



Horizon 2020

Societal Challenge 2 “Food Security, Sustainable
Agriculture and Forestry, Marine, Maritime and Inland
Water Research, and the Bioeconomy”

Advisory Group Recommendations

Programming Period 2018-2020

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**Societal Challenge 2 “Food Security, Sustainable Agriculture
and Forestry, Marine, Maritime and Inland Water Research, and
the Bioeconomy”**

Advisory Group Recommendations

Programming Period 2018-2020

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In accordance with the mandate of the Advisory Group, this draft report aims to identify future strategic research and innovation (R&I) priorities for the Horizon 2020 Societal Challenge `2 **“Food Security, Sustainable Agriculture and Forestry, Marine and Maritime Research, and the Bioeconomy”** for the programming period of 2018 – 2020. The priorities devised are based on the results of the AG discussions and comments provided by the AG members on different subjects addressed, and draft reviews by the AG working subgroups taking into account insights from the Gap Analysis conducted for SC2 by the European Commission.

FOREWORD

The Horizon 2020 Societal Challenge 2 Programme was created to develop and implement an EU research and innovation policy for more sustainable and resource efficient agriculture, forestry, inland water and marine systems that supply European society with sufficient food, feed, biomass, and other raw materials, as well as ecosystems services, and support thriving rural and coastal livelihoods.

The European Commission has established Societal Challenge Advisory Groups to provide consistent and consolidated advice - by way of opinions, recommendations and reports - on relevant research objectives and scientific, technological and innovation priorities for its strategic and annual work programmes.

Our Societal Challenge 2 Advisory Group includes a wide range of members with remarkably rich and diverse backgrounds and affiliations, including researchers, academics, former policymakers - stakeholders covering the whole spectrum of relevant research and innovation domains.

Our Advisory Group has met twice formally since our establishment in February 2016, and has used other opportunities for extensive discussion and engagement on the issues surrounding this Societal Challenge. We see Societal Challenge 2 as not only extremely important as a challenge in itself, but also strongly linked with other Societal Challenges such as health, demographic change and wellbeing, climate action, environment, resource efficiency and raw materials, and inclusive, innovative and reflective societies in a changing world. And as the agriculture, forestry, fisheries and food sectors comprise a very large number of smaller businesses – themselves serving large scale processing and retail business sectors – there are strong links between our contribution and the input of groups advising on innovation in small and medium-sized enterprises, international cooperation, nanotechnologies, advanced materials and advanced manufacturing and processing.

Our Advisory Group's first task has been to prepare this report to answer five specific questions posed by the Commission and provide input into the strategic programming cycle of the Work Programme for 2018-2020. We have identified some overriding strategic priorities, and backed those with the results of a more detailed analysis of the gaps that need to be addressed. And we highlight the cross-cutting nature of this programme and the importance of an integrated approach to maximise the overall impact of the current Horizon 2020 programme. We hope that the insights in this report may also assist in the identification and prioritisation of research needs and strengthen the Commission's strategic and impact-oriented approach in future years.

Richard Wakeford

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REPORT OF THE ADVISORY GROUP ON SOCIETAL CHALLENGE 2 - "Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research, and the Bioeconomy"

1. Introduction

Food security, sustainable agriculture and forestry, the bioeconomy and the management of marine, maritime and inland waters are among the most important elements influencing European society and the wider world. These elements are at the heart of sustainable development that delivers strong communities through a flourishing economy that respects the environment – development that the world’s children and grandchildren will thank us for.

Research under the heading of Horizon2020 Societal Challenge 2 should be hugely influential in delivering that goal. Ambitious targets have been set, and significant progress should result from research projects already approved or subject to calls already published. But, our Advisory Group has identified much more that is needed in many areas of research. Despite progress with regard to the more specific strategic targets and the calls launched to achieve them, we believe that much more needs to be done in the next work programme – potentially the last under the current Horizon2020 goals.

It is clear that there is an urgent need to increase efforts to deliver the SC2 targets, in a comprehensive and integrated way. These efforts need to take place at all levels and involve not only the EU and its scientific community, but also a broad range of stakeholders. These stakeholders include the governments of member states and their research councils – particularly those responsible for research that will help businesses, land and sea managers. They also include the non-government organisations with the potential of informing and influencing consumers through messages that are well informed by science and research.

We have seen our review, therefore, as not just a bureaucratically driven review of progress to date, identifying gaps in knowledge and recommending priorities for the last Work Programme 2018-2020. We have lifted our eyes to a further horizon – and embraced new priorities flowing from the rapid changes in the world and global agreements since Horizon2020 was designed.

So, this is the 2016 report of the Horizon2020 Expert Advisory Group for Societal Challenge 2. It provides strategic advice from an expert perspective on the priorities for European Commission funded research under the themes of food security, sustainable agriculture and forestry, the bioeconomy and marine, maritime and inland water research.

This report provides expert advice on priorities for the third Horizon 2020 work programme – the one covering 2018-2020. The Commission will consider it alongside the interim evaluation of Horizon 2020 and other inputs from stakeholders - including European Technology Platforms, European Innovation Partnerships and the Agriculture, Food Security and Climate Change Joint Programming Initiative. Taking account of all these inputs, the Commission will then engage Member States and publish calls for research proposals not earlier than autumn 2017. The Commission then allows considerable time for consortia to come forward with proposals, and for those proposals to be assessed before any research can be started.

So our task as an expert Advisory Group has been essentially to assess – for the themes we cover - the research needs of design, manufacture and service businesses, national and local governments and communities in the early 2020s. How will people of the 2020s benefit from the knowledge gained and analysed? What will policymakers of the 2020s need? What will businesses of the 2020s need – in all the various sectors, including farmers, advisors, foresters, timber processing, fishermen, agri-food industries, retailers and caterers and so on?

More specifically, we have addressed five questions posed of us by the European Commission:

- What are the challenges in the field concerned that require action under the Work Programme 2018 – 2020? And would they require an integrated approach across the societal challenges and leadership in enabling and industrial technologies?
- What is the output/impact to be foreseen? Which innovation aspects could reach market deployment within 5-7 years?
- Which gaps (science and technology, innovation, markets, policy) and potential game changers, including the role of the public sector in accelerating changes, need to be taken into account?
- Which areas could benefit from integration of horizontal aspects such as social sciences and humanities, responsible research and innovation, gender aspects, and climate and sustainable development?
- In view of the recent evolution of the socio-economic and policy context, what are the emerging priorities for Societal Challenge 2?

2. Our method

We took as our starting point the overall strategy set out in the Horizon 2020 programme launched in 2013, which embraced:

2.1. Sustainable agriculture and forestry

- Increasing production efficiency and coping with climate change, while ensuring sustainability and resilience
- Providing ecosystem services and public goods
- Empowerment of rural areas, support to policies and rural innovation
- Sustainable forestry

2.2. Sustainable and competitive agri-food sector for a safe and healthy diet

- Informed consumer choices
- Healthy and safe foods and diets for all
- A sustainable and competitive agri-food industry

2.4 Bio-based industries and economy

- Fostering the bioeconomy for bio-based industries
- Developing integrated biorefineries
- Supporting market development for bio-based products and processes

2.3 /2.5 Unlocking the potential of aquatic living resources; and marine and maritime research

- Developing sustainable and environmentally friendly fisheries
- Developing sustainable and environmentally friendly aquaculture
- Boosting marine and maritime innovation through biotechnology
- Climate change impact on marine ecosystems and the maritime economy
- Developing the potential of marine resources through an integrated approach
- Cross-cutting concepts and technologies enabling maritime growth

The Advisory Group then reviewed action by the European Commission, following the Group's work over the last two years – in particular its previous report and some more strategic follow-up work which identified four main themes to guide research calls – Sustainable Food Security, Rural Renaissance, Blue Growth and Bioeconomy. We drew on two foresight reports - SCAR¹ and Strategic Foresight². There is also the CIMULACT³ project, which is engaging a significant representative sample of citizens and stakeholders through focus groups, on-line consultations and face-to-face interviews on priorities for future EU research and innovation policies and topics.

We have also reflected significant strategic game-changers since the original Horizon2020 launch – for example:

¹ Sustainable Agriculture, Forestry and Fisheries in the Bioeconomy - A Challenge for Europe. 4th SCAR Foresight Exercise

² Strategic Foresight: Towards the 3rd Strategic Programme of Horizon 2020. Directorate-General for Research and Innovation

³ www.cimulact.eu

- the Juncker Commission's policy priorities to maximise the opportunities and assets of the EU; these assets include people, land, businesses, scientific knowledge and financial capital;
- Commissioner Carlos Moedas' emphasis on an open approach engaging global partners in global challenges such as energy, health, food and water;
- development of the EU DG Agriculture Research Strategy;
- increasing international collaboration in commissioning research programmes, such as Future Earth;
- the international agreement on climate change action reached in Paris in December 2015, and the likely actions needed to reduce emissions from the Land Use, Land Use Change and Forestry sector;
- the application of the new UN Development Goals to national policies;
- the implications of newly implemented revised Common Agricultural and Fisheries Policies;
- new international trade agreements, such as TTIP, following the failure of the Doha Round;
- and, the impact of migration into the EU on a hitherto unseen scale.

We have drawn on our own individual expertise, and on foresight and other evidence and assessments of research and innovation trends and market opportunities. We have identified themes that would require an integrated approach across the societal challenges, and those requiring leadership in enabling and industrial technologies. We have reflected on the role of the public sector in accelerating changes and in responding to changes in society. In short, we have looked forward to the 2020s and identified gaps in the current research agenda that policymakers and creative business leaders of the next decade would thank us for identifying.

3. Earlier work of the Advisory Group

The Advisory Group's October 2014 report recommended priorities for inclusion in the Strategic Programme 2016-17 for Horizon2020 Societal Challenge 2. At their meeting on January 2015, the Group went on to emphasise research themes of importance under four main groupings, set out in Annex 1.

Commission officers provided a "gap analysis" of the 2014-15 call, breaking down the topics by activity and financial resource. This showed that by far the biggest use of resource has so far been devoted to sub-activities "increasing production efficiency and dealing with climate change, while ensuring sustainability and resilience" and to "a sustainable and competitive agri-food industry". Forestry and marine issues seem to be under-represented if measured only in funding terms – the basis of the analysis the Commission provided to us. **That analysis did not show what is missing or what should have been achieved, in particular when comparing sub-activities with very uneven coverage.**

Some might see increasing production as a perverse investment during a period when food production is already on a scale that has raised societal concerns about the integrity of food, and has seen market prices dip sharply (creating significant stress in the farm sector). Many farmers across the European Union have lower incomes, due to a range of factors; many don't have access to the capital needed to modernise and improve the efficiency of production; and some who have stretched themselves to invest in the past have gone out of business due to lack of income to pay the interest on their borrowing.

Rather less research investment has been devoted to ecosystems services and public goods provided by agriculture and forestry, for which it might be argued that there is a market failure with farmers insufficiently rewarded for the societal benefits they deliver, or perhaps provided with subsidies not founded in sufficiently researched specific needs.

