculture: a national and global perspective. Fish and Fisheries DOI:10.1111/faf.12086

139 ibid Jones et al. (2014)

140 The State oft he World Fisheries and Aquaculture. FAO (2014)

141 e.g. Probst, W.N. and Oesterwind D. (2014) How good are alternative indicators for spawning stock biomass (SSB) and fishing mortality (F)? ICES JMS, 75:1137-1141.

This translates into extension of research on **integrative** and **cooperative** (mostly coastal) **concepts** but goes far beyond this into the deep sea[142]. Integration is an essential part of the concepts since the overall societal paradigm has developed from "go and take" to "use and keep". Therefore, the concepts need to integrate (and reconcile conflicts of) food production in the seas and oceans and resource exploitation with sustainability requirements, targets and thresholds, as well as technological development of aquaculture and its off-shore expansion with environmental restrictions, human and social activities on coastal regions, ecosystem conservation, with biodiversity change and all this with societal acceptance. Moreover, advanced offshore aquaculture, smart fisheries and ocean literacy[143] are subjects prone for becoming an integral part of international and transatlantic cooperation, in support of the Galway Statement of 2013.

The overall task for the next EU-research programme should therefore be to develop regional-specific integrated coastal concepts. Following the identification and definition of ecological, political and societal regions (possibly Adriatic Sea, Western Baltic Sea etc.) the integrated concepts need to be developed with clear ecological, political and societal problem-identification, before it is possible to develop regional-specific integrated solutions and subsequently to produce feasible, achievable but still ambitious implementation plans. Since this goes far beyond marine spatial planning it is imperative to develop "meta-concepts" first, i.e.: to identify what the overall strategy for each particular region should be to come to an integrated concept and then how to implement this. The outcome is likely to be a Do-List for politicians, the Joint Programming Initiative(s), the scientific financing bodies as well as the scientific organisations. In short: the overall question is what exactly does each particular region need to come to agreements and solutions?

To unlock the potential of the seas and oceans for sustainable and environmentally friendly food production in an environment of rapid climate change[144] requires thinking beyond the horizon of current and contemporary research[145]. Otherwise neither the challenges will be tackled nor the potential be unlocked. This is the case not only for the North Atlantic, the Mediterranean, Baltic and Black Seas (and namely their shelf and coastal areas) but for all seas and oceans. Of course the suit of requirement applies to each of the sea basins differently and according to its own specificities, as a result of the different ecosystems, climate and stress factors, as well as socio-economic, cultural and political contexts. For this reason there is a strong element of regionalization in the new CFP. The proposed research corroborates this concept.

Advanced offshore and sustainable aquaculture

A great need exists in Europe to unlock the potential of space in the sea for sustainable and environmentally friendly food production. Aquaculture production is predicted to rise to 85 Mt year^{-1} until

142 Barbier, E., Moreno-Mateos, D., A. Rogers, J. Aronson, L. Pendleton, C. Van Dover, R. Danovaro R., L-A., Harvey, T. Morato, & J. Ardron. (2014). Protect the Deep-sea. Nature, 505: 476-477.

143 http://atlanticoceanliteracy.wp2.coexploration.org/

144 Mora C., Wei, Chih-Lin; Rollo, Audrey; Danovaro R. et al. (2014) Biotic and human vulnerability to projected changes in ocean biogeochemistry over the 21st century. PLoS Biology, 11: 10 Pages: e1001682.

145 Anadón R., Danovaro R., Dippner J.W., Drinkwater K.F., Hawkins S.J., O'Sullivan G., Oguz T., Reid P.C. (2007) Impacts of Climate Change on the European Marine and Coastal Environment. MB ESF, 84 pp.

2030[146][147] and, at a growth at of nearly 9% year^{-1}[148] is therefore expected to exceed the catch of wild fish in the near future. It is thus un-debated that conventional land-based aquaculture and coastal aquaculture will continue to grow, thereby playing in the future a massively growing role in a high quality food supply for a population that will reach 9 billion by 2050[149]. The sustainability of intense marine aquaculture and its associated environmental impacts as one of the key limiting factors were identified as such more than a century ago[150] apart from the availability of space.

Provided a number of technical challenges are met, the installation of offshore wind farms as unconventional and modern technologies opens new and huge spaces for aquaculture within the wind farms since ship traffic as well as fishery are usually prohibited in these areas. Offshore wind farms have generated new potentials by (in principle) opening space in the sea for new forms of utilization. These spaces are urgently needed since near-shore spaces for aquaculture expansion have become rare and, where it is geographically still possible to expand, are mostly conflicting with environmental concerns. Thus, governments and international organizations (e.g. FAO) worldwide are responding to the *blue revolution* by becoming increasingly interested in expanding aquaculture to foster food security, nutrition and income generation. Offshore aquaculture comprises different forms such as submergible cages for fish, mussel cultures on ropes as well as seaweed culture on flexible or hard structures. The huge offshore spaces open new opportunities to keep fish in greater spaces and possibly at greater individual distances, which reduces the vulnerability of aquaculture by diseases. As already now done in the Mediterranean with juvenile tuna, undersized wild fish could be brought alive to offshore cages for further growth until the fish have reached their biological optimal size for harvesting.

The potential of offshore technologies and production in the space of marine wind parks is developed in different places in Europe. The overall challenge is to combine the forces and to develop new technologies synergectically within Europe.

Aquaculture: Drivers and Trends

The fundamental driver is the international pressure on the marine living resources and the need to feed a growing population.

The exploitation of the natural (wild) marine living resources underlies the social megatrend of conversion into an environmentally friendly and sustainable use of the natural living resources, taking into account the requirements of the entire ecosystem, having fully acknowledged that the productivity of the marine living resources is limited and that fully sustainable exploitation may mean that at least in the medium term the overall harvest may sink, while the world population grows.

Another megatrend is the request of the society to exploit the ecosystems environmentally responsible, which implies for the coming decades the gradual move away from ecologically destructive open sea fisheries towards smarter fish production on high seas, creating high expectations from new technologies.

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146 FA0 (2007) Fisheries and Aquaculture Statistical Database. FAO, Rome. http://www.fao.ord/fishery/statistics/global-auqaculture-production/en.

147 FAO (2012) The state of world fisheries and aquaculture . FAO, Rome, 230pp.

148 Jones, A.C. et al. (2014) Prioritization of knowledge needs for sustainable aquaculture: a national and global perspective. Fish and Fisheries DOI:10.1111/faf.12086

149 World Population Prospects (2012) Population Division oft he Department of Economic and Social Affairs of the United Nations Secretariat, 2012 Revision. http://www.esa.un.org/unpd/wpp/index.htm

150 e.g. Naylor et al. (2000) Effect of aquaculture on world fish supplies. Nature: 405:1017-1024.

The development of marine offshore aquaculture technologies is a truly cross-cutting challenge for science and industry, supporting food production, blue growth and marine ecosystem conservation, thus fitting directly to the social megatrend "*conversion towards conservation*".

Another social megatrend is the invention of new technologies to make better use of the increasingly limited space for food production in Europe. For an increase of aquaculture new areas must be found since coastal aquaculture is going to find its limitations soon.

Finally, the European and transatlantic megatrend is to achieve technological innovation by synergy through cross-cutting cooperation and collaboration.

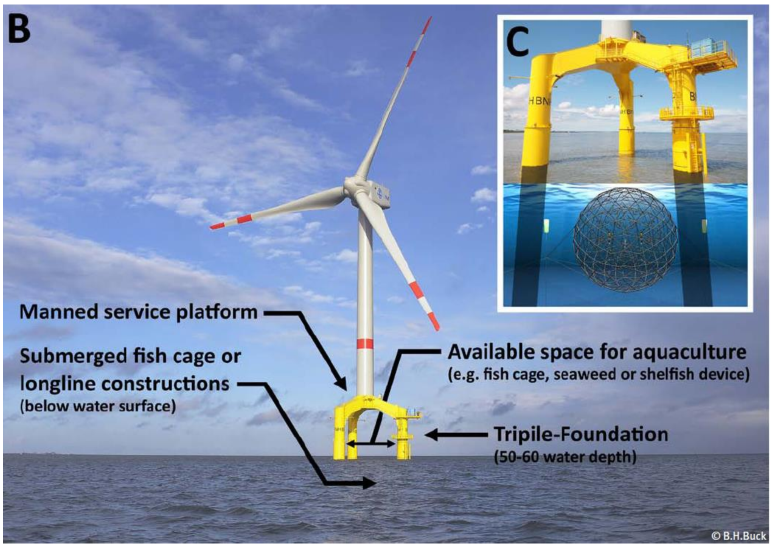

Fig. 2 Example of a submerged cage. Photo: B.H.Buck

Offshore-aquaculture: Bottlenecks, future challenges, gaps in R&I, potential threats

In contrast to near-shore systems in sheltered regions, aquaculture in high-energy environments (e.g. hostile near-shore, offshore) will require much higher inputs of capital and needs as well a new level of cooperation from a wide range of social, technological, economic, and natural resource users. Moving offshore holds furthermore the potential for lesser stakeholder conflicts over allocation of space. Over the past decade major advances and new offshore use concepts have evolved, and several of them have been successfully tested at the pilot scale level, while others have failed. These experiments and scale-up trials suggest that offshore aquaculture does have substantial potential to bring global aquaculture production to new levels to meet future human needs. However, to date global trade masks the social and ecological implications of consumption as it distances the society from production areas and the supporting ecosystems. At present, the world, especially the western world, is too dependent on aquaculture development and its international trade, as aquaculture is threatened by i.e. coastal urbanization, industrialization, and water pollution. Weighing these issues highlights the urgent need to develop offshore aquaculture, while complying with the FAO Code of Conduct for Responsible Fisheries and Aquaculture as well as with other environmental regulatory frameworks in support of sustainable aquaculture development.