Sustainable forestry and climate-friendly farming could also be said to merit more investment, given the importance of the LULUCF (Land Use, Land Use Change and Forestry) action needed if Europe is to meet the 2030 climate change targets the Commission has adopted.

The 2016-17 Societal Challenge 2 call covers further themes, but until the applications are fine-tuned, contracts are let and projects get under way, it is hard to judge just how much the gaps identified previously will be covered by the consortia with successful applications.

From the perspective of policymakers, the Advisory Group could find no readily accessible analysis or evaluation of how useful the findings of Horizon2020 funded research projects had proved for policymakers in Member State governments – for example in influencing fiscal and regulatory measures (evidence-based policymaking).

4. The changing context for research

The Advisory Group has identified the following important considerations in identifying the research needs, relevant to Societal Challenge 2, of manufacturing and service businesses, national and local governments and communities in the early 2020s:

- **Hyper-connectivity and big data** informing and driving accelerated change and innovation;
- **Social networks**, crowd sourcing and new ways of exchanging information;
- The **cost of energy** as potential game changer;
- **Global population growth, changing demographics and migration** as important for innovation in Europe;
- The **changing food supply and consumption chain** driven by and driving societal change and industrial innovation
- The **impact on businesses of market crises** caused by unpredictable impacts such as trade barriers, international trade agreements (or not) and fluctuating energy prices
- **Health as a major driver** not least because poor health can result from food consumption choices people make, and thus impact on economic productivity and public expenditure on national health services
- the **changing demography** of European society and the **impacts of migration** – both internally within Europe and internationally from outside Europe;
- **Cultural and environmental diversity** in the face of social and economic integration
- **Climate change, oceans and space** as projects important for humanity as a whole;
- **Primary sector innovation** as a strategic concern, as a key for sustainability and well-being;
- **Biotechnology** as the next wave of disrupting technologies;
- **Instability**, as a new norm in global society (and within the European Union itself).

This represents a huge breadth of challenges, which are often interlinked. For example, in thinking about **climate change and sustainable development** – and the COP21 goals agreed in Paris – there is a complex picture embracing new weather patterns, drought, storms and migration of invasive species and diseases of animals and humans. Challenges to farming practice may result from that weather (requiring adaptation measures), or from new measures to mitigate climate change in the longer term. There is a need to minimise the loss of soil (in the interests of long term production from land) while also storing more carbon in the land. And all the time, the food, water and energy nexus will create challenges for every owner and tenant of land – whether cultivated or forested.

Modern thinking about a **more “circular” economy** is also important. This concept is often considered in a purely land-based way, or in a way constrained by national or administrative boundaries. But that is too limited an approach; the concept must clearly embrace both land-based and marine resources. As the OECD have pointed out, ocean is increasingly recognised as indispensable for addressing many of the challenges the world faces – from international food security to the provision of natural resources, energy and improved medical care. The oceans hold the promise of immense resource wealth and the potential for boosting economic growth, as well as potentially locking up carbon. Yet, as the ocean has no real boundaries, action at source is needed against land-based pollution such as agricultural run-off, chemicals and plastics. If one nation’s efforts in addressing the need for a circular economy are not to be undermined by others, an international approach to marine management will be crucial in delivering the full benefits a circular economy approach can deliver.

Food security is also an issue that crosses both the land and marine agendas – requiring approaches compatible with sustainable development principles. Global food security is vital if the world is to avoid famine-driven disasters and migration. At the same time, the obesity crisis in so many western nations is creating huge challenges – rendering some people unfit to work or care for families, and increasing the costs of maintaining public and personal health and wellbeing. On

another front, many citizens in the European Union demand more organically sourced food and improved animal welfare while barring products derived from genetic modification - while not fully understanding the wider implications if land and farm products are not used to their full potential within the parameters of sound science. More reliable and easily accessible traceability of product sourcing and processing will be important to ensure a properly informed market.

The EU is updating its **bioeconomy** strategy in 2016 and a number of Member States are working on their strategies. The EU is also planning its climate policy for Land Use Land Use Change and Forestry and how to treat biomass-based bioenergy in the future. All these are central to the future development of the forest-based bioeconomy.

Rural development remains an important priority, especially in marginal areas without access to the same services of public interest as towns and cities. Yet modernisation of agriculture and forestry may itself reduce employment, especially of those with only basic skills. Different rural development challenges are emerging in the different micro and macro regions of the EU and diversity and integration focused research would help to understand and handle differences and tensions. Rural diversification is important if vital and viable villages are to remain a significant element of society through the 21st Century. Social media, big data availability and new business models – such as internet-based retailing, Uber and AirB’nB – may well bring a new dimension to rural life. But a particular rural challenge will remain – that of an ageing population with challenged mobility demanding health and other essential personal services.

The outcomes of the **Milan EXPO conference on long term strategy for European agricultural research and innovation by 2020 and beyond** also provide strategic analysis of future rural priority needs. It may be that only an organisation with the European Commission’s resources will be able to sponsor research looking at seriously long term scenarios – embracing food, forestry, and human health and wellbeing in the post 2050 world. It may also be essential to research the challenges to those themes if the world fails to deliver on the COP21 targets and climate change accelerates as a result.

5. Future prioritisation within Societal Challenge 2

Beyond the four main headings set in the HORIZON2020 instrument however, it became clear to the Group that there were important connections both *between* the topics covered by these four original headings set out in the legal instrument, and in themes that might flow from *wider* integration *across* other societal challenges. Food security, sustainable agriculture and forestry, marine and maritime and inland water research, and the bioeconomy link clearly strongly with several of the following themes:

- Health, demographic change and wellbeing;
- Secure, clean and efficient energy;
- Smart, green and integrated transport;
- Climate action, environment, resource efficiency and raw materials;
- Europe in a changing world - inclusive, innovative and reflective societies;
- Secure societies - protecting freedom and security of Europe and its citizens.

A meeting of Advisory Group Chairs also suggested that crosscutting themes were essential to deliver integrated approaches across a number of strategic themes. These included social science and humanities, gender, climate action, sustainable development, and international cooperation. The following slide presented at that meeting provides one example of how food security research should be integrated with other challenges. It shows that food chain issues run from agriculture and its externalities, through processing and marketing to consumption, personal health and ultimately the cost of national health systems;

+ Other societal challenges	Our relevant suggested areas of integration
Climate action: <ul style="list-style-type: none"> • Environment • Resource use • Raw materials 	<ul style="list-style-type: none"> • Agricultural and forestry practice (mit & adapt) • Mesoplankton • Circular economy: reducing food, farm and forestry waste; avoiding plastic soup in the sea • Optimal use of land and sea: food, energy, carbon sink
Europe in the changing world <ul style="list-style-type: none"> • Inclusive societies 	<ul style="list-style-type: none"> • Food as a unifying strand between distinctive societal groups
Health <ul style="list-style-type: none"> • Demographic change • Wellbeing 	<ul style="list-style-type: none"> • Food production, manufacturing, marketing, information • Ecosystems services from land • Food safety
Energy <ul style="list-style-type: none"> • Secure, clean, efficient 	<ul style="list-style-type: none"> • Food production efficiency
Secure society <ul style="list-style-type: none"> • Freedom • Security of citizens 	<ul style="list-style-type: none"> • Resilient supply systems • Protection of facilities • Food security (ie growing enough)
Transport <ul style="list-style-type: none"> • Green • Integrated 	<ul style="list-style-type: none"> • Supply chain logistics/packaging • Air miles • Warehouse to my house delivery

FOOD 2030 linking most of the societal challenges?

The meeting suggested **criteria for identifying potential focus areas:**

- Strong integration of elements from relevant societal challenges and Leadership in Enabling and Industrial Technologies;
- Sufficient scale and scope to achieve a critical mass of support on the basis of clearly defined objectives and impacts;
- Targeted and evidence-based research elements, addressing elements of a larger work programme;
- Using a range of different types of action across the full innovation cycle in a coordinated and seamless way.

Taking account of those suggested criteria, the Societal Challenge 2 Advisory Group felt that their main potential is in the following areas of social science and humanities, gender, climate action, sustainable development, and international cooperation:

- Food consumption, societal wellbeing and the consequent cost of health services
- Rural development and renewable energy (from crops, forestry products, wastes or structures)
- Environment, resource efficiency and the best use of land – given that farming (40%) and forestry use over half the land resource of the EU
- Innovation and farming and land management – the challenge of promoting new ways of working to many of the 12.2 million farmers and 16 million forest owners operating across the EU

In addressing these areas research should focus on Key Enabling Technologies such as biotechnology, advanced materials, advanced manufacture and processing as well as ICT – and how these innovative technologies can be generally applied across a farming and fisheries sector dominated by small and medium sized enterprises.

While the Advisory Group was not resourced to do more than report against the formal structure set by the Horizon2020 measure, we felt that future work in prioritising research investment might draw on a more rational set of headings – essentially reflecting the “horizontal interdependence” of land and water and the “vertical flows” of product from “farm to fork” and its impact on consumers:

- **Integrated management of the land, inland waters and sea as a resource – impact of primary production, other ecosystems services and climate change mitigation and adaptation;**
- **Primary products: food, feed and biomass safety and security - from land, sea and inland waters;**
- **Competitive food and biomass processing, markets and promotion - and the impact on consumer choices, consumer health and health service costs;**
- **Overall strategic progress towards a bio-based society – including blue growth and the circular economy⁴**

During the period of preparation of this report, the Netherlands Presidency prepared a discussion paper “Food of the Future – the Future of Food”⁵. This is not the first such constructive and challenging publication coming from that member state. A decade ago, then Minister of Agriculture, Nature and Food Quality, Dr Cees Veerman, published “The Choice for Agriculture: a Vision for the Future of Dutch Agriculture – addressing the whole production and supply chain from farmer and grower to consumer, posing big challenges and looking for answers in the face of

⁴ The **circular economy** is a generic term for an industrial economy that is producing no waste and pollution, by design or intention, and in which material flows are of two types: biological nutrients, designed to reenter the biosphere safely, and technical nutrients, which are designed to circulate at high quality in the production system without entering the biosphere as well as being restorative and regenerative by design

⁵ <https://english.eu2016.nl/binaries/eu2016-en/.../2016/.../food-of-the-future-en.pdf>

increasing competition, a reduction in the level of government support and the need for extra efforts to reduce environmental pollution.

The latest discussion paper again addresses how to use potential reforms of the Common Agricultural Policy (one of the European Union's biggest policy delivery tools) to shape the food supply chain for the benefit of European society. The challenges are set out clearly in the paper:

- Food is unevenly distributed on a global level;
- One in ten people remains malnourished;
- Obesity and overweight occur on a large scale (perhaps 40% of the population);
- Population growth, urbanisation and changing eating patterns will increase the pressure on global food supply.

Food security, public health, ecological sustainability and the industrialisation of food production – the discussion paper says – necessitate a demand-driven policy, rather than the current supply-driven Common Agricultural Policy bearing mainly on the primary producer.

It would have been satisfying to recommend research gaps that would help to inform answers to the questions posed in the Netherlands Presidency paper. But HORIZON2020 is perhaps more strategic; the time taken by the process of designing programmes and allowing a good time for responses to calls means that action for the next Common Agriculture Policy will need to be informed by research already commissioned!

Looking at the relatively uneven coverage of the overall Societal Challenge 2 priorities, as set out in the Horizon 2020 programme finalised in 2013, the Advisory Committee considered that a marginally different set of sub-themes would lead to a more comprehensive approach. The choice of elements from within the range of Societal Challenge 2 topics might be better informed by cutting across the elements in a different way. The thinking was, for example, to separate out research designed to secure delivery of better, healthier food products, from research addressing how the land and sea should be managed sustainably as a resource for the long term. Beyond that were two more distinct areas for research – considering how the added value manufacturers add to primary food products (whether from sea, freshwater or land) best meet the needs of society; and how food and other elements can best serve a bio-based society where waste is minimised in a circular economy.

6. Immediate priorities for the third HORIZON2020 call

Taking account of:

- the Advisory Group's review of the goals of the Horizon2020 programme;
- the elements of the first two calls under H2020;
- the prioritisation the previous H2020 Advisory Group delivered in February 2015; and
- the significant prospective incremental changes in Europe and the wider world,

the principal gaps requiring research investment over the next five years in the opinion of the Advisory Group, under the original Horizon2020 headings are:

Activity 2.1 Sustainable agriculture and forestry

For the thematic category '*Pathways for sustainable and resilient primary production*' we recommend research:

- to explore the sustainability potential of different modes of agricultural and forestry production – such as climate smart agriculture, precision farming, ecological intensification, agroecology and regenerative agriculture
- to develop a multidisciplinary, transdisciplinary and holistic systems approach to plant and animal health, and animal welfare
- to understand the synergetic effects of increased trade and climate change on animal and plant health
- to develop and implement efficient technology providing a growing sustainable and market driven utilization of forest based products (improve revenue-cost) and ecosystem services fitting societal needs while operating with improved environ-gentleness and reduced carbon footprint

For the thematic category '*Resource management*' we recommend research:

- to better understand, monitor and measure the specific effects of agricultural practices and farming and forestry systems on soils and its various productive and ecosystems functions
- on water use and management in and by agriculture
- on the access to and renewal of genetic resources
- to explore the role of agriculture (including urban and peri-urban agriculture) in the circular bio-based society

For the thematic category '*Multiple functions and benefits of land and rural areas*' we recommend research:

- to explore the impacts of farming systems at landscape and wider spatial scales
- to develop methods that link the ecological and the socio-economic values of agriculture and forestry systems
- to explore the role of forests in mitigating climate change and in contributing to the bioeconomy
- to map real land use and changes over time
- on the fiscal and regulatory and public governance influence over current and future use of land
- to analyse the impacts of structural and temporal rural demographic change on the vitality of and quality of life in rural areas
- to explore the experiences of less developed EU regions in social integration challenges such as food, energy or social care security
- to guide the transformation of non-urban Europe by exploring what levers have led to successful rural economies and how public policy measures can accelerate change, drawing on the lessons of the more advanced rural economies

For the thematic category '*Human and social capital and social innovation*' we recommend research:

- to enhance the skills, human and social capital of farmers, foresters and other actors of the rural economy
- on how to involve young land managers in less developed EU regions in the adoption of good practices, through boosting innovation and cooperation, creating possibilities for expanding farming and supporting knowledge sharing
- on how to support successfully the generation change of the entrepreneurs in the agri-food and forest-wood sectors in the less developed EU regions
- to look into the functioning and further development of knowledge and innovation systems
- to better understand the pros and cons of working with big data

Activity 2.2 Sustainable and competitive agri-food sector for a safe and healthy diet

For the thematic category '*Healthy diets, healthy people*' we recommend research on

- consumer preferences, attitudes, needs, behaviour, lifestyle and education, and communication between consumers and the food chain research community and its operators
- malnutrition and micronutrient deficiencies in certain population groups, for example the elderly, those hospitalised or in care, lower socioeconomic groups, and diverse minority groups
- the different biological, ecological, psychological, sociological and socio-economic drivers of consumer behaviour across Europe
- tackling obesity and non-communicable diseases through food formulations, changes in retail and catering practices, and changes in consumer behaviour utilising advanced technological, psychological, and social approaches.
- smart nutrition solutions for the next decades to establish how food production technologies, new delivery methods, and ICT approaches might be used to provide smart personalised nutrition solutions and health care
- the gut microbiome

For the thematic category '*Food safety, security, defence, and integrity*' we recommend research:

- on rapid at-line or on-line detection tools for food and feed safety including follow-on preventative and mitigation measures
- on allergen presence and control in food and feed,
- to understand how antibiotic resistant bacteria establish and persist in food production systems and in food products and how food environments influence transfer of antibiotic resistance genes
- on safety of nano-materials and low dose chemicals in foods and feed
- data analytics to identify emerging risks in foods
- on food safety and the growing elderly population in Europe, especially on the factors that contribute to increased morbidity in elderly people in relation to food borne infections and the higher carrier rate of antimicrobial resistant bacteria
- on threats in feed and food supply chains to establish vulnerability to fraud or intentional contamination or adulteration, and develop risk prevention, protection, and mitigation strategies for food business operators
- on innovative packaging and smarter supply chains

For the thematic category '*Sustainable, competitive, and innovative food manufacture*' we recommend research:

- on reduction of food waste, solutions for re-work of waste (or by-products), and approaches or technologies for valorisation of food waste or by-products
- on optimisation of food production using advanced engineering and IT solutions
- on the environmental impact of various mixed food systems

For the thematic category '*Food policies, supply chains, markets, and communities*' we recommend research:

- on short local food chains for health, considering microbial connections from soil to humans,
- on the role of non-market based networks of food provisioning for food security
- on urban/city-region food policies – in other words the process through which cities across Europe develop and implement food policies, the extent to which public authorities, private sector and civil society are involved in policy design and implementation and the domains and themes that these policies focus on,
- on food product development and ethno food marketing taking account of migration and changing demographics in Europe
- on innovation support systems and networks for food SMEs, especially micro-SMEs and traditional food producers

Activity 2.4 Bio-based industries and economy

For the thematic category '*Production of biofuels and biomolecules in the framework of a circular economy*' we recommend research to:

- map biomass supply, building on existing knowledge, approaches and tools
- explore new, innovative, energy saving preservation strategies for different types of biomasses - developed, validated and standardised on biomass level
- use cost-benefit analyses of bio-based plastics/polymers vs traditional plastics on a global scale
- use evidence to establish how alternative uses of renewable resources can influence carbon emissions
- foster the demand for bio-based products from a consumers' perspective through gathering evidence on consumers' practices in relation to bio-based products and how these may form new market places
- new innovative and inclusive business solutions using bio-based services
- understanding the impact of the global bioeconomy development on the availability of biomass resources on the global markets
- comprehensive mapping of the policy framework affecting the bioeconomy in the European Union and its Member States

For the thematic category '*Demonstration plants/testbeds for cascading use of biomasses*' we recommend research to:

- create an optimal network of laboratories supported by new infrastructure to form test beds that can develop process technologies and new products in a demo-scale that underpin the development of biorefineries (industrial scale) for maximising biomass use

Activities 2.3/2.5 Unlocking the potential of aquatic living resources; and marine and maritime research

For the thematic category '*Exploring new options for exploiting marine resources*' we recommend research on:

- Seaweed and phytoplankton production and processing (human edible proteins, fine chemicals, energy, bio-based materials, methane low ruminant feed stocks)
- Interactions between commercial fishing and game fishing (in an ecosystem based approach) related to new perspectives of ecotourism in remote rural areas.
- Sustainable exploitation of large mesoplankton stocks for producing high value substances
- Deep ocean mining and the related knowledge gap about deep ocean environment and biodiversity

For the thematic category '*Applying new technologies to exploitation of marine resources*' we recommend research on:

- High Tech Field Observations in marine environmental management, big data retrieval, handling of data in management support systems, using the potentials of the internet of things
- Aquabreeding: improvement of the resilience, robustness and efficiency of the main aquatic production species using smart breeding programmes based on genomics and precision phenotyping, including ethical aspects
- Multiple purpose use of offshore production sites, integrating biomass and energy production in a "building with nature" approach
- Bio-mimicry discoveries for marine nature inspired technical innovations

For the thematic category '*Fostering the marine environment and biodiversity*' we recommend research on:

- Plastic soup related marine pollution: remediation of existing concentrates, mitigation of new pollution, and development of marine degradable bio-based plastics.
- Marine ecosystem resilience and regime shifts, in relation to climate change
- Marine governance in international waters related to societal acceptance of Blue Growth perspectives and "building with nature" principles
- Integrated large marine and inland water ecosystem based management at regional level: develop institutions and best practices, with a special emphasis on larger inland water systems and remote overseas European marine territories

7. Ensuring research findings reach policymakers: the communication of conclusions

The Advisory Group also advises that greater attention needs to be paid, in designing calls and shaping the programmes of successful research consortia, to the communication of the outcomes of the research. An objective evaluation of potential impact should be included as a pre-requisite deliverable in all new projects.

Every project should be required to make clear how the results will be communicated beyond scientific papers, so that they are accessible to:

- Businesses ready to take forward ideas within European Union nations
- Policymakers and others in government, national and regional
- Non-government organisations
- Responsible media and thus society at large

New media will be crucial in the above, but the European Commission should ensure that this amounts to more than a one way posting of results on a website. There should be evidence that potential users have received news of the findings in a shape that helps them draw on the research investment. Post hoc evaluation should clearly assess at least the beginnings of the impact.