Developing high-tech solutions for off-shore marine aquaculture in wind parks appear in very differnet technical forms (e.g. Fig.3) and bears both risks and challenges, and there are at least four major bottlenecks associated: (1) Harsh weather conditions and major wave impacts require the development of completely new technological approaches, (2) improved management of wild fish stocks could increase the stock sizes of wild fish, leading to relatively low prices of fish on the world market. This could make it difficult for fish or mussels from "high-tech farms" to compete with products caught in the wild, to the effect that investments become difficult to calculate, which increases the uncertainty of finding industry partners, (3) fragmentation of research in Europe on this topic, and (4) limited biological knowledge about the behaviour of farmed animals in a high sea environment.

Offshore aquaculture: Inputs, strategic recommendations related to research and innovation

Strategies are in need to be developed with strong participation of all affected stakeholders interested in the social-ecological design and engineering of innovative offshore aquaculture food systems. Indeed, such aquaculture operations are social-ecological systems acting under specific economic conditions. Thus whilst recognizing that the integration of offshore food and energy systems (e.g. aquaculture systems and wind farms; oil and gas, desalination etc.) appear to be especially promising, the use marine spatial planning, and transparent, adaptive management for spatial efficiency and conflict resolution requires notwithstanding a high level of innovative technology.

It is recommended to develop calls explicitly for pan-European industry - science cooperation. This research area should directly be addressed towards the SMEs that should be supported when seeking collaboration with research institutes or *vice versa*. Presently offshore wind farms are built or planned to be built in many places in Europe and the Americas and research on the utilization of these new spaces are widespread.

The goal must be to overcome European fragmentation in this field of research and innovation and to work on European solutions at best in transatlantic cooperation with the Americas or other transatlantic nations. The research is biological, ecological, technological and economical. It is of high complexity and demands a high level of integration. It is truly future-oriented and aims at safeguarding a European top-position in technological development and environmental management while meeting the prevalent social challenges of food security, blue growth and employment provision.

It is recommended to support the organization of the international research and development platforms involving countries active or intending to initiate (*inter alia*) offshore aquaculture[151].

Offshore aquaculture: How success would look like

Naturally, the success depends largely on (1) development of new and largely unconventional aquaculture technologies that can sustain high-energy environments, (2) the development of the prizes of seafood at large on the international fish and seafood markets, and (3) on the degree of successful implementation of pan-European and transatlantic research cooperation amongst the research facilities but also (an namely) the industrial partners in sea-going aquaculture.

[151] Recommendation 6 of the Bremerhaven Declaration on the Future of Global Open Ocean Aquaculture (2012): www.aquaculture-forum.com.

If these conditions are (at least to some extent) met, then true synergy can be generated together with a much more efficient research and development, if the hitherto fragmented and nationally oriented small-scale research can join forces to develop a critical mass.
This is the true challenge: Throughout the entire European and US/Canada coasts and shelf areas the problems are similar. So far relatively isolated and small groups design, develop and test small-scale experiments that generally lack the appropriate funding and long-term approach.
It is time to unify these single-approaches and to build critical masses by pan-European and transatlantic research cooperation.

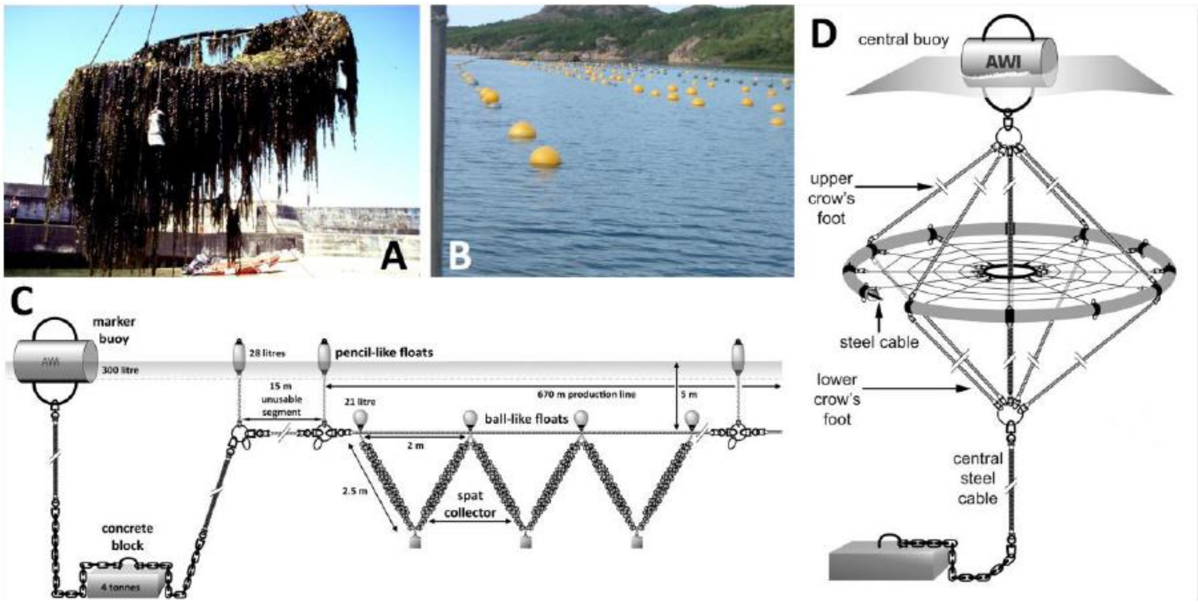

Fig. 3: Aquaculture constructions suitable for the cultivation in high-energy environments. (A) Offshore ring design for the cultivation of macro-algae (here: harvesting after grow-out in the harbour of Helgoland), (B) example of a near-shore submerged long-line design for mussels and oysters, (C) schematic drawing of a submerged long-line suitable for exposed sites, and (D) a technical illustration of the ring design and its mooring system[152].

Smart fisheries technologies: Drivers and Trends

As a consequence of the increasing industrialization and the fragmentation of the space the traditional fisheries will have to change and will have to adapt, since the space in the sea to conduct fishery in the conventional ways shrinks continuously. The wider coastal areas (this is Baltic Sea, North Sea and European shelf areas as in contrast to the blue ocean) are in the process of being increasingly industrialized (wind, wave and current energy, seabed mining and exploitation, oil and gas extraction, gravel extraction etc.) and segmented (e.g. NATURA 2000 habitats, bird protection areas, pipelines), a process that requires planning while taking into account the ecosystem services of the diverse benthic habitats[153]. Marine Spatial Planning (MSP) is by nature a regional-specific approach in which fisheries and aquaculture are just a part of the

152 Modified after Buck & Buchholz (2004) and Buck (2007) from Bremerhaven Declaration, part 2 (2014)
153 Galparsoro, I., et al. (2014) Mapping ecosystem services provided by benthic habitats in the European North Atlantic Ocean. Frontiers in Marine Science 1:23 DOI:10.3389/fmars.2014.00023.

different forms of utilization and need to fit into this process. This however will not function without adaptation of the fishery and aquaculture to the other needs.

Thus, in order to survive as an industry and as an important part of our (at least) coastal culture the fishery will inevitably have to change from catching fish more or less indiscriminately and making high by-catches and discards, to methods that are very specific, selective and environmentally acceptable. Both the technical conversion and the management of the "fisheries in change" are huge challenges. In foreseeing this there are different systems under development at present by the industry that is surmised under "Eco Harvesting" (while the term as such is a trademark for the AKER company in krill fishery[154] to harvest krill alive and avoiding unwanted by-catches of seals and fish).

The principle driver for the industry (mostly Norwegian and New Zealandic) is the prospect that the fishery is heading towards a far more conscious and prudent way to use the resources in the future, attributing the overall societal shift of paradigm from "*go and take*" to "*use and conserve*".

Technically, the core-principle of what is approached presently to meet these demands (and to give an example here), is to use camera systems in the nets that film each fish swimming into the net[155]. The images (Fig. 4) are automatically processed on board of the vessel in real-time, the fish are identified and measured in length. Based on the setting it is automatically decided whether the fish needs to be released or not. If the fish is undersized or is not covered by a quota a trapdoor opens and the fish is released unharmed, making discard-free fishery possible. Otherwise the trapdoor remains shut and the fish is (by means of an air-bubble stream in a wide hose) pumped on deck into a basin where it remains alive and in best shape.

Fig. 4, Image of a saithe in the codend during Norwegian trials of "Deep Vision".[156]

During such a smart fishing processes fish that is too small for profitable marketing but is larger than the minimum conservation size would not be killed and sold for little revenue but kept alive and could be brought into the offshore aquaculture where it is further reared to optimal market size, thus making best use of the natural resources.

154 http://en.wikipedia.org/wiki/Eco-Harvesting
155 http://www.youtube.com/watch?v=ql2tDl-Y7xk
156 CRISP Annual Report 2011. http://www.imr.no/crisp/filarkiv/crisp_annual_report_2011.pdf/en

Smart fisheries: Drivers and Trends

Future fish production in the sea, no matter if derived from fishery or aquaculture, needs to make the best out of the marine resources. Fish is valuable, will become even more valuable and must be treated accordingly (D 7 *food security*). Huge potentials of ecological services and opportunities from the sea are presently not used or directly wasted. New harvest technologies and completely different fish production strategies are required to solve this.