HORIZON2020 SOCIETAL CHALLENGE 2 ADVISORY GROUP

July 2016

ANNEX 1

Societal Challenge 2 Advisory Group's previous conclusions on research themes of importance (January 2015)

Sustainable food security

- Develop agro-ecological & organic based practices including diversification at farm & landscape scales for improved resilience & sustaining ecosystem services, demonstrating high value products / value chains, with engagement of farmers, value chain agents, consumers, educators, policy makers;
- Improve understanding of short supply chains / value chains based on local production & consumption and potential for outscaling and as a driver for improved diets linked to diversification of farming
- R&I into precision farming (ICT, robotics, sensor ...) for supporting diversification and agroecological and organic farming practices (ecointensification)
- Developing a competitive food industry
- Improve knowledge and understanding of linkage and interaction between food supply in value chains and diet, consumer choice, and health issues
- Research breeding, feeding and management of livestock so that improved animal health enables fewer losses, reduced need for medication, increased resource efficiency, resilience, product quality and human health

Rural Renaissance

- Unlock bioeconomy opportunities for rural and coastal areas by mobilising and strengthening primary production and ecosystems services delivery, especially new and diversified products in low-carbon short-chain delivery systems.
- Enable agriculture to deliver important ecological services through increased agro-ecological practices, and combining of food and non-food production with increased use of green biomass from crops for combined food, feed and bio refinery production.
- Improve the potential of ecologically sustainable intensification of land use, by informing rational, competitive and environmentally friendly procurement of biomass combined with innovations in harvest and transport technology, operational planning, high-precision monitoring, business models and ICT
- Efficient transformation of typical resources of rural and coastal regions within a cascade processing chain including returning waste and nutrients to the land
- Develop eco-functional intensification to improve efficiency in the use of nutrients, water and other resources in conventional and organic agricultural systems, which build on and enhance ecosystems services
- Develop 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

Bioeconomy

- Involve all actors of the knowledge and value chains for cross-sectoral fertilisation and education
- Develop an international set of definitions, criteria, indicators and statistics for the elements of a bioeconomy
- Secure sustainable biomass supply for bio-based goods and services
- Create integrated biorefinery solutions for efficient transformation of regional resources into chemicals, materials, energy and fuels – and innovation to secure a cascade/ recycling processing chain, including returning waste and nutrients to the land.
- Create a coherent knowledge base and improve transfer of knowledge by conducting systematic market analysis per and cross sector.

Blue Growth

- Support combined offshore aquaculture and industrial development of the shelf seas (ie wind energy)
- Develop integrated management plans for the regional seas in support of the MSFD and new EU-CFP
- Develop smart fishing gear for better selection of fish at the point of catch
- Investigate potential plankton and fish dynamics under influence of climate change, using advanced Ocean Observation Systems
- Improve the European ocean literacy.

ANNEX 2

Sustainable agriculture and forestry; gaps and recommendations

Background

Appropriate knowledge, tools, services and innovations are necessary to support more productive, environmentally friendly resource-efficient and resilient agriculture and forestry systems that supply sufficient, high quality, safe food, feed, biomass and other raw materials and deliver ecosystems services while at the same time protecting biodiversity and supporting the development of thriving rural communities and economies. Research and innovation should therefore provide options for integrating agronomic, environmental and societal goals into sustainable production.

The sustainable agriculture and forestry activity (Activity 2.1) consists of four sub activities:

1. Increasing production efficiency and coping with climate change, while ensuring sustainability and resilience. This encompasses research addressing productivity, losses and resilience of terrestrial production systems as well as the underpinning research aimed at providing policy support for these issues (*Sub-activity 2.1.1*).
2. Providing ecosystem services and public goods. Research activities will contribute to a better understanding of the complex interactions between primary production systems and ecosystems services and will support the provision of these public goods and services, through the delivery of management solutions, decision-support tools and the assessment of their market and non-market value (*Sub-activity 2.1.2*).
3. Empowerment of rural areas, support to policies and rural innovation. Socio-economic research and science and society studies along with social and institutional innovations is needed to ensure cohesion of rural areas and prevent economic and social marginalisation, foster diversification of economic activities (including the service sector), ensure appropriate relations between rural and urban areas, as well as facilitate knowledge exchange and capacity building and foster participatory resource management (*Sub-activity 2.1.3*).
4. Sustainable forestry. This includes research on the sustainable production of biomass, the development of multifunctional forestry systems, the delivery of forest ecosystem services and strategies to improve tree health and protect and restore forests (*Sub-activity 2.1.4*). There are significant overlaps between this sub-activity and the other three.

Sustainable agriculture and forestry can contribute to a number of societal challenges within and linked to the UN's Sustainable Development Goals:

- Reducing hunger, by enhancing the development and implementation of more productive and more resource-use efficient production systems.
- Promoting health, by producing more nutritious and healthful food items and by reducing the spread of zoonotic diseases and anti-microbial resistance through integrated resilient livestock systems.
- Adapting to and mitigating climate change, by developing climate-smart agriculture and forestry.
- Protecting ecosystems and biodiversity, by implementing sustainable use of terrestrial ecosystems and their services.
- Enhancing sustainable production and consumption, by reducing post-harvest food losses and improving resource-use efficiency in primary production.

Game changers

Key game changers for sustainable agriculture and forestry are:

- Food 2030: the transition from an agricultural policy to an integrated food policy concomitant with the rise of cities and city-regions as food policy making authorities (i.e. decentralised and

context-specific food policies, shaping agricultural development, agriculture and forestry's multiple functions and benefits and urban-rural relations) will imply a paradigm shift from quantity to quality of agricultural production and products.

- National health care costs: increases in national health care costs are partially caused by diet-related ill-health (obesity, malnutrition, hunger), zoonotic diseases and antimicrobial resistance. Reducing health care costs and improving people's health requires an integrated Global One Health approach to sustainable agricultural production resulting in more resilient systems producing more nutritious foods.
- Climate change: agricultural production systems are an important contributor to GHG emissions while at the same time climate change will affect agricultural productivity. It is therefore important to develop climate smart agricultural production and forestry systems adapted to and capable of mitigating climate change.
- Resource-use efficiency & circular economy: agriculture production systems require a variety of resources that can be optimised at various levels, from soil, plant or animal to agro-ecosystems and value chains. In agriculture, the circular economy is expected to lead to new ways of using residues and by-products, of operating farms and reducing the use of natural resource inputs.
- Rural demographic change: the quality of life in and the vitality and competitiveness of rural areas is changing due to a range of different demographic processes, such as depopulation, ageing, in migration of migrants (refugees) and seasonal workers, counter-urbanisation and new entrants in agriculture and rural enterprises.

What has been addressed so far

Research covered (2014/2015 work programme) or to be covered (2016/2017 work programme) under the four sub-activities of Horizon 2020 includes:

- *Sub-activity 2.1.1 Increasing production efficiency and coping with climate change, while ensuring sustainability and resilience.*
 - Management and use of natural resources and ecological services with a focus on soil, nutrients and genetic resources;
 - Plant and animal health
 - Various levels at which resilience against shocks – including those arising from climate variations – can be dealt with, ranging from animals/plants through breeding and on-farm management to functional biodiversity and other ecosystems services at farm and landscape level.
 - Understanding and exploiting the complex mechanisms involved in the availability and uptake of resources by plant and animals and their efficient use in agriculture, with special attention for promoting technologies such as ICT and precision farming for better use of inputs.

- *Sub-activity 2.1.2 Providing ecosystem services (ESS) and public goods (PG)*
 - Innovative and practical ways of operationalizing the concepts of PG and ESS
 - Linking farming systems to the delivery of PGs and ESS
 - Delivering of specific public goods (drinking water quality).

Only six topics have so far been covered, suggesting that there is more to do.

- *Sub-activity 2.1.3 Empowerment of rural areas, support to policies and rural innovation.*
 - New openings for rural growth in rural areas, focussing on urban-rural and rural-coastal linkages and on fostering sustainable food and non-food chains.
 - Development of human and social capital (boosting innovation), ranging from networks of farms and advisors' role in innovation to research and innovation system capacities, including further developing policies geared at rural innovation, while little has been done on social innovation
 - Socio-economic research and support to policies, such as food security, EU quality policy and short food supply chains, functioning of the food chain and land use.
- *Sub-activity 2.1.4 Sustainable forestry.*

- Information and decision-making tools for sustainable forest management.
- Management and use of forest genetic resources.
- Sustainable and climate change resilient forest production systems.
- Policies, business models and mechanisms for the delivery of forest ecosystem services and public goods.

Emerging gaps recommended for further research

Taking account of the gap analysis of sub activity 2.1 carried out by the Commission, the strategic agricultural research agenda of DG AGRI, and the SCAR 4th Foresight analysis we have identified 21 emerging gaps which we recommend future research. These can be grouped into 4 broad thematic categories (which in turn can be linked to the three sub-activities as defined by the Horizon 2020 legal framework for Societal Challenge 2):

1. Pathways for sustainable and resilient primary production (primarily sub-activity 2.1.1 and 2.1.4)
2. Resource management (primarily sub-activity 2.1.1 and 2.1.4)
3. Multiple functions and benefits of land and rural areas (sub-activities 2.1.2, 2.1.3 and 2.1.4)
4. Human and social capital and social innovation (primarily sub-activity 2.1.3)

 For the thematic category '*Pathways for sustainable and resilient primary production*' we recommend research:

- to explore **the sustainability potential of different modes of agricultural and forestry production – such as organic agriculture, agroecology, climate smart agriculture, precision farming, ecological intensification, agroforestry and regenerative agriculture** -

... *in order to* enhance the resource-use efficiency, productivity and quality of primary production by exploring the adaptive capacity of plants, animals and production systems to cope with rapidly changing environmental/climatic/social conditions and increasingly scarce natural resources. This should result in an evidence base on the economic, environmental and social benefits of different modes of primary production, assessment of the effectiveness of different modes relative to one another and to existing modes, and a set of integrated practices tailored to regions and production systems to operationalise the inclusion of different approaches into primary production. It should respect animal welfare as a societal concern. Widespread adoption of sustainable and resilient modes of primary production could potentially strengthen rural economies, by increasing European competitiveness, securing or enhancing rural employment, and by building resilience to environmental change.

- to **develop a multidisciplinary, transdisciplinary and holistic systems approach to plant and animal health and animal welfare**

... *in order to* construct and implement more resource-efficient production systems, promoting biodiversity (in soils, crops, animals and landscapes) with less environmental impact and use of pharmaceuticals, and more societal acceptable production from a citizen perspective, taking the diversity of cultural and environmental contexts in Europe into account. In the case of livestock systems, a holistic approach should decrease the need for antibiotics, facilitate detection strategies for early signalling of health-disease status of animals (animal signals of disturbance of health) with new biomarkers and smart farming practices, respect animal welfare requirements and reduce the risk for unhealthy livestock emissions of infectious microorganisms, thereby reducing the impact on human health.

- to **understand the synergetic effects of increased trade and climate change on animal and plant health**

... *in order* to create a "buffer zone scientific network" to support monitoring of and stopping these transboundary pathogens in the CEE countries and prevent a further spread to the rest of Europe. Trade liberalisation offers easier trade of living and processed animal and plant products (and their packaging material) and increases our vulnerability from the animal health and phytosanitary point of view (e.g. African swine fever, bovine besnoitiosis). Moreover the impact of climate change increases the possibility of modified disease behaviour making spreading easier and causing a European level problem (e.g. grape and apricot phytoplasma). Research could help to strengthen CEE countries as a buffer zone for emerging and changing pathogens caused by globalisation and climate change in the Continental and Pannonian Bio-geographical Region.

- to **develop and implement efficient technology providing a growing sustainable and market driven utilization of forest based products (improve revenue-cost) and ecosystem services fitting societal needs while operating with improved environ-gentleness and reduced carbon footprint**

... *in order to* a) have an efficient wood supply leading to value-added, increased productivity, gentle production and supply of wood for different industrial processes, b) increase in operational efficiency and more efficient planning, wood mobilisation and forest regeneration as well as optimised driving distances, improved work environment and decreased environmental impact (reduced energy consumption and soil impact), and c) increase environmental gentleness regarding soil impact and carbon footprints with a substantial cost reduction for logging, haulage and forest regeneration operations, still allowing increased mobilisation of biomass.

For the thematic category '*Resource management*' we recommend research:

- to better **understand, monitor and measure the specific effects of agricultural practices and farming and forestry systems on the various productive and ecosystems functions of soils**

... *in order to* further enhance farming systems and the function of soils as carbon and nitrogen sinks, thereby supporting the role of agriculture and forestry in climate change mitigation as well as in combating desertification and land degradation. Research should focus on tools, practices and strategies to preserve and/or improve soil fertility and functions by optimising its biological, chemical and physical properties. This will include encouraging measures that increase soil carbon content and soil biodiversity, while also reducing soil erosion., in mixed crops-livestock systems.

- on **water use and management in and by agriculture**

... *in order to* reduce water consumption and pollution by agriculture. Research should focus on different farming systems and strategies to improve on-farm water management and promote novel technologies, tools and methods that are able to connect different types of data. On-farm water management should be linked to soil and land management to maximise synergies between these aspects. Research on agricultural water management should not be confined to

the farm level, but also take the territorial dimension into account comprising both the natural environment as well as the social, economic and political environment.

- on the **access to and renewal of genetic resources**

... *in order to* sustain plant and animal breeding activities by breeders as well as by farmers and foresters and cope with future demands in farming, forestry and food consumption. Genetic resources underpin agricultural production and are considered as a prerequisite for ensuring food security in a range of (changing) environments. Current food and non-food systems rely heavily on a small number of crop varieties and animal breeds, often owned by a limited number of companies. Research should promote the in-situ and ex-situ conservation (and the interlinkages between the two) of a wide range of plant and animal genetic resources (including underutilised plant varieties and animal breeds). Numerous local breeds and landrace varieties of crops and livestock still exist in Europe and can be better explored. Activities should also improve networking activities that help characterise, inform and improve access to genetic resources and thus encourage their use by breeders, farmers/foresters and in value chains for food and non-food products.

- to **explore the role of agriculture (including urban and peri-urban agriculture) in the circular bio-based society**

... *in order to* create new ways of integrating urban and rural areas through resource efficient food systems - through designing, developing, experimenting with and implementing new ways of valorising and using residues and by-products, in farm operations and reducing the use of natural resource inputs. The role of mixed crop-livestock systems is to optimise the production of human edible proteins per hectare of land without depleting resources.

For the thematic category '*Multiple functions and benefits of land and rural areas*' we recommend research:

- to explore **the impacts of farming systems at landscape and wider spatial scales**

... *in order to* develop integrated ecological approaches linking farm and landscape/catchment levels reciprocally. Until now the mutual interaction between different farming systems and ecosystem services at landscape level is not well understood. Improving our understanding of this mutual interaction will result in a better use of ecosystem services that is expected to strengthen the sustainability and resilience of farming systems. Synergies and trade-offs between the different environmental challenges and productivity and profitability aspects have to be considered in order to create mutual beneficial relations and design pathways to sustainable and resilient farming systems.

- to develop **methods that link the ecological and the socio-economic values of agriculture and forestry systems**

... *in order to* better reward their provision of public goods and ecosystem services, enhance sustainable production systems and foster the sustainable development of rural areas. Rural land, and agricultural and forestry activities in particular, is both a vital resource for production

of food, feed, timber, fibre and bio-based energy, and a source of public goods and ecosystem services that benefit society. Despite this, these goods and services continue to be undervalued in conventional markets and policy/institutional responses, with general under-provision or deteriorating trends observed, relative to societal needs or appreciation. The main cause of this is the lack of methods that are able to integrate the bio-physical/ecological values with the societal and economic values. In addition, data on the relative merits for society of agricultural products are poorly captured, recorded, translated and communicated throughout the production chain.

- to explore **the role of forests in mitigating climate change and in contributing to the bioeconomy**

... *in order to* design new strategies to deal with conflicting targets between climate change mitigation and the bioeconomy. The Paris agreement has set clear goals for future climate change. This will require large emissions reductions as well as enhanced emphasis on land use sinks, mainly forests. At the same time the EU has also set bioeconomy strategies that aim at many new products and energy from forest biomass. The forest resource and management aspects need to get a boost in order to fulfil these goals. Research can support these challenging demands by finding and identifying regionally specific management strategies capable of addressing both goals simultaneously (ie Climate Smart Forestry).

- to **map real land use and changes over time**

... *in order to* better inform spatial planning and policy making about the territorial dynamics of Europe's agriculture and forestry. There are many drivers of changes in land use, which results in highly dynamic territorial dynamics affecting agriculture and forestry. These changes have led to new land uses that do not match the standard categories of urban and rural land uses. In addition, agriculture is an increasingly diverse and multifunctional activity. This diversity can be observed in the many spatial, physical and functional gradients and contrasts found in Europe. A similar observation can be made about forestry, in which diverging uses can be found in one plot, ranging from mono-functional timber production to broader functions including environmental conservation and public amenity and recreation. These atypical, transitional and complex forms of land use (e.g. edges, buffers, hybrids of two contrasting land uses) are hidden in the current mapping, which is based on the dominant land use category. Agro-forestry land use types are also affected. This situation is an impediment to any spatial analysis and territorial planning, and has also implications for governance and land use research. Mapping at the appropriate spatial and temporal scales should be emphasised.

- on the **fiscal and regulatory and public governance influence over current and future use of land**

... *in order to* support national and local governments in shaping and governing future land use. How land is used is largely in the hands of individual and business landowners. What is not clearly recognised in strategy and policies in many countries is the significance of national and local governments in shaping the use of land, and hence the outcomes future generations depend on. This will become more important as we demand more food, more bio-based materials, more biodiversity, more bioenergy, more clean water and more attractive landscapes in which to take our leisure - all at the same time. This sustainable intensification presents difficult choices between competing uses or mixed systems. But how can governments best encourage the best uses, the optimal outcomes of sustainable intensification? And how can they encourage innovation and upskilling of rural people to tackle the challenge, given the current drift in many nations of younger, better qualified people to

cities? If the public sector in member states responded by adopting more effective measures, a rural renaissance could result through creating a market in which the exploitation of land to its full potential to deliver ecosystem services would deliver new business opportunities and stronger rural economies across the European Union.

- to analyse **the impacts of structural and temporal rural demographic change on the vitality of and quality of life in rural areas**

... *in order to* support local and regional authorities in designing effective policies to cope with and adapt to these changes. Rural Europe has to deal with significant demographic changes due to rural depopulation, in-migration (refugees and seasonal labour) and counter-urbanisation. These processes are highly diverse and contextual and thus create a plethora of challenges and opportunities for employment, level of public services, provisioning of public goods and ecosystem services.

- to **explore the experiences of less developed EU regions in social integration challenges such as food, energy or social care security**

... *in order to* contribute in the long term to the satisfying production of the European Union's agricultural, bioeconomy and rural stakeholders (or agricultural society) according to the changes in the number and composition of the population, making it easier to increase their income generating ability and their standard of living. Research can help the decision makers with authoritative and credible data, research results, and policy recommendations to develop an agricultural- and rural development policy to reflect the challenges related to internal and international migration, and to develop integrated policy strategies and action plans which promote resilience based on the partnership of the state, market, civil and research society.

- to guide **the transformation of non-urban Europe by exploring what levers have led to successful rural economies and how public policy measures can accelerate change**, drawing on the lessons of the more advanced rural economies

... *in order to* design an Agenda for Rural Development, for action by all Member States, and taking the potential of ecosystem services and public goods as a significant driver. In this context, it will be important to look beyond agricultural and forest products, and their food products, to embrace the ecosystem services and public goods that land management can supply. These by-products of land management are often at the heart of the attractions for other business investment – such as in tourism and leisure, field sports and equine industries, and the attraction of retired people with pension income to spend in rural communities. The research should also identify investment opportunities for businesses not connected with agriculture and forestry – to secure rural diversification and a transformation of local labour markets.

For the thematic category '*Human and social capital and social innovation*' we recommend research:

- to **enhance the skills, human and social capital of farmers, foresters and other actors of the rural economy**

... *in order* to enhance rural growth and innovation. The dynamics of rural economies depend on their social and human capital. In order to enhance growth and innovation it is important to a) better understand the values of current and future rural actors as well as their current and future needs, and b) to provide the hard and soft skills. This is why education, training and lifelong learning need to be at the heart of any endeavour to boost knowledge and innovation in rural areas and to keep pace with societal change.

- on **how to involve younger land managers in less productive EU regions in adopting good practices, boosting innovation and cooperation, creating possibilities for business expansion and better knowledge sharing**

... *in order to* establish a comprehensive transparent AKIS. The justification is that the agricultural and forestry output of family, small and young farmers in less developed EU regions represents a much lower level of production value than is achieved in other parts of Europe sharing similar agricultural and forestry production potential. The reasons include the limited flow of information, lack of knowledge and cooperation between research institutions, policy makers and farmers' organisations. The gap is also evident in big data usage and machinery. Deepening of cooperation between farmers would be crucial and the understanding and overcoming of trust barriers would be important.

- on **how to support successfully the generation change of the entrepreneurs in the agri-food and forest wood sectors in the less developed EU regions**

... *in order to* support the generational renewal in the agriculture and the food industry, thereby increasing the number of farms operated by young entrepreneurs open to innovative solutions and sustainable use of natural resources. In the less developed EU regions workplaces in the agricultural sector are not attractive for potential employees due to physical work, low wages and seasonality. This is made extremely difficult by the fact that there are no family or social patterns to follow as this is the first significant generation change since the regime change.

- to look into **the functioning and further development of knowledge and innovation systems**

... *in order to* further improve the interactive innovation model being implemented through the European Innovation Partnership "Agricultural Productivity and Sustainability" (the so-called EIP-AGRI). Research should also focus on the action research, multi-actor organisation, innovation and learning environments that facilitate or hamper participatory and transdisciplinary approaches.

- to **better understand the pros and cons of working with big data**

... *in order to* improve the ICT literacy of rural entrepreneurs and communities. In the near future it is very likely to have the availability of nearly free, near-real time imagery over every piece of land, which can be applied to agriculture, forestry and rural development. The challenge is not how to capture this data, as it will exist and be available, but rather on how to put it to use, not only by large corporations, but also by family farmers, other rural entrepreneurs and rural communities. One line of research should focus on the question what to do with all this data: what can we do now that we couldn't do before we had near-real time

data over all the land? The other line of research should focus on how to make these capabilities available to the entire community, for example, even to small farmers. The key issue here is having simple enough and actionable information, provided over the most appropriate channels (e.g. mobile, social networks, etc.) and the knowledge and skills to interpret these data and translate this into practices and strategic action.