As a societal reaction to the irresponsive exploitation of the seas the contemporary paradigms of how to utilize the marine living resources have changed and have grown into a megatrend towards (1) undertaking great efforts to reduce overfishing and where this has accomplished, to reverse the effects of overfishing that still dominate in large parts of the seas. This comes (2) along with the relatively new overall paradigm to integrate ecological requirements into the management of the fish resources in order to safeguard the ecological services of nature for the society, minimizing the human impact and to preserve the seas and their wealth for future generations. It is never the less societally accepted and a clear trend to make use of the natural living resources for human consumption and to improve the food security, this however in the most efficient and sensible way.

The goal of sustainable and ecologically integrated exploitation has not yet been reached. It is still and will remain to be a major societal and political driver and challenge. While there are areas in the Atlantic and Mediterranean that make good progress, there are others lacking widely behind, while at the same time the pressure on the resources continues to grow, which is another and antagonistic driver.

For those areas where progress is visible, the question arises: What comes next? How will food (mainly fish) be produced in a world of sustainability in its ecological balance, being at the same time under pressure to increase its production, since at the same time the population and the demand for high quality food continue to grow? How can Blue Growth resolve this, remain ecologically tolerable and even support the development of those areas where sustainable management is not yet reached?

The answer is likely to lie in advancing the fishing system technologies and coupling these to new food production strategies in aquaculture. Future food production systems, be it fisheries or aquaculture, will both need to develop technologically and by doing so form together a production complex of mutual benefit, increasing the food production in Europe.

This can be accomplished by utilizing intelligent solutions and through development towards smart fisheries and aquaculture technologies that work hand in hand and are economically linked. Capturing wild fish needs to be redefined and executed completely differently in the future. In the light of what is technologically possible the current fisheries practices are rather anachronistic, considering that huge amounts of precious fish are currently discarded and growth potential of fish is wasted when fished at suboptimal size.

Smart catching methods may change this and first attempts are tested by the industry already. The essential of this is that fish are caught life, rather than being chased, stressed, squeezed and killed in the process of fishing, then partly discarded if not fulfilling the criteria. Caught intelligently the fish stay

unharmed and in best condition. If too small and not sold directly they can be transferred to aquaculture for further rearing. This would give aquaculture in the whole totally new perspectives and opportunities of growth through a huge supply of small fish and helping to minimize the discard problem at the same time.

More specifically: In smart fishing operations the codends of nets may be covered with a plastic sheet or lining and the fish swim freely in a bucket of water when hauled on deck. In another approach the fish are continuously pumped from the codend into a tank on deck during the process of fishing. Cameras film the fish when they pass through a tunnel into the cod-end, they are identified by species, are measured in length and enter the database on the bridge before having left the tunnel. Flap-doors guide the fish either to the hose to be pumped aboard or are guided out of the net, in both cases the fish remain in best condition and health.

Smart fisheries: Bottlenecks, future challenges, gaps in R&I, potential threats

Such ("smart fishing") technologies are just developing; they are currently totally new territories of research and development and are economically not yet an option for the traditional fishery for human consumption, which is a real bottleneck in development. Moreover, better management and subsequently recovering fish stocks also meet the demand for increased food supply and European food security, reducing the incentives for industry to invest into smart fishing and aquaculture practices.

This is however likely to change in the future. In a world of growing population under sustainable and ecological resource utilization the fish stocks as a whole are too precious as to treat them as done at present. The best possible product needs to be made out of the resource, thus out of the catches and finally out of each single fish. Through progress in aqua- or mariculture a market will arise for small and life fish of species that are currently discarded in the fishery and cannot be reproduced artificially. Instead of killing or selling huge amounts of small and undersized fish these could be harvested sustainably and intelligently and brought into aqua- or rather mariculture facilities for further growth. It is evident that this requires progress in aquaculture technologies towards robust and sea-going devices, which poses a considerable technological challenge.

Smart fisheries: Inputs, strategic recommendations related to research and innovation

Fisheries and aquaculture can be foreseen to grow closer together in a logical way and along the line as is already performed in the Mediterranean with juvenile tuna. Fisheries and aquaculture will form a complex of technological innovation for mutual benefit to increase food production in an environmentally acceptable context, forming a pillar of intelligent blue growth. In the long run this is the only way to achieve simultaneously, (1) the sustainable utilization of the natural marine resources in an ecologically integrated manner, (2) to optimize the food supply for human consumption and (3) to reduce the European dependency on food (here fish) import.

Smart fisheries: How success would look like

Without repeating the above it is clear that success can only be expected if research and innovation are planned and performed with long-term goals. The key to success is the long-term-planning and the forward thinking towards solutions which for questions of tomorrow. Only then the time is given to develop technologies that will be ready and available when actually needed. The overall success is given, if the "smart-fishing and aquaculture complex" makes best possible use of the catches and realized that fish are far too precious to waste and discard them, by having developed the right incentives.

Moreover, the spin-offs go far beyond this. The technological development towards a "smart-fishing and aquaculture complex" is likely to be very beneficial also to the areas of continuous mis-management. With the establishment of new aqua- and mariculture facilities real blue growth will be initiated, job opportunities created also in these areas that produce blue societal value and therefore an economical counter weight to the traditional fishery. Smart fishing will demonstrate widely and convincingly that there are real alternatives to rigorous overfishing, thus pushing also politically towards better management and increased sustainability.

The feed for the fish in aquaculture is however conventionally fishmeal. The huge spaces that are available in wind-farms open though the door for developing poly-culture systems, i.e. producing the fish feed within or in the near proximity of the cages by establishing trophic chains (algae cultures[157] feeding herbivorous crustaceans and fish as primary or secondary consumers, being fed to the carnivorous fish in the pens). The development of such offshore marine poly-culture systems is scientifically at present still far-fetched but important in order to reduce the dependency on fishmeal production and import.

Regionalized management concepts: Drivers and trends

There are different ways to manage the natural living resources in the seas, namely fish. The fisheries management principles have changed with time[158], along with change of the ecological conditions and with the change of trends within the society[159]. Throughout the past 30 years the societal perception of the seas and oceans changed completely. For the society at large the seas have developed from space of "*unlimited resources*", to seas with "*threatened resources*", and further to seas of "*endangered ecosystems*", the latter is where we are at present. The societal perception is likely to further progress into seas of "*highly precious resources*". These might require completely different management approaches. So, the question is: fisheries management in the regions and beyond CFP – what is next?

The wind-farms, the aquaculture sites and the fishing need to be integrated in area-concepts for use, i.e. into the marine spatial planning (MSP) that is an integral part of the European Action Plan of the North Atlantic (Priority 2, section 5 "Marine Spatial Planning and Integrated Coastal Management")[160]. There is an urgent need to plan for the comprehensive development of land- and water-based infrastructures needed for the technical and logistical support and supply of the offshore aquaculture[161] and to develop **region-specific management concepts** that take all forms of utilization into account (therefore "integrated" management concepts). MSP is by nature regional-specific and needs to integrate the afore-mentioned

157 e.g. Enzing et al. (2014) Microalgae-based products fort he food and feed sector: an outlook for Europe. JRC Scientific and Policy Reports.

158 E.g. Lassen, H., et al. (2014) ICES advisory framework 1977-2012: from Fmax to precautionary approach and beyond. ICES JMS 71:166-172, doi:10.093/icesjms/fst146

159 E.g. Rice, J. (2014) Evolution of international commitments for fisheries sustainability. ICES JMS 71:157-165, doi:10.1093/icesjms/fst078

160 Action Plan for a Maritime Strategy in the Atlantic Area COM(2013) 279.

161 Recommendation4 of the Bremerhaven Declaration on the Future of Global Open Ocean Aquaculture (2012): www.aquaculture-forum.com.

activities. With regards to the fishery the CFP requires likewise regional fisheries management concepts and therefore both the MSP and the regional fisheries management will initially overlap and then eventually merge. However, the fisheries management itself needs to change and adapt to the climate change conditions, i.e. to altering distribution and migration of fish (see below). For this reason, integrated concepts for regional management of the fishery and the aquaculture development are required. This also needs to take into account the entire suit of ecological services that is rendered to society and is thus going far beyond simple fishery management as at present, since the entire cultural and recreational value of the seas needs to be taken into account.

This process will produce Blue Growth but will strongly require **cross-sectorial cooperation**. It will however change largely the way the public perceives the seas as a cultural and recreational area. In order to find public support for the entire process of Blue Growth in general and the paradigm shift of utilization of the seas in particular, it is imperative to make the public a part of the process to take them along by building up the ocean literacy and overall ocean-competence[162]. There is an urgent need to address the question how societal values and policies affect acceptance, structures, and types of offshore aquaculture[163] and changes in the utilization of the seas. Moreover, it is important to increase the public awareness of biodiversity and its changes due to climate change and alterations of the use of the sea. It is important to facilitate and encourage the engagement of citizens on marine biodiversity issues, including activities to monitor biodiversity and to promote its conservation and sustainable use[164].

Marine ecosystems are uniquely delivering commercial products and are managed in a very traditional way that has been changed and modified continuously according to societal need but lacking behind the societal and ecological development due to the complexity of the subject and its administrative and multi-national integration. Thus, as a whole, the management is still conservative in so far as it is dominated more by tradition than by the real societal needs. This has lead to economic inefficiency, since the entity of marine ecosystems could possibly provide more to society than only fish and shellfish: it renders in wider sense public goods also of cultural and recreational value, and thus important ecological services beyond direct food supply[165]. These are, however, currently not an aspect of consideration in the present resource management.

The multi-industrial expansion in the seas and subsequently the marine spatial planning, the Marine Strategy Framework Directive, i.e. conservation at large, and the seas as an important space for recreation require new thinking about the traditional fisheries management.

Therefore, **research needs to be carried out to better understand the complex interactions between the ecosystem and its services as a production system, and the provision of these public goods and services to the society as a whole**.

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162 Green Paper Marine Knowledge 2020_com2012_ COM 473.

163 Recommendation 3 of the Bremerhaven Declaration on the Future of Global Open Ocean Aquaculture (2012): www.aquaculture-forum.com.

164 Draft of the Fourth Edition of the Global Biodiversity Outlook. UNEP Subsidiary Body of Scientific, Technical and Technological Advice, 18th meeting, June 2014.

165 As further detailed in a benthic mapping assessment of European North Atlantic ecosystems and their services by Galparsoro et. al. (2014) Mapping ecosystem services provided by benthic habitats in the European North Atlantic Ocean. Front. Mar.Sci. DOI:10.3389/fmars.2014.00023.

In other words, other utilization forms of the seas, namely tourism and recreation in its different forms as a societal value need to be integrated in all, the marine spatial planning and the regional resource management as well as the fisheries management. As a first step, the latter will be easiest to be adapted if the recreational fishery was better integrated into the fisheries management[166]. The traditional view of the management of living marine resources was in the past the utilization of the seas as a source of protein and is driven now by both, achieving biological goals for conservation and, due to goal-definition by political bodies, the wealth creation: the fish in the sea benefits presently mainly the fishery[167], and, to a regionally very different extent, the tourism and recreational fishery.

In the process of the industrialization of the seas, the societal megatrend has developed to redefine and to think differently about the use of the seas in terms of space and in redefining the term “who owns the oceans?” In the wake of this it is evident that also the question arises whether there are possibly better ways for a regional management that is effective, transparent, fair and equitable to all resource users, i.e. quantifying the economic gains and significance from each sector of resource-user: Which level of economic and cultural importance does each sector have?

It is evident, that the economic importance of the traditional marine fishery has significantly decreased and declined not in all but in many parts of the Europe, especially due to concentration effects[168]. At the same time, the recreational fishery increased significantly, supporting an enormous angling and tourism industry constituting a major source of employment and contributing substantially to the economy of deprived coastal communities. Thus the question arises whether allocating the entire resource of fish stocks in an area to the recreational fishery would not possible provide more economic wealth and growth to society (jobs, NGP) than leaving the resource to a relative small number of fishers.

It is therefore the overall goal to **develop regionalized management concepts that integrate the fisheries management with the other forms of resource exploitation and conservation, namely recreational fishery and the conservation goals**. Specifically, it is (1) a research task in itself to define regions that make sense politically and ecologically where these are not as obvious as in the North Sea, Kattegat or Adriatic Sea. It is (2) a task to bring the relevant stakeholders together to develop integrated management concepts: i.e. the development of fisheries management plans in an ecological context thereby fulfilling the requirements of the MSFD. It is in a next step (3) the task to develop one comprehensive management plan per region that comprises nature conservation (NATURA 2000 sites, special bird protection areas, fishing areas, wind farms, offshore aquaculture, gravel extraction, naval routes, recreational fishing, tourism etc.). How to achieve this is a task in itself (developing concepts and *modi operandi*) but should be based on on-going work of MSP, since there are projects that have laid the foundation and are showing the direction (e.g. PartiSEAate, VASAB). Building on this the MSP should be elevated onto a level of the development of the integrated regional management plans.

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166 first steps into this direction are already done and changes are under way: e.g. Strehlow et al. (2012) Cod catche staken by the German recreational fishery in the western Baltic Sea, 2005-2010: implications for stock assessment and management. ICES JMS, 69:1769-1780, doi:10.1093/icesjmas/fss152, or: Ferter et al. (2014) Unexpected high catch-and-release rates in European marine recreational fisheries: implications for science and management. ICES JMS, 70: 1319-1329, doi:10.1093/icesjms/fst104.

167 the negative effects of the modern quota system on a Scottish fishing communities are described e.g. in Cardwell, E. (2014) Selling the Silver: The enclosure oft he UK’s fisheries. The Land Magazine 15, Winter 2013/14: 36-38.

168 Ibid Cardwell, E. (2014)

The integrated management concepts should be regional-specific and adjusted to the different parts of Europe, for the different ecosystems and their societies. The questions are: could recreational fisheries be monitored more effectively and controlled by authorities? Would then sustainable management be easier than at present? Would the society at large benefit more from allocating a larger part of the total allowable catch to the recreational fishery rather than to a few commercial fishing vessels? Would the impact to the ecosystem be less (trawl damage on the seafloor, by-catch mortality, discard etc.)? Would this benefit not only the ecosystem but also the society?

A potential problem in performing such a mega-analysis is the patchiness of the required data that are partly available for some regions and sectors and less for others. Moreover, it is a real challenge to weigh intangible values cultural importance against tangible assets of the industrial economy.

Regionalized management concepts: Inputs, strategic recommendations related to research and innovation

Marine recreational fishing is an integral part of European coastal life and communities, with more than 8 million anglers spending over €8 billion every year and with a continuous growth of the sector at large. This invoked resource allocation problems as traditional accesses to fishing resources are touched and a societal debate is in the process of starting with regards to "who owns the resources?" and how fishing privileges can be allocated to the commercial and recreational sectors in a fair and equitable way? However, there is currently no framework that attempts to balance ecosystem impacts, management requirements, control issues, jobs and wealth creation, cultural significance etc. against economic and social benefits of recreational fishing and its wealth generation, jobs, growth etc. in a societal plan, or sets clear management goals within an ecosystem services framework. Thus this is a truly pan-European problem that requires taking the cross-cutting nature of, on the one hand, sustainable resource utilization, and takes, on the other hand, the ecosystem consideration into account as well as industrial and blue growth, the securing of employment opportunities, tourism development and the recreational value from a medical point. Thus this task requires a truly holistic and pan European integrated management analysis that is in nature a profound social challenge for Europe. Due to the complex nature it is imperative to develop such holistic management approach in close transatlantic cooperation with the Americans and Australia where the same or similar problems (though in different specific constellations) are currently approached.

By providing such a meta-analysis a solid foundation would be generated for the use in political decision-making, showing what cultural role, significance and economic potential each different sector to the society at large has and how we can utilize the full potential of the fishery resources.

Fish migration and distribution under climate change

Climate change is showing its effects in the seas. The most notable effect is the increase of the water temperature in the seas and oceans and in particular in the North Atlantic (south-east of Greenland, Barents Sea and the Baltic Sea). As a result the distribution of a number of fish stocks has changed throughout the past years and a number of fish from the Lusitanian region have expanded their distribution area northwards into the North Sea[169]. Already about a decade ago it was shown and extensively described in the scientific literature[170] that widespread and rapid changes in fish distribution were under way.

This is now showing its full impact: Mackerel for instance has widened its summer distribution considerably west and northwards[171] appearing now even in Iceland, Greenland and as far north as Jan Mayen Island and has caused a collapse of the scientific survey and assessment methods and caused difficult political negotiations amongst the EU-COM, Iceland, Norway, the Faeroe Islands and Russia for many years. Due to the rapid expansion of the mackerel stock distribution and apparently due to the significant widening of its spawning area the long-term series of data on the spawning of mackerel over the European shelf edges cannot any more be used as an appropriate indicator of the spawning stock, in other words: the more than 20 year series has, for the time being come to an end and needs significant scientific adaptation. Such adaptation can however only be achieved by significant scientific input, re-designing the assessment methods and the scientific surveys.

However, at the same time climate change progresses further and with it the change of the ecology of the seas and the distribution of species. Facing these rapid biological changes it is of dire need to invest more into investigating the changes of the fish distributions, its migrations and spawning behaviour.

Moreover, it is imperative to invest into changes of the **scientific approaches** that are employed to assess these changes: **How do the scientific survey and assessment methods have to change** in order to address the rapid changes that take place in the seas and oceans?

Zooplankton dynamics and production

Linked to the shift of distribution of many fish stocks it is likely that the zooplankton communities as basis of the fish nutrition in the sea change even faster than the fish communities do. Although there is some information on the zooplankton dynamics in the North Atlantic as a function of climate change[172], and the phyto- and zooplankton community is monitored on routine transects [173] far too little is however known about its large-scale quantitative aspects: How does the nutritional basis for fish changes quantitatively and qualitatively, since both is vital for the adults as well as the juvelines. It is proposed to **support zooplankton research in the Atlantic in connection with climate change and to explore the most cost-efficient ways to obtain these data.** Since this is a cross-Atlantic task this is also a candidate for intense transatlantic cooperation and should be advertised as such.

169 e.g. Inman, M (2005) Fish moved by warming waters. Science 308, no. 5724: 937.

170 Perry, L. et al. (2005) Climate change and distribution shifts in marines fishes. Science 308 no. 5730: 1912-1915.

171 ICES (2013) advice on widely distributed and migratory stocks: Mackerel in the NE Atlantic. http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2013/2013/mac-nea.pdf

172 Planque, B., and Taylor, A.H. (1998) Long-term-changes in zooplankton and the climate oft he North Atlanantic. ICES JMS 55: 644-654.