ANNEX 3

Sustainable and competitive agri-food sector for a safe and healthy diet; gaps and recommendations

Background

According to the **H2020 legal framework**⁶ a sustainable and competitive agri-food sector for a safe and healthy diet should be prioritised, and the following should be considered:

' Consumer needs for safe, healthy and affordable food have to be addressed, while considering the impacts of food consumption behaviour and food and feed production on human health and the total ecosystem. Food and feed security and safety, the competitiveness of the European agri-food industry and the sustainability of food production and supply will be addressed, covering the whole food chain and related services, whether conventional or organic, from primary production to consumption. This approach will contribute to (a) achieving food safety and security for all Europeans and eradication of hunger in the world (b) decreasing the burden of food- and diet-related diseases by promoting the shift towards healthy and sustainable diets, via consumer education and innovations in the food industry (c) reducing water and energy consumption in food processing, transport and distribution and (d) reducing food waste by 50 % by 2030'.

This was envisaged as incorporating **three main areas**:

- 2.2.1. *Informed consumer choices*
- 2.2.2. *Healthy and safe foods and diets for all*
- 2.2.3. *A sustainable and competitive agri-food industry*

What has been addressed so far

In conducting the current '**gap analysis**', the two H2020 SC2 Work Programmes have been analysed with respect to topics covered for a 'sustainable and competitive agri-food sector for a safe and healthy diet'.

In the **2014-2015** Work Programme, there was a Call for proposals on '**Sustainable Food Security**' which included topics under three broad themes:

- Sustainable food production systems
- Safe food and healthy diets and sustainable consumption
- Global drivers of food security

⁶ COUNCIL DECISION establishing the Specific Programme Implementing Horizon 2020 - The Framework Programme for Research and Innovation (2014-2020)

Topics relevant to food also appeared under the Calls for 'Blue Growth' and 'Innovative, Sustainable and Inclusive Bioeconomy'.

Projects funded through the 2014-2015 Programme are only recently underway.

In the current **2016-2017** Work Programme, there is a Call for '**Sustainable Food Security – Resilient and resource-efficient value chains**' that includes topics under four broad themes:

- More resilient and resource efficient value chains
- Environment-smart and climate-smart primary production
- A competitive food industry
- Healthy and safe foods and diets for all

Other relevant Calls include 'EU-Africa Partnership on Food and Nutrition Security and Sustainable Agriculture', 'EU-China FAB Flagship initiative', 'Rural Renaissance - fostering innovation and business opportunities', and the Horizon Prize on Food Security.

As well as conducting a gap analysis on the two Work Programmes, we have analysed many other publications in order to ensure that our recommendations for research Calls in 2018-2020 take account of the **latest drivers, game-changers, and foresights** (see list of references). Clearly the global food system faces significant challenges between now and 2050. Food production and the food system must be prioritised to address the unprecedented challenges that lie ahead and bold actions will be needed by politicians, business leaders, researchers and other key decision-makers, as well as engagement and

support by individual citizens everywhere, to achieve the sustainable and fair food system the world so desperately needs⁷.

Food is relevant to at least six of the **Sustainable Development Goals**⁸:

- **Goal 2:** End hunger, achieve food security and improved nutrition and promote sustainable agriculture
- **Goal 3.** Ensure healthy lives and promote wellbeing for all at all ages
- **Goal 11.** Make cities and human settlements inclusive, safe, resilient and sustainable
- **Goal 12.** Ensure sustainable consumption and production pattern
- **Goal 14** (Oceans, seas and marine resources)
- **Goal 15** (Terrestrial ecosystems)

According to the **4th SCAR Foresight Exercise**⁹ a number of key drivers are foreseen, including: human population growth, the global economy, climate change, changes in diet globally in particular an increased demand for food (protein), increased demand for animal feed, food prices, increased demand for biomass, change in land use, pressure on resources (land use, freshwater use, soil, water), waste reduction targets, and conflict and unrest. The new energy landscape, ecological intensification, slowing yield growth, current and emerging technologies and engineering solutions, emerging plant and animal diseases, population migrations, CAP reform, trade

⁷ Foresight. The Future of Food and Farming (2011). Final Project Report. The Government Office for Science, London.

⁸ TRANSFORMING OUR WORLD: THE 2030 AGENDA FOR SUSTAINABLE DEVELOPMENT. A/RES/70/1. United Nations.

⁹ Sustainable Agriculture, Forestry and Fisheries in the Bioeconomy - A Challenge for Europe. 4th SCAR Foresight Exercise.

agreements and standards, and new business and policy models, are also important considerations for future research programmes. The foresight exercise points out that 'substantial research and innovation investment will be required to strengthen and support dynamic rural transformations, promote responsible investment, sustainable and climate-smart agriculture and food value chains, and foster multi-sectorial approaches to nutrition, even in areas of conflict and crisis'.

The latest strategic research agenda of the **JPI 'A healthy diet for a healthy life'**¹⁰ considers the social and economic burden of diet- and lifestyle-related diseases (e.g. type 2 diabetes, cardiovascular diseases and certain cancers), malnutrition and micronutrient deficiencies (as for example in elderly, young born and diverse minority groups), and the association of food with pleasure, culture and symbolism. Biological, ecological, psychological, sociological and socio-economic drivers of behaviour, and differences across Europe, need to be taken in to account.

In terms of delivering on EU **food safety and nutrition in 2050**, a number of drivers have been identified¹¹ including: global economy and trade, global cooperation and standard setting, EU governance, demography and social cohesion, consumer attitudes and behaviour, product diversification, new food chain technologies, competition for key resources, climate change, emerging food chain risks and disasters, and new agri-food chain structures. Various **scenarios** are anticipated such as: a rapid surge in global trade in food and feed, with highly concentrated agri-food industries; break-down of global cooperation in a multipolar world; long-term austerity and a shift to private food safety controls in the EU; severe inequality linked to food insecurity of vulnerable consumers and polarised diets; a strong shift in EU consumer preferences to food from alternative production systems; widespread consumption of high-tech functional foods; global resource depletion; global disruptions of agriculture from climate change ; and a breakdown in consumer trust in food following the emergence of food chain risks.

Unsustainable super-consumption needs to be considered, as well as future consumer needs and demands, which are likely to vary according to prosperity levels. In **Consumer Futures 2020**¹² a number of key drivers have been identified, including: critical systems such as food, energy, finance; global recession – challenges to our economy and way of life; scarcity of key resources, rapid population growth, climate change and loss of biodiversity; major consumer changes expected in retail in next 10 years; demand for oil, water and staple crops will increase, prices will rise; growing consumer demand for responsible and transparent value chains; and the New Green Economy.

Emerging gaps recommended for further research

Taking the previous Work Programmes in to account (H2020 2014-2017), the key drivers and foresights summarised above, and significant game-changers (hyper connectivity and big data, falling cost of energy, migration and changing demographics, health, climate change, primary sector innovation, biotechnology, and instability as the new norm in global society¹³), the Expert Advisory Group considers that there are **four thematic categories** where further research would be likely to deliver useful results in the early 2020s:

¹⁰ Strategic Research Agenda 2012 -2020 and beyond. Joint Programming Initiative 'A healthy diet for a healthy life. 2nd edition – June 2015

¹¹ European Commission Directorate General for Health and Consumers. Scoping study 2013. Delivering on EU food safety and nutrition in 2050 - scenarios of future change and policy responses.

¹² Consumer Futures 2020. Scenarios for tomorrow's consumers. 2011.
www.forumforthefuture.org/project/consumer-futures/overview

¹³ Strategic Foresight: Towards the 3rd Strategic Programme of Horizon 2020. Directorate-General for Research and Innovation

1. *Healthy diets, healthy people* ... covering consumer options, consumer behaviour, food quality, nutrition, and the social and economic burden of diet [links to H2020 legal framework '2.2.1. Informed consumer choices']

2. *Food safety, security, defence, and integrity* ... covering food safety, security, threat and vulnerability, bioterrorism, fraud, authentication, transparency, responsible food production [links to H2020 legal framework '2.2.2. Healthy and safe foods and diets for all']

3. *Sustainable, competitive, and innovative food manufacture* ... covering sustainability, traditional/SME/large food companies, competitiveness at local and global scales, innovation, optimisation of food processing, food packaging, food technologies, food waste, food loss [links to H2020 legal framework '2.2.3. A sustainable and competitive food industry']

4. *Food policies, supply chains, markets, and communities* ... a new theme covering governance, regulation, economics, food policies, supply chains, all types of food markets (retail, wholesale, farmers markets, bartering, etc.), food transport, food communities.

For the thematic category '*Healthy diets, healthy people*' we recommend research on

- **consumer preferences, attitudes, needs, behaviour, lifestyle and education, and communication between consumers and the food chain research community and its operators**

... *in order* to improve informed choice, sustainable consumption and their impacts on production, inclusive growth and quality of life, especially of vulnerable groups. Social innovation, and innovative models and methodologies in consumer science will deliver comparable data and lay the ground for responses to Union policy needs. Changes in diet, shifts in consumer preferences (e.g. to food from alternative production systems), and attitudes to, and consumption of high-tech functional foods should be considered. Nutritional needs and the impact of food on physiological functions, physical and mental performance should be addressed as well as the links between diet, ageing, chronic diseases and disorders and dietary patterns. Dietary solutions and innovations leading to improvements in health and well-being should be identified. A holistic approach should be taken in order to inform the consumer (through clear labelling and information) on better consumption patterns that promote sustainability, equitability or other desirable goals.

- **malnutrition and micronutrient deficiencies in certain population groups, for example the elderly, those hospitalised or in care, lower socioeconomic groups, and diverse minority groups**

... *in order to* develop relevant policies and guidelines, populate open databases to provide robust evidence bases, assess risk, inform food manufacturing through recommendations for new food formulations, technologies or delivery systems, and inform carers, dieticians, and relevant NGOs, ultimately to ensure healthy and balanced diets for all.

- **the different biological, ecological, psychological, sociological and socio-economic drivers of consumer behaviour across Europe**

... *in order to* understand negative and positive aspects of consumer behaviour in relation to food consumption and inform key stakeholders such as policy makers, food producers, the medical profession, retailers and caterers, IT and technology innovators and developers, economists, food marketers, and citizens.

- **tackling obesity and non-communicable diseases through food formulations, changes in retail and catering practices, and changes in consumer behaviour utilising advanced technological, psychological, and social approaches.**

... *in order to* reduce the burden and costs to individuals, employers and national health services of diet-related diseases and involve key stakeholders in finding meaningful solutions for food-related diseases. Pilot demonstration activities should be considered in order to show how all relevant stakeholders could translate findings into practice.

- **smart nutrition solutions for the next decades to establish how food production technologies, new delivery methods, and ICT approaches might be used to provide smart personalised nutrition solutions and health care**

... *in order to* transform the entire food chain with new players, new alliances and new services and a high value for consumers and providers. Resulting innovations could include point of care assessment measures for the health status of consumers and customized food production and delivery services (including ICT solutions for a healthy and sustainable consumption). Special population cohorts should be considered.