173 E.g. Barton, A.D., Greene, C.H., Monger, B.C. and Pershing, A.J. (2003) The continuous plankton recorder survey and the North Atlantic Oscillation: Interannual- to Multidecadal-scale patterns of phytoplankton variability in the North Atlantic Ocean. Progr. In Oceanogr., 58: 337-358.

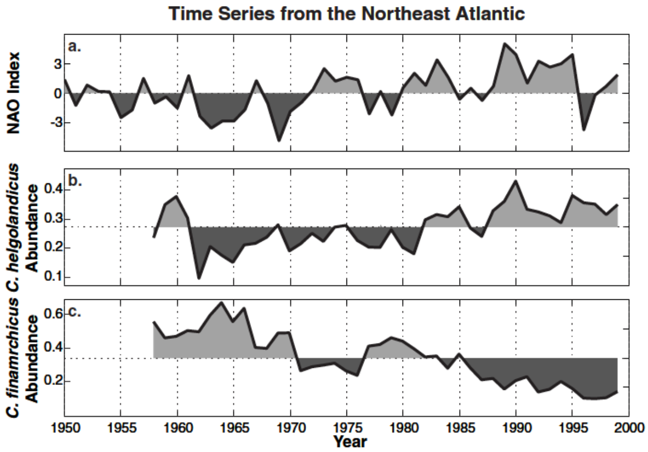

Fig. 5 Atmospheric conditions over the North Atlantic associated with the North Atlantic Oscillation.[174]

Ocean Literacy: "How Oceans and Humans Connect", Drivers and Trends

The seas ecosystems contribute virtually to every aspect of human well-being and the functioning of the global biosphere and thus also to the functioning of our economies and the stability of human societies and are to some degree comprised under "ecosystem services" and it is no question that the rapid changes of the ecosystems in the context of exploitation and climate change put these services severely at risk on many levels. The effects within the ecosystems are not even half way scientifically understood and even less the multiple spin-offs and ramifications into especially the coastal economies and societies.

This is scientifically widely accepted. To society at large this is however communicated on a rather abstract level. In many cases, not on all however, conclusions are drawn on a more emotional or in tendency esoteric level, opening a wide field of misinterpretation and half-information and opening a door for all shades of doom-mongers and profiteers.

In times of great climate, ecological and societal changes it is not only imperative but also a huge and powerful societal trend to invest into development of not only the appropriate and effective information flow but rather into sea literacy of the society at large.

The most obvious driver behind this is the rapid change of the global marine ecosystems. Apart from performing basic science to understand these changes it is imperative to rapidly advance our understanding of sea life and the ecosystem functioning, to redefine the term "sustainable seas for science and society" and to communicate this effectively to the society.

The fundamental driver underlying the process is the urgent need of the society to learn to make ecosystem and climate change a part of societal change. Without doubt, there are enormous threats to the entire aquatic ecosystems. However, in adapting to these there are also new chances, hitherto maybe unrecognized. This process of adaptation is a huge societal challenge for the next decades.

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174 Pershing, A.J., Greene, C.H., Planque, B., and Fromentin, J.-M. (Manuscript) The influence of climate change variability on North Atlantic zooplankton populations. http://oceandata.gmri.org/environmentalprediction/docs/OUPchapter-1.pdf.

Ocean Literacy: Bottlenecks, future challenges, gaps in R&I, potential threats

The changes are substantial and very complex and (to list only few) stretch from changing weather, increased frequency of floods and draughts, to societal changes due to migration caused by deteriorating ecological, economical and societal conditions, and further to warming of seas, acidification and fundamental changes in the biodiversity and bio-complexity, and not only far away in the sea but right in front of the pier and shore at home.

Even though these threats are serious, it is (as a future challenge) imperative not to leave information to doom mongers or to those journalists who make a living out of the amalgam of semi-correct information and bad news but to build up more information-competence. A governmental information strategy of "*react and correct*" is not appropriate, is not enough and not sufficient in the future. An active strategy of "*foresee and inform*" is needed to build up sea literacy and environmental competence in society to enable society to psychologically, socially and economically adapt to the upcoming challenges.

The identified drivers complement the requirements of the specific programme directly by developing real meaning to what so far is only vaguely understood as "Ecosystem Based Management (EBM)". Up to now the EBM is a widely accepted concept in the society. It is well accepted because it is at the first glance an appealing concept with a very positive connotation. However, the concept as such is scientifically elusive and not yet well defined. Never the less many nations worldwide have embraced it for sea ecosystems without really understanding how to define it and how to achieve it. Never the less, heading towards EBM is a societal and scientific paradigm shift that is imperative. However, to achieve to goals of the Specific Programme, it requires substantiating the paradigm shift by producing science of direct societal relevance and demands that scientists strive to communicate the implications of their work for policy and society.

However, there are significant societal constraints and bottlenecks as marine systems also support tremendous and often unexpected diversity that eventually feeds back into ecological functions with their particular productivity and eventually economic exploitation that affects resistance and resilience to global changes and, first of all to adaptation. Threatening changes invoke to a large extent societal resistance and conservatism leading ultimately to a polarization of the society that overlays and hampers the information processes, the paradigm shifts and counteract the building of societal sea literacy and sea competence. Moreover, economic resistance to change must be expected even if climate change in general may also offer new economic perspectives. It is clear that there will be economic sections that will lose out. Severe resistance to any kind of change must be expected from this side and is in fact well known since years.

Only building-up public the knowledge and progressive translation of sea science into public knowledge can overcome this and lead to public connectedness to the sea systems, its ecosystems and its biodiversity.

Moreover, cumulative impacts complicate human connectedness to marine systems and human society can only gain connectedness to a changing sea if processes beyond the sea surfaces are communicated to them effectively.

Ocean Literacy: Inputs, strategic recommendations related to research and innovation

More specifically it is imperative to make society understand the impact and change of human activities on the marine ecosystems and to adapt sensibly to the environmental megatrend of the seas, by adjusting its mode of utilization to both the benefit of society and the functioning of the ecosystems. This is already a social megatrend that needs to be guided and supplemented with solid science. It needs to be communicated that profound science is the basis of blue growth and economic prosperity in good agreement with nature conservation in a changing sea.

The over-arching challenge is to translate marine science or better, scientific findings into societal knowledge. A prominent and central part of this is the understanding of the changes of the marine biodiversity. This is of particular relevance for coastal communities that rely economically fundamentally on an intact coastal environment for its fishery, aquaculture as well as tourism and recreation. Understanding the biodiversity and its functional interconnections implies comprehending the ecological functions of the building bricks of the ecosystems. Only then ecosystem functioning and subsequently Ecosystem Based Management are possible. The management of the natural biological resources needs to have the societal support by bridging what so far is perceived as a gap between exploitation and conservation.

This implies *inter alia* the development of new tools for biodiversity identification, assessment and monitoring. This however, not only by *de novo* research but also by more cooperative interconnection of existing sea observatory systems, further to integrate across disciplines to study ecosystem functions and to define appropriate spatial scales.

The **overall objective** to further the sea literacy of society requires the **outreach to society not as the last item of the deliverables of scientific projects or as an afterthought when scientific projects have been completed but rather as a novel component at the onset of scientific research. And even more: Translation of science into public should be a core research topic on its own.**

A more **specific objective** is to **bridge disciplinary boundaries to develop and integrate concepts and theories to predict and value marine biodiversity and its links to ecosystem functions and services and to transport this effectively, positively and constructively into society**.

It is the **goal** to **develop strategies to advance communication and visualization of how biodiversity contributes and is an essential part of ecosystem understanding and Ecosystem Based Management that eventually will contribute to the sea's health and our plant's future**.

Ocean Literacy: How success would look like

For Europe and neighbouring regions the unique aspects of marine ecosystems suggest that predicting scenarios for future sea biodiversity and its relationship to people will require a paradigm shift towards integrative trans-regional thinking and cooperation and the utilization of new theories and methodologies to combine state-of the-art natural and social science approaches.

Success would mean that the multi-functionality of the key-elements of ecosystems is scientifically understood. Then, when the specific role of organisms in the ecosystem is understood, the nature of links between species is identified and it is understood how in the food webs the ecosystems functions emerge from the interaction of network nodes. The first step of success is therefore the evaluation and understanding of the multi-functionality of ecological networks, based on the relationship between sea biodiversity and ecosystem functioning.

Success is when science matters in society and is perceived as such. Transformative sea management and governance require deep, systematic, and robust natural and social scientific evidence, especially when dealing with complex relationships between the physical environment, ecological structure and function, and human well-being. The transformation process is successful when the evidence has been accumulated, processes have been understood and have become a part of public knowledge and debate.

Finally all topics together: Bottlenecks, future challenges, gaps in R&I, potential threats
There are significant societal constraints and bottlenecks as marine systems also support tremendous and often unexpected problems. As an example, the Black Sea and Mediterranean are subject to an extremely complex political and socio-economic scenario, lacking still appropriate ocean observing systems to provide the necessary data for making qualified and responsible management possible, while Turkey is advancing in this respect.

Progress will however only be made if **conflict-solving strategies** have been **identified** and **implemented**. This reaches beyond classic parties of contradicting interests (e.g. conservation contra exploitation) but requires the intent of all parties to communicate effectively[175] with clear-cut goal-orientation in the process of Marine Spatial Planning. The implementation of the new Common Fisheries Policy and along with it its self-obligation to adhere to scientific recommendations has led to recovery of a number of fish stocks[176] and is a good example for this. Even though this is the case more or less only for those stocks that are sufficiently large and for that sufficient data have been collected[177]. Attention needs therefore to be put on effective and conflict-solving strategies with the incentive of economic growth and prosperity. The success of the implementation of the Precautionary Principle and the Maximum Sustainable Yield is paradoxically also a bottleneck for the above-described development: recovering fish stocks increase the yield and lead to decreasing prices, reducing the incentives of the industry to invest into the development of the environmentally advanced technologies.

At the same time however, continuation of the scientific root-work is imperative. Science can only support policy and management with qualified and usable advice if the required data are available. With increasing political and ecological complexity the data demand is increasing exponentially and climate change adds to this. The dogma of the 1990s and 2000 years of substituting the lack of costly data compilation by modelling has largely come to an end and is no appropriate solution any longer, if it ever has been. As a consequence, strategies need to be developed to build-up conscience on the level of *national governments* to secure data sampling and longer-term research funding (i.e. more than 3 years only, e.g. for fatigue tests of materials in offshore aquaculture, zooplankton and fish dynamics in the seas or monitoring the environmental impact of management measures).

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[175] E.g. Gluckman. P. (2014) The art of science advice to government. Nature 507: 163-165.
[176] E.g. Fernandes and Cook (2013) Reversal of Fish Stock Decline in the Northeast Atlantic, Current Biology, http://dx.doi.org/10.1016/j.cub.2013.06.016.
[177] e.g. Hilborn, R. & Ovando, D. (2014) Reflections on the success of traditional fisheries management. ICES JMS 71: 1040-1046, doi:10.1093/icesjms/fsu034

Climate change and economic crisis invoke to some extent societal conservatism leading ultimately to a polarization of the society, which overlays and hampers the information processes, the paradigm shifts and counteract the building of societal sea literacy and sea competence. Moreover, economic resistance to change must be expected even if climate change at large may also offer new economic perspectives. It is the great challenge to communicate also the opportunities, alternatives and prospects that lie in the development of the seas and oceans and the blue growth as such.

SECTION 5

How success would look like

It is implicit that success would open the door to further industrialization of the seas (mainly the shelf areas) by establishing new forms of offshore aquaculture, implementing far more selective and less destructive fishing gears and to develop alternative management methods. However, it would already be a success if by aid of funding the fragmented research initiatives in Europe would form pan-European research consortia having an international and even a transatlantic dimension, also including science and industry. However, success cannot be forced by funding alone. The time must be right for courageous innovations and changes. Society needs to be taken along, needs to be prepared and must acquire a positive attitude towards these innovations by means of effective communication, information and learning. Success would be if the general attitude would change positively due to good, qualified and modern information and the realization that these innovations come along with job creation and increase of societal wealth at simultaneously integrating the nature conservation and guarding the principles of sustainability.

Naturally, the success depends largely on (1) development of new and largely unconventional aquaculture technologies that can sustain high-energy environments, (2) the development of the prizes of seafood on the international fish and seafood markets, and (3) on the degree of successful implementation of pan-European and transatlantic research cooperation amongst the research facilities but also (an namely) the industrial partners in sea-going aquaculture.

If these conditions are (at least to some extent) met, then true synergy can be generated together with a much more efficient research and development, if the hitherto fragmented and nationally oriented small-scale research can join forces to develop a critical mass.

This is the true challenge: Throughout the entire European and US/Canada coasts and shelf areas the problems are similar. So far relatively isolated and small groups design, develop and test small-scale experiments that generally lack the appropriate funding and long-term approach. It is therefore time to unify these single-approaches and to build critical masses by pan-European and transatlantic research cooperation.

6 LINKING THEMES AND ACTORS – BOOSTING INNOVATION IN EUROPE: exploring thematic links within Societal Challenge 2, and between Societal Challenge 2 and other Societal Challenges

Draft Report for SC2 Strategic Programming 2016-17

Linking issues in the current Work Programme

Innovation is based on new ideas, technologies or insights. Innovations will help advance European societies, but only when the innovation relates to the aspirations of European citizens. Innovations must be socially and environmentally sustainable.

Research can be disciplinary, multi-disciplinary, inter-disciplinary and trans-disciplinary. Excellent research is the base of much progress, but successful innovation requires a more complete, "linking" or "cross-cutting" approach. Linking activities combine knowledge and engagement from actors that are not usually considering each other and are not always aware of each other.

The European Commission is supporting such an integrated approach by defining societal challenges and focus areas of activity for the next years. This integrated approach has already transformed the outlook of many actors in the European research and innovation area. Scientists, entrepreneurs, representatives of the public, educators and other stakeholders are ready to work together, across fields of expertise and across national boundaries. They must be given the opportunity for cooperative work, by specifically targeting such cooperation in future Work Programmes.

The current Work Programmes support some linking activities. However, in many instances topics in the Work Programmes at present originate in a disciplinary view, and then ask for (an often minor or secondary) support from other areas of expertise. For example, natural scientists look for a private company to realise their laboratory ideas. In reality, companies may also be able to help scientists to define the most important study objects. In other cases, natural scientists or engineers request an input from social science, but sometimes simply to explain their view to the public. We argue that in future it may be just as important for scientists to consider public aspirations when suggesting a project for European funding. In the long-term, innovation results should be useful for the intended end-users. This may include aspects of improved organisation and social innovation. In other topics, at present the suggestion is to study the "side effects" of certain technological changes and innovations. In future, a more comprehensive view on positive or negative impacts of an innovation on ecological, environmental or cultural values is necessary.

It has also been noted by other Advisory Groups (according to their "one pagers" distributed on July 9, 2014) that linking issues need more notable support in future Work Programmes. For example, the Advisory Group on "Marie Skłodowska-Curie Actions" "expresses its concern about suboptimal conditions for multidisciplinary and intersectoral research and innovation projects".

Thus, in future Work Programmes more room should be given to fully cross-cutting and linking thematic approaches, with a possibility to include actors from different steps of the innovation chain. All disciplines contributing to a possible innovation should be able to participate in the solution on an equal basis. This requires more linking of themes within the Work Programmes of the individual Societal Challenges, and more linking of themes for innovations that combine two or more of the Societal Challenges.

It is important to realise that for innovation projects to be successful, they need to have excellent partners and must be fast and attractive in management. Thus, cross-cutting initiatives must not consist of large networks. Rather, they need to include all partners required for a step in an innovation chain. More than before, emphasis in European programmes should be on innovation applicable to less developed regions and helpful for parts of the population with less income.

Recommendation: The Advisory Groups highly appreciate that linking issues within the SCs and between the SCs are clearly considered in the current Work Programme. ***We recommend putting even more emphasis on linking (cross-cutting) issues in future Work Programmes****, and to develop topics and programmes based on fully integrating innovation perspectives (linking of themes and actors).*

Linking issues within SC2

The Framework Programme for Research and Innovation of SC2 lists the topic "2.5 Cross-cutting marine and maritime research". The aim is to unlock the potential of seas and oceans across the range of marine and maritime industries, while protecting the environment and adapting to climate change. This linking approach within the marine and maritime research is a very helpful step towards sustainable innovation in this area.

In other parts of the current Work Programme of SC2, inter- and trans-disciplinary approaches are usually mentioned in topic descriptions. However, truly cross-cutting and linking issues are not well explored in these parts of the Work Programme of SC2. For example, animal and plant production systems are linked in energy and nutrient cycles, but research and innovation is mostly sectorial. In another example, aquaculture and land use are clearly linked, through fish feed production, area requirement or nutrient management, but innovation efforts remain sectorial.

In future Work Programmes of SC2, more linking (cross-cutting) approaches should be taken. This includes unlocking the genetic potential of plants and animals in terrestrial environments, and to link terrestrial and marine and maritime innovation issues. The specific chapters of this Advisory Group report list many examples of such thematic linking issues within SC2.

Recommendation: The SC2 Advisory Group supports the linking (cross-cutting) approach in the current Work Programme in unlocking the potential of ***blue growth****. We recommend extending this approach to other areas within SC2, with the aim of* ***unlocking the potential of living organisms also in terrestrial environments****, considering* ***links between maritime and terrestrial processes and between crops and livestock****. Landscape patterns, farming systems, resource use, and ecosystems services are linked issues that must be considered in innovation efforts.*

Linking issues between the SCs

Programmes in the individual Societal Challenges in many cases refer to needs and options from other areas of innovation.

Although such links between the Societal Challenges are often mentioned in the Work Programme, the approach is often with a strong emphasis in one Societal Challenge. Aspects from other Societal Challenges are then taken into account as an addition or as a side issue only. Many innovation efforts in Europe in the past were unsuccessful or are controversially debated, probably because they were promoted without taking social, economic, environmental or technical implications fully into account.

In future Work Programmes, issues with thematic links between the Societal Challenges should have a more prominent place, and the emphasis given to the different actors, disciplines and approaches should be oriented towards the innovation goal. The twelve focus areas considered in the first calls of the Horizon 2020 (personalising health and care, sustainable food security, smart cities and communities, mobility for growth, ...) should receive even more attention in the future.

Many areas linking the different Societal Challenges are mentioned in the commission documents and in the (preliminary) reports by the Advisory Groups. We recommend that these thematic cross-cutting areas need stronger focus in future work programmes.

The high importance of such linking issues between the Societal Challenges and with horizontal issues has also been noted by other Advisory Groups (see the "one pagers" distributed on July 9, 2014). The Advisory Group on **Inclusive, Innovative and Reflective Societies** list several convincing and well-reflected descriptions of linking issues. Suggesting a focus on facing the turbulence of regional and global change, they point out that cross-links to other challenges and pillars such as with SC2 (concerning the deprivation of land giving rise to social unrest), with SC5 (concerning the water crisis which affects the Middle East and fuels radicalism and civil war in the region), and with SC 7 and other focus areas are necessary.