- **the gut microbiome**

... *in order to* advance our understanding of this ecosystem and harness the potential to unlock a wealth of undiscovered genetic resources, to improve food quality, and develop precision/optimal nutritional products to promote health. New knowledge is needed to investigate the connection between gut microbiome health and other micro-organisms in the food chain. The microbiome is not only a target for treatment and prevention of disease, it is a repository for functional food ingredients and a source of novel biomarkers of disease risk. The human microbiome market (consisting of probiotics, prebiotics, foods, medical foods, other supplements, devices, and drugs) is expected to grow. Regulatory frameworks, policies, consumer acceptance and the patent landscape should be considered in the proposed development of new functional food ingredients or changes to foods, as a result of increased understanding or exploitation of the gut microbiome.

For the thematic category '*Food safety, security, defence, and integrity*' we recommend research:

- **on rapid at-line or on-line detection tools for food and feed safety including follow-on preventative and mitigation measures**

... *in order to* investigate how rapid easy to use, and affordable on-line or at-line tests for biological and/or chemical contamination in the food and feed supply chain might reduce the incidence of food contamination and allow earlier detection, thus protecting the consumer, optimising food manufacture, and reducing food waste.

- **on allergen presence and control in food and feed,**

... *in order to* establish the extent of allergen contamination in the food and feed supply chain, make information available on open accessible databases, and to develop detection, control, and mitigation systems and thus facilitate detection by food inspectors, food business operators, and consumers and reduce allergen contamination and food recalls.

- **to understand how antibiotic resistant bacteria establish and persist in food production systems and in food products and how food environments influence transfer of antibiotic resistance genes**

... *in order to* prevent food and water born transmission of resistance, and protection of human health.

- **on safety of nano-materials and low dose chemicals in foods and feed**

... *in order to* establish the level of risk and make practical recommendations to policy makers, regulators, inspectors, food and feed manufacturers, consumers, and to protect human health.

- **data analytics to identify emerging risks in foods**

... *in order to* assess sources and causes of risks, as well as mitigation measures for food and feed manufacturers.

- **on food safety and the growing elderly population in Europe, especially on the factors that contribute to increased morbidity in elderly people in relation to food borne infections and the higher carrier rate of antimicrobial resistant bacteria**

... *in order to* determine how best to prevent food borne infections in the elderly, to develop new food items for elderly people with high food safety and appropriate gastronomic and nutritional characteristics, and to demonstrate tools and procedures for increased hygiene in the elderly persons kitchen.

- **on threats in feed and food supply chains to establish vulnerability to fraud or intentional contamination or adulteration, and develop risk prevention, protection, and mitigation strategies for food business operators**

... *in order to* protect the integrity and reputation of food and feed supply chains important to European economy and society, and provide tools and guidance for food businesses.

- **on innovative packaging and smarter supply chains**

... *in order to* ensure food product safety, integrity and quality (including nutrients), and enable wider distribution of European food products.

For the thematic category '*Sustainable, competitive, and innovative food manufacture*' we recommend research:

- **on reduction of food waste, solutions for re-work of waste (or by-products), and approaches or technologies for valorisation of food waste or by-products**

... *in order to* provide robust and accessible data on levels of waste, reduce waste at different stages of the food supply chains (farm to fork) and develop more integrated and coherent strategies and approaches involving multi-actors.

- **on optimisation of food production using advanced engineering and IT solutions**

... *in order to* implement more innovative and sustainable resource-efficient processes which could reduce or recycle water, energy and other key resources, reduce costs, and increase competitiveness. Food processing, transport and distribution should be considered.

- **on the environmental impact of food systems**

... *in order to* fully understand the real environmental including those of greenhouse gas emission consequences of different food production practices and develop incentives to help sustain ecosystem services and reduce the footprint of the food system. It is important to consider the carbon footprint of mixed systems from an integrated, circular perspective instead of linear productions chains perspective. Research should include aspects of food design, processing, packaging, process control, waste reduction, by-product valorisation and the safe use or disposal of animal by-products. The resilience of the food chain against environmental and climate risks, and the limitation of negative impacts of food chain activities and of changing diets and production systems on the environment should be assessed.

For the thematic category 'Food policies, supply chains, markets, and communities' we recommend research:

- **on short local food chains for health, considering microbial connections from soil to humans, animals and plants,**

... *in order to* help characterise agroecological agriculture, its biological functioning specifically studying the flow of microorganisms from soil to products and defining the role of the microorganism in product quality in interaction with "terroir", farmer know-how and end-users practices, *and thus* increase confidence in natural and local products for all citizens, improve steps of production and interactions between actors involved in the food chain, develop and recognise terroir qualities and agroecological practices, boost rural renaissance, and increase market value of local products.

- **on the role of non-market based networks of food provisioning for food security**

... *in order to* design and implement effective planning strategies and social policies to enhance food and nutrition security that include the contribution of non-market based networks of food provisioning (e.g. grow your own, informal exchange of food, food charities, food banks etc.) to food and nutrition security.

- **on urban/city-region food policies – in other words the process through which cities across Europe develop and implement food policies, the extent to which public authorities, private sector and civil society are involved in policy design and implementation and the domains and themes that these policies focus on,**

... *in order to* understand how effective urban food policy making can be generated and (through monitoring over time) better the impact of urban food policies across a range of areas related to systems of food provisioning, such as climate change, diet-related ill-health, transport, employment, social (in)equality and urban-rural linkages.

- **on food product development and ethno food marketing taking account of migration and changing demographics in Europe**

... *in order to* identify opportunities for food production, technologies, marketing, and tourism and contribute to a stable and integrated society using food as a common language. The association of food with pleasure, culture and symbolism should be highlighted.

- **on innovation support systems and networks for food SMEs, especially micro-SMEs and traditional food producers**

... *in order to* improve the business skills of SMEs to facilitate growth management and provide alternative routes to market.

ANNEX 4

Unlocking the potential of aquatic living resources, and marine and maritime research; gaps and recommendations

Background

Blue Growth is considered to be a key pillar of the H2020 programming, in order to support the unlocking of the potentials of sea and oceans. More than 70% of planet earth is marine environment, holding 90% of the global biomass. With the maritime economy currently accounting for as little as 7 % of GVA, this potential use of marine resources cannot be ignored in a bio-based society.

In the H2020 work programmes 2014-2017, the research and development relating to Blue Growth has been concentrated on new maritime technologies for exploration and exploitation of sea-based resources (food, energy, materials), to be developed in harmony with a better insight in the functioning of marine life, in a so called ecosystem based and nature inspired approach.

For the last phase of H2020 programme 2018-2020, the main need is to integrate Blue Growth into the circular bio-based society. This implies an integrated vision on sustainable nutrition security on the basis of mixed food systems including seafood, the development of blue and green energy production and also societal land-sea connections ranging from the urban development of coastal metropolises up to rural development of more remote coastal regions. All embedded by a sound understanding of land-ocean interactions including climate change and other environmental issues. Blue Growth should also be considered with a due consideration to large inland water systems.

Blue Growth will thus contribute to the grand societal challenges within the global sustainable development goals:

- Circular Economy in a Bio-based Society; including the so far unexploited marine biomass supplies
- Food 2030: integrated food policy including freshwater and seafood
- Climate Smart & Resilient Economy; including the emerging maritime economy
- Resource Use Efficiency; including marine and inland water resources, biomass, energy, fresh water)
- Adaptation to Climate Change; in marine life, coastal zones and large inland waters
- Nature based Coastal Development (environmental engineering) can meet the needs of metropolises in urbanizing deltas or assist in revitalisation of remote rural coastal regions

Game changers

The relevant game changers relevant informing Blue Growth research needs can be summarised as:

- The United Nations Sustainable Development Goals, which require responsible approaches to Blue Growth, especially SDG14 "Life below water"

- The drive towards a sustainable and circular biobased society, which requires an integrated approach in managing the use of biomass resources from land and sea
- New multipurpose offshore technologies that can enable better use of the sea, as an alternative to more intensive and less sustainable use of land
- The decommissioning of offshore oil/gas platforms offers opportunities for innovative reuse in this perspective
- New coastal engineering concepts (Building with Nature) allow a more natural connection between land and sea and possibilities for combining food/feed/energy production and more effective coastal protection
- Development of salt water agriculture (algae, seaweed) for the production of food, feed, nutraceuticals and energy at sea will simultaneously take off pressure on land and inland water use
- Climate change related sea level rise and its impact on coastal zones and deltas; and the climate change related sea temperature rise and acidification and its impacts on marine food production perspectives
- Climate change related impacts such as those of storms, flooding and droughts on large inland water systems
- Emerging technologies enable new solution sets for the above mentioned perspectives: Gen Tech, High Tech, Remote Observation Tech, Sensor Tech, Big Data, Internet of Things
- Marine governance and societal acceptance of responsible use of the seas.

What has been addressed

In Horizon 2020, so far, the following Blue Growth topics have been well addressed:

- Ecosystem based management: regional coastal zone management and marine spatial planning
- Aquaculture: novel fish cultivation, disease management, integrated multi-trophic aquaculture; Mediterranean aquaculture
- Fisheries innovations and discards management
- Climate change and fish production
- Marine derived (bio)chemicals and materials
- Marine based energy
- Marine pollution control and clean shipping
- Subsea vehicles
- Atlantic Ocean observations
- Ocean literacy
- Arctic development

Emerging gaps recommended for further research

In the view of the Expert Advisory Group, there are three main areas of priority where further research would be likely to deliver useful results in the early 2020s:

1. *Exploring new options for exploiting marine resources ...* covering seaweed and phytoplankton production; mixed commercial and game fisheries; mesoplankton and deep ocean mining
2. *Applying new technologies to exploitation of marine resources ...* covering High Tech Field observation; aquabreeding; multiple purpose offshore production sites and biomimicry

3. *Fostering the marine environment and biodiversity...* covering “plastic soup”; marine ecosystem resilience; governance of Blue Growth perspectives in line with Building with Nature principles to enable an ecological sound reconnection of land and water and integrated marine and inland water ecosystem based management at regional level

For the thematic category “*Exploring new options for exploiting marine resources*” we recommend research on:

- **Seaweed production and processing (human edible proteins, fine chemicals, energy, bio-based materials, methane low ruminant feed stocks)**

... *in order to* study the use of seaweed as a main crop in marine biomass production from a food, feed, fine chemistry and energy perspective. Research should include the identification of best producible species for offshore production in various European waters; the set-up of breeding and selection of cultivar strains; the development of suitable offshore production facilities; the processing of yields into various fractions with highest values. This should lead towards large scale seaweed production sites in order to achieve a significant contribution to the resourcing of the bio-based society. At the same time, environmental impact of such novel production and processing activities should be considered.