Also other Advisory Groups stress the need for more links between SCs. For example, the group on **Information and Communication Technologies** recommends to "develop the collaboration between ICT and societal challenges". The Advisory Group on **Nanotechnologies, Advanced Materials, Biotechnology** recommends "to set a strong link with the societal challenge pillar under this aspect and speed up innovation by working in complementary rather than in a sequential mode", and lists many examples for such linking issues, for example CO_2 conversion. The Advisory Group on **Smart, Green and Integrated Transport** in their one page report recommend more joint (interdisciplinary) research actions and cross-cutting areas/common challenges. "Challenges of sustainable provision of food and water" is one of the linking issues between SCs identified the Advisory Group on **Climate Action, Environment, Resource Efficiency and Raw Materials**. Even the Advisory Group on **Space** (sometimes considered to be a topic apart) points out the need for more linking between themes. They recommend, for example, in energy research to relate space missions to several societal challenges and to "foster interdisciplinary activities by engaging space and non-space actors".

The SC2 Advisory Group argues that science involved in SC2 has a long tradition in inter- and transdisciplinary research. Farmers have always needed a comprehensive understanding of environmental and biological processes as well as of market opportunities to be successful. Agricultural research has in fact been based since a long time on the idea that innovation in land and water use is based on new biological and environmental knowledge. Therefore, the SC2 Advisory Group supports the recommendations from other areas of expertise for more linking research opportunities with full emphasis.

From our view, changes in agriculture or aquaculture systems necessarily must consider environmental implications. For example, innovative energy systems often have implications for land use and water quality. We recommend focusing research and innovation to help Europe with a **defossilisation** strategy - more carbon in energy and food cycles, and less use of carbon from fossil fuels.

Health programmes are often based on food related issues. The "**One Health**" perspective mentioned in the SC2 Work Programme 2014-2015 has very clear links to SC1 (Health). The Advisory Group on Health, Demographic Change and Well-Being points out that "the need for interdisciplinary research is obvious across our research themes, and it is also relevant that health research collaborate with to other scientific disciplines as life sciences, natural sciences, technical sciences, social sciences and humanities to solve the pertinent societal challenges to create convergence."

*Recommendation: There is a need to facilitate in future Work Programmes **distinctly more linking (cross-cutting) research and innovation activities between the Societal Challenges**. The Advisory Groups point out that a sustainable innovation in the European focus areas must **result in social and economic benefits** (including improved preservation of natural and environmental capital) **for the European population**. This should be reflected in distinctly more calls in the Work Programmes that require **a combination of knowledge of different research, extension and application areas**.*

Linking issues in Horizon 2020

The Work Programme is only small part of the European innovation system. Many other opportunities are available in Europe to support innovation. There is a high (and increasing) number of European programmes and initiatives (such as Research Infrastructures, KETs, Smart Specialisation, JPIs and Marie Skłodowska-Curie Actions). The SC2 Advisory Group suggests that the Work Programmes are central in linking the best research in Europe with the many actors that need to be involved in innovation chains.

The cooperation between DG Agriculture and DG Research and innovation is a necessary and exemplary move to link European policy with European research and innovation. The Advisory Group supports this cooperation and recommends placing a strong emphasis on further discussions between DG Agriculture and DG Research, helping with theme definition and involvement of excellent science.

Without science and research, sustainable innovation will not be possible in modern societies. On the other hand, scientific research alone may produce results without societal benefit. While the ERC is often rated as "successful" in public statements, the Advisory Group believes that the Work Programme has a great potential to boost European innovation, with the real success of better living conditions for Europeans. A stronger link between European cohesion, social, regional and political funds and innovation activities will help to support research and innovation in all European regions, and create innovation opportunities for more European citizens.

Recommendation: Individual topics in the Work Programmes reflect European policies. However, the Advisory Groups recommend ***linking in future innovation and research programmes much closer to European policies and policy instruments****. This will help to make European societies more innovative.*

Recommendation: We also recommend that ***a set of more precise definitions and objectives*** *related to the terms "linking (cross-cutting)" and "innovation" are developed. This set of definitions should include aspects of 1) trans-disciplinarity (e.g. combining environmental and social sciences with natural and technical sciences), 2) linking interphases between different societal challenges (e.g. integrating aspects of food production and diets/health) and 3) how to involve and engage different type of actors in joint efforts.*

Recommendation: The SC2 Advisory Group strongly recommends ***a process of discussion between Advisory Groups*** *when all reports of the groups are available, to* ***further clarify the links between within and between the Societal Challenges, and the better integration of horizontal issues*** *(such as gender, internationalisation and e-infrastructures) in the upcoming Work Programmes.*

In the following, the SC2 Advisory Group highlights several linking (cross-cutting) issues in more detail. This information is taken from other parts of this report:

FOOD, AGRICULTURE AND HEALTH

The impact of diet on our health is undoubtedly a challenge for society and will be a future driver of innovation within the food industry. Chronic non-communicable diseases, including cardiovascular diseases and diabetes are major, life-style and obesity related diseases, directly related to food consumption. Research focused on showing the benefit of Farm-to-Fork surveillance to be seen in a developing One Health context - European success should be documented scientifically. The concept of One Health needs to be integrated in research on control of pests and diseases in plants and animals, because of the close linkages between human, animal and plant health. Creation of operating networks should be promoted for the appraisal of risks and human health of endemic, exotic and emerging diseases at national, transnational and local level. Associated knowledge gaps need to be addressed, for example, concerning the interrelationship between human physiology, microbial flora and food intake (including microbial flora added to or inherently in the food) and the relationship between this flora and major life-style diseases.

There is a challenge also in creating strong links between socio-economic sciences and humanities and technical/biological sciences. Costs in relation to poor health for example should be integrated with the economics of food production. Cross-sectoral research could pave the way for better and more coherent policies (and thus food industry potential). There is also a need for further insights into the determinants of consumer behaviour especially in relation to dietary knowledge, food and health considerations, environmental impact, influence of gender, impact in the home, education and so on. There is a major research gap in relation to the links between risk assessment and communication, consumer behaviour and economical implications of consumer choice and food standards. There is a need for research that will develop competitive food technologies for industry, with an integrated learning approach between the food sectors, ensuring a more sustainable, differentiated and competitive food production and affordable food products, which goes hand in hand with increased knowledge and ongoing learning of dietary and eating behaviours from the social sciences and with the environmental/sustainability standards retained by international institutions.

Across the sub-challenges within SC2 there is a widespread need for development and use of innovative and consistent forms of “Sustainability assessment” of primary production linked with processing, consumption etc. and reflecting also relations with and feedback on ecosystems services and links to human health. This needs scientific links with health, social and business sciences - for example around the concept of resilience and integration with innovation and regulation aspects.

BIOBASED INDUSTRY AND NEW GENERATION BIOREFINERIES INTEGRATED WITH THE TERRITORY

Acting regionally for joining global value chains: Bio-based processes should be optimized within biorefineries to reach the production of biofuels, materials and fine chemicals from local biomass in full compliance with the biodiversity of the territory. Biomass and other raw materials should be delivered while at the same time protecting biodiversity and supporting the development of rural and coastal livelihoods, harmonizing, benchmarking. potential, also developing specific LCA parameters referred to the specific eco-system and social context. (Links to: SC1, SC5, SC4, Excellence in Science, LEIT, PPP on Bio-based industry

Involving all actors of the knowledge and value chains for cross-sectorial fertilization and education: Working with partners across the knowledge and value chain (agriculture, marine, ecology, forestry, environmental management, computational sciences, chemistry, biotechnology, ICT, economy etc..) has the potential of bringing new knowledge to all actors, thus overcoming the risks of fragmentation.

GREEN BIOMASS FOR SYNERGI IN AGRO-ECOLOGICAL LAND USE, FOOD and NON-FOOD PRODUCTION

In order to support the pull of agriculture, forestry and bio economy sectors jointly in a more sustainable direction a joint effort of Research and Innovation is needed in combination with other tools such as market development and policies. The need for developing at the same time 1) value chains for alternative use of biomass and 2) the resilient, environmentally-friendly and economic farming and forestry systems and 3) the related processing methods for the green biomass into valuable products presents a triple and interconnected bottleneck.

A combination of research and innovation could create a basis for transforming monoculture annual cropping systems into diversified and resilient landscapes providing more and improved ecosystems services and public goods while producing higher total biomass yields with reduced environmental load for processing in biorefineries dedicated to green biomass (in the sense dedicated crops harvested for this purpose as opposed to residues). This needs cross-disciplinary integration of environmental and ecological economics in a new approach to integrating socio-economic research in a form which supports the pro-active and management oriented focus of agro-ecology. Moreover knowledge of social innovation in terms of organization of new business forms and collective processes in business development as well as public regulation from other SCs.

SUSTAINABLE FISHERIES

Both marine research and fisheries research in particular are by nature highly cross-cutting and international cooperation has a long tradition in these fields of research. Sustainable fisheries are not possible without a high degree of international cooperation since fish are in distribution and migration not confined to national boundaries and management of the resources is only possible by means of highly organized international cooperation. In acknowledgement of this the International Council of the Exploration of the Sea (ICES) has been founded more than 110 year ago and there is not a single topic of research that has not a strong international cooperation component. Even the regionalization of the management is depending on good international cooperation since there is hardly a single management region that is not bordered by at least two nations. Thus, it goes without saying that marine spatial planning, development of regional management plans, offshore aquaculture, investigation in fish distribution and migration are not possible to pursue without international cooperation.

Moreover, these issues are thematically highly cross-cutting. Development of off-shore aquaculture for instance comprises technological development in marine engineering as well as material research (research of fatigue of material in high energy marine environments), basic ecological research on trophic relationships, disease research and behavioural research. The development of regionalized management is cross-cutting all forms of utilization of the seas, from shipping to naval engineering, sea-bead exploitation, nature conservation etc. Moreover, the social aspects of fisheries management have come more and more into focus in the management of the marine resources. Therefore, the impact of the management measures on the society at large as well as on the local level are addressed but need to addressed more intensely in the future.

ANNEX 1 TEMPLATE FOR REPORTING RESULTS OF SUB-GROUP ACTIVITIES WITHIN SC2 AG

Objectives of the present consultation:

- to identify the strategic research and innovation priorities for 2016-2017
- to provide strategic advice in the process of strategic programming towards preparing the next work programme covering 2016-2017.

How to proceed:

- analyzing the Specific Programme looking at a number of factors listed in the "Consultation paper" (F1-F7)
- considering the potential implications of drivers of changes (D1-D8) provided in Annex II
- analyzing the Specific Programme by addressing at least some of the questions (Q1-Q9) listed in the "Consultation paper"

See the complete list of Factors, Drivers, Questions at the end of the document)

The AG SC2 group of facilitators agreed early April 2014 to a joint format for suggesting ideas and strategic focus areas within the subgroups. This has been the basis for a consultation phase with the AG members at the Yammer web site. Input should follow a certain logic by responding to the headlines in an Excel file, starting with making reference to specific points in the EC "Specific Programme" and to the main drivers and Trends being important for this selection of issues described under societal challenge 2, . FOOD SECURITY, SUSTAINABLE AGRICULTURE AND FORESTRY, MARINE, MARITIME AND INLAND WATER RESEARCH, AND THE BIOECONOMY. From this the proposals should each identify Bottlenecks, future challenges, gaps in R&I, (and, if relevant, potential threats) for overcoming the challenges in focus and based on this give strategic recommendations related to research and innovation. Finally each proposal should be described by answering the ECs question: what would success look like?

AG sub-group facilitators had dialogue on the input between May 5-9 and agreed on a process of following up by synthesizing the input from members and further developing the description of key strategic ideas. The aim is to have a description of a number of strategic ideas for discussion and (if necessary) subsequent prioritization at the AG meeting June 19 in Brussels.

Based on the input provided by AG members the next phase will be to consolidate the input and transform the Excel format into narrative descriptions of each strategic idea following more or less the same headlines but with more documentation and responding more clearly to the questions raised by the EC (see below). Thus, each strategic idea or the merging of different ideas should clearly take a starting point in references to the specific program and main and well selected drivers, and trends including "how the drivers impact on the issues of the Specific program" etc. Then, there should be a logical lead into "Bottlenecks, future challenges, gaps in R&I, potential threats" and "inputs, strategic recommendations related to research and innovation" and "How success would like".

It is important that each strategic document - these narratives are all at a strategic level – does not address too “specific topics”, but also avoiding to be too general so that one loses the sight of a specific strategic challenge and possible solutions. Each proposal should clearly describe a Research and Innovation potential which addresses a certain selection of the Specific programme (could be cross-cutting as well) and in light of drivers and trends. The narrative should include data and other information with references to key reports, documents, foresights etc. as so-called “intelligence” and “sense making” in order to support the proposed strategic focus. Finally, it should be clear “what success would look like” and which societal challenge this success would help solving. Thus, the narrative should have a logical flow and a red thread.

While writing the narrative the list of questions provided by the EC should be addressed in the way most suitable for each strategic idea. The following outline should be used for describing the strategic ideas. Questions from the EC have been suggested for each section, for inspiration (need not be used as structure of the text).

REPORT

SECTION 1

Priorities selected from the Specific Program

The thematic content of the Specific Programme has to be translated into work programmes: prioritisation is needed as everything cannot be done at once.

Provide explanations for your choice and provide sources of data.

Q1) What is the biggest challenge in the field concerned which requires immediate action under the next Work Programme? Which related innovation aspects could reach market deployment within 5-7 years?

SECTION 2

Drivers and Trends

Taking into consideration the issue/priority identified within the Specific Programme, identify possible links to the driver(s) of changes selected by EFFLA and listed here below

(see more in the report " Using foresight to support the next strategic programming period of Horizon 2020 (2016-2018)" ; Vincent rousselet Final report.

D1) Population changes

D2) Globalisation and fragmentation

D3) High expectations from new technologies

D4) Transversality in new technologies and individual empowerment

D5) ICT: the big disturbances are yet to come

D6) Vulnerabilities are testing our resilience

D7) Environmental degradation, food security, scarcities of natural resources and bioeconomy potentials

D8) Constraints on materials and energy and the search for new opportunity spaces

Explain how the drivers of changes and the identified priorities identified in the Specific Programme are interconnected. Provide sources of data.

F1) Analyzing how key issues (austerity, societal change, aging population; big data; globalisation; resource constraints; environmental concerns, etc.) affect research prioritisation

Q2) What are the key assumptions underpinning the development of these areas (research & innovation, demand side and consumer behaviour, citizens' and civil society's concerns and expectations)?

Q6) In which areas is the strongest potential to leverage the EU knowledge base for innovation and, in particular, ensure the participation of industry and SMEs? What is the best balance between bottom-up activities and support to key industrial roadmaps?

Q7) Which areas have the most potential to support integrated activities, in particular across the societal challenges and applying key enabling technologies in the societal challenges and vice versa; and cross-cutting activities such as social sciences and humanities, responsible research and innovation including gender aspects, and climate and sustainable development? Which types of interdisciplinary activities will be supported

SECTION 3

Bottlenecks, future challenges, gaps in R&I, potential threats

Provide advice based also on your expertise, as well as considering the state of the art in research and innovation

Q4) Which are the bottlenecks in addressing these areas, and what are the inherent risks and uncertainties, and how could these be addressed?

Q5) Which gaps (science and technology, markets, policy) and potential game changers, including the role of the public sector in accelerating changes, need to be taken into account?

SECTION 4

Inputs, strategic recommendations related to research and innovation

Provide strategic recommendations, also with the aid of “Factors” listed below. Provide solutions, sources of data or research tools.

F2)Mobilising resources to build scale and critical mass;

F3) Exploiting the existence of mature research and innovation agendas building on European knowledge strongholds and business strengths which require a significant investment and for which such investment would act as a clear leverage;

F4) Realizing impact and maximizing the chances of securing world class scientific and innovative breakthroughs as they help generate excellence through European and international competition and cooperation;

F5) Providing genuinely cross-cutting approaches, notably by addressing challenges and areas cutting across different specific objectives and parts of Horizon 2020;

F6) Aligning implementation with major political initiatives and/or improving synergies with national programmes, while identifying the most important and most urgent research and innovation issues

F7)Improving synergies with international projects and fostering international cooperation.

SECTION 5

How the success would look like

Q3) What is the output that could be foreseen, what could the impact be, what would success look like, and what are the opportunities for international linkages?

Drivers of changes

D1) Population changes
D2) Globalisation and fragmentation
D3) High expectations from new technologies
D4) Transversality in new technologies and individual empowerment
D5) ICT: the big disturbances are yet to come
D6) Vulnerabilities are testing our resilience
D7) Environmental degradation, food security, scarcities of natural resources and bioeconomy potentials
D8) Constraints on materials and energy and the search for new opportunity spaces

Questions

1) What is the biggest challenge in the field concerned which requires immediate action under the next Work Programme? Which related innovation aspects could reach market deployment within 5-7 years?

2) What are the key assumptions underpinning the development of these areas (research & innovation, demand side and consumer behaviour, citizens' and civil society's concerns and expectations)?

3) What is the output that could be foreseen, what could the impact be, what would success look like, and what are the opportunities for international linkages?

4) Which are the bottlenecks in addressing these areas, and what are the inherent risks and uncertainties, and how could these be addressed?

5) Which gaps (science and technology, markets, policy) and potential game changers, including the role of the public sector in accelerating changes, need to be taken into account?

6) In which areas is the strongest potential to leverage the EU knowledge base for innovation and, in particular, ensure the participation of industry and SMEs? What is the best balance between bottom-up activities and support to key industrial roadmaps?

7) Which areas have the most potential to support integrated activities, in particular across the societal challenges and applying key enabling technologies in the societal challenges and vice versa; and cross-cutting activities such as social sciences and humanities, responsible research and innovation including gender aspects, and climate and sustainable development? Which types of interdisciplinary activities will be supported?

Factors
F1) Analyzing how key issues (austerity, societal change, aging population; big data; globalisation; resource constraints; environmental concerns, etc.) affect research prioritisation
F2) Mobilising resources to build scale and critical mass;

F3) Exploiting the existence of mature research and innovation agendas building on European knowledge strongholds and business strengths which require a significant investment and for which such investment would act as a clear leverage;

F4) Realising impact and maximising the chances of securing world class scientific and innovative breakthroughs as they help generate excellence through European and international competition and cooperation;

F5) Providing genuinely cross-cutting approaches, notably by addressing challenges and areas cutting across different specific objectives and parts of Horizon 2020;

F6) Aligning implementation with major political initiatives and/or improving synergies with national programmes, while identifying the most important and most urgent research and innovation issues

F7) Improving synergies with international projects and fostering international cooperation.