- **Interactions between commercial fishing and game fishing (in an ecosystem based approach) related to new perspectives of ecotourism in remote rural areas.**

... *in order to* study the options for sustainable game fishing in more detail, in relation to the carrying capacity of water bodies for fishing by commercial fisheries. Research should focus on stock assessment and management instruments for game fishing, and integration of game fishing in regional, ecosystem based fisheries models, in order to achieve a common understanding of mixed commercial and game fisheries management.

- **Sustainable exploitation of large mesoplankton stocks for producing high value substances**

... *in order to* map the distribution and dynamics of oceanic mesoplankton to enable a sound assessment of the maximum sustainable yield (MSY) by selective fishing. Sustainable harvest strategies need to be developed for stocks and species that are at the very base of the food chain and that are the staple food of higher organisms, including fish, birds and marine mammals. Smart harvesting avoiding by-catches and processing technologies require development to achieve sustainable production of high value fatty acids and proteins.

- **Deep ocean mining and related knowledge gap about deep ocean environment and biodiversity**

... *in order to* continue developing smart technologies for the exploration of mineral deep sea resources, informed by good mapping and understanding of geological formations and biodiversity, and guided by planning for sustainable mining strategies not harming the marine environment and

in line with international legislation and conventions. This research should include the development of appropriate impact assessment methodologies. The North East Atlantic is the most interesting area for investigation, as is the Pacific Ocean's Clarion-Clipperton Fracture zone. Special attention should be given to areas of particular environmental interest. These activities should build further the concept of "Ocean Literacy".

For the thematic category "*Applying new technologies to exploitation of marine resources*" we recommend research on:

- **High tech field observations in marine environmental management, big data retrieval, handling of data in management support systems, using the potentials of the internet of things**

... *in order to* further develop an ecosystem based marine management approach, emerging technologies can be integrated in the fleet of commercial vessels to intensify the recording of the environmental status by remote observation and observed data integration systems in a context of the Internet of Things. This is an extension of the SFS-22-2017 call to implement new technologies to achieve real time data acquisition and management at fisheries vessels. This could also include the integration with the scientific ocean observation technologies (GOOS) on specific (research) vessels and additional supporting systems such as drifting stations, platforms, remotely operated vehicles and drones, airborne and satellite surveillances.

- **Aquabreeding: improvement of the resilience, robustness and efficiency of the main aquatic production species using smart breeding programmes based on genomics**

... *in order to* develop smart breeding programmes for commercial aquaculture fish species based on novel precision phenotypes derived from physiotyping and metabolotyping, using "within-species-gene-editing" techniques , including the ethical and environmental aspects of breeding. The main focus in aquabreeding should be on health related traits, to achieve more resilient, robust, and resource efficient breeds that are less sensitive to pathogens, parasites and climate change-related environmental stress. This should lead to the desired growth of the European aquaculture sector.

- **Multiple-use of offshore production sites, integrating biomass and renewable energy production in a "building with nature" approach**

... *in order to* explore the possibilities to design multiple purpose offshore installations for combined and integrated renewable energy and biomass production; including new developed energy parks for wind, solar or tidal/current based energies; multitrophic aquaculture parks (sea farming) and refit of abandoned oil/gas platforms; to enable the most efficient use of the sea with platforms designed on the basis of the novel concept of "building with nature" leading to eco intensification.

- **Bio-mimicry discoveries for marine nature inspired technical innovations**

... *in order to* explore the potentials of marine nature for bio-inspiration of new technological developments related to fine chemicals (pharmaceuticals, nutraceuticals, antifoulings, probiotics etc.), materials (micro- and nano- technologies) and designs (robotics, hydrodynamics), to enable a wider scope for nature-inspired innovations to meet the global development goals.

For the thematic category "*Fostering the marine environment and biodiversity*" we recommend research on:

- **Plastic soup related marine pollution: remediation of existing concentrates, mitigation of new pollution, development of marine degradable bio-based plastics.**

... *in order to* investigate in more detail the dispersion and fate of plastic materials in the marine environment. To separate and classify potential effects of plastics to the environment (larger versus smaller particles, plastics versus associated chemicals, types of plastic, etc.) to allow a more precise environmental risk assessment in support of more focussed mitigation strategies, technologies and actions for current pollution; and to enable a sound legislation to prevent further pollution.

- **Marine ecosystem resilience and regime shifts, in relation to climate change**

... *in order to* improve the understanding of changes in the marine eco-dynamics due to climate change related changes in environmental conditions (warming, anoxia, acidification, sea level rise, extreme stormy weather conditions) and consequent changes in biodiversity; to enable a better prediction of and anticipation to crucial regime shifts throughout the food-chain from microbial primary producers up to large top predators. From a global ecosystem perspective, the focus should be on North Atlantic and Arctic in a transatlantic cooperation with US-Canada.

- **Marine governance in international waters related to societal acceptance of Blue Growth perspectives and "building with nature" principles**

... *in order to* build up capacity in arranging a governance system for a sustainable exploration of the seas, to enable a sound basis for the development of the maritime economies guided by marine spatial planning. An integrated approach in exploitation and protection of marine resources, marine space and marine life requires a joined-up approach to ocean health, living resources, ecosystem services and human well-being on a long term perspective. This approach requires development of tools, methods and educational curricula at the scale of global modelling to support sound and smart foresight analyses that allow the combined and cumulative impacts of human activities to be assessed.

- **Integrated large marine and inland water ecosystem based management at regional level: development of institutions and best practices ,**

... *in order to* develop regional specific ecosystem based, management frameworks to enable multinational and multi-stakeholder management of regional seas, rural and metropolitan coastal zones and large inland water systems. The principle of environmental engineering (Building with Nature) is basic guidance that can enable the recreation of ecologically sound land and water interactions. This should include impacts of climate change on regional development in terms of development of more resilient food production systems due to sea-level rise, salinization or risks of flooding. The development of regional databases for sharing information is needed for an integrated approach. Special emphasis needs to be given to remote overseas European territories in all oceans to strengthen the position of EU in negotiations about exploration and exploitation in the high seas, and the protection of hot spots of biodiversity.

ANNEX 5

Bio-based industries and the bioeconomy; gaps and recommendations

Background

Background

The Bioeconomy is set to make major contributions to society, including:

- renewable, sustainable energy generation
- effective use of the biomass through cascading biorefineries
- new pharmaceutical products
- new sustainable sources of proteins and lipids
- new sources of bulk chemicals
- biomass products that don't require land
- the potential to contribute to a zero waste society through products that form part of circular economies while at the same time turning waste streams into valorized and validated bio-based products

Increasing those contributions to societal goals will depend on actions by business and governments informed by sound research – especially research making links between different sectors. So, for example, we foresee an overall transition from fossil fuel energy dependence into a better joined-up bioeconomy approach to the use of natural resources. Beyond that, there is the prospect of innovation that delivers new products that help to reduce greenhouse gas emissions. Progress will depend on consumer and market practices that evolve, drawing on demonstration plants and test beds for cascading the use of biomass resources throughout society, in Europe and globally.

Biotechnology as a gamechanger

In short, the Advisory Group sees biotechnology as a "game changer" – as part of the next wave of disrupting technologies. Biotechnology has the inherent power to change the economic and social landscape, how people work and live with implications for quality of life, practices and values as well as the serving the environment for protection and sustainable use of ecosystem services. Biotechnology will be the cornerstone in a bio-based society; biotechnological breakthroughs will strongly support a transition towards a bio-based society by 2025. Integration of biotechnology with new tools for big data analysis will accelerate biotechnological innovation and widen the application of biotechnologies in multiple societal and industrial frames.

Strategic innovation in the primary sector will be one key to unlock sustainability progress and wellbeing in society. Social networks, crowd sourcing and new ways of exchanging information will be important. It will be important to recognise and draw on the trend towards increased "soft" use of information and communications technology (ICT) for communication and knowledge exchange.

As actors increasingly organise themselves in networks across Europe, and globally, the result will be pressure to change the rules of current organisations. The use of social networks, crowd sourcing and new ways of organising communication and knowledge exchange is increasing and provide important options and entrances for learning and innovation for the future. This could spark the development and use of bio-based products.

Climate change, oceans and space are big dimensions important for humanity as a whole. As fossil fuel infrastructure is decommissioned, bio-based infrastructure may be expected to take its place. There are also clear links to hyper-connectivity and big data informing and driving accelerated change and innovation. The bio-based society will benefit from use of already existing data to map the production and flow of biomasses and waste streams; it will also be possible to combine data to make predictions and models on supply chains, geographical dependencies, and the availability of biomass supply. At the same time, there are risks of externalities – for example the potential negative impact on biodiversity from increased cultivation of single-species biomass for use in the bioeconomy

What has been addressed so far

In Horizon 2020, so far, the following bioeconomy topics have been well addressed:

- the use of fisheries by-catches and discards
- the potential of marine derived (bio)chemicals and materials
- marine based energy
- sustainability schemes for bio-based products
- adaptive tree breeding strategies and tools for forest production systems resilient to climate change and natural disturbances
- intelligent solutions and tools in forest production systems, fostering a sustainable supply of quality wood for the growing bioeconomy
- statistical data collection methodology for bio-based industries and bio-based products
- action plans for mobilising and spreading information about the potential of bio-based products
- regional potential of bio-based industries – drawing on stakeholder platforms

The wider enabling of a bio-based society is implemented through Bio-Based Industries Joint Undertaking (BBI-JU), which is a Public-Private Partnership between the EU and the Bio-based Industries Consortium operating under Horizon 2020. In this report, therefore, the Societal Challenge 2 topics are concerned mainly with primary production and supporting market development.

Emerging gaps recommended for further research

In the view of the Expert Advisory Group, there are three main thematic categories where further research would be likely to deliver useful results in the early 2020s:

1. *Production of biofuels and biomolecules in the framework of a circular economy*
2. *Demonstration plants/testbeds for cascading use of biomasses and for multi-actor use*
3. *Marine biomass use and production (for example seaweed, phytoplankton and discards)*

Where appropriate, the research priorities listed below should embrace possible biomass waste streams that might be processed and valorised within circular economy approaches.

For the thematic category '*Production of biofuels and biomolecules in the framework of a circular economy*' we recommend research to:

- **map biomass supply, building on existing knowledge, approaches and tools**

... in order to further assess the sustainable biomass resource base for bioeconomy in Europe and help to achieve the full potential of a secure, sustainable year-round biomass supply, with an emphasis on European indigenous capacities and locally sourced biomass potential.

- **explore new, innovative, energy saving preservation strategies for different types of biomasses - developed, validated and standardised on biomass level**

... in order to address the challenge that the new biomass streams in the emerging bioeconomy are highly sensitive to degradation, due to challenges in both transportation and storage, and this hampers valorisation in an efficient market economy

- **use cost-benefit analyses of bio-based plastics/polymers vs traditional plastics on a global scale**

... in order to investigate the potential to replace conventional plastics and inform a better informed market in bio-based plastics and polymers, that will in turn stimulate more investment and more appropriate choice in the use of bio-based or traditional materials, taking account of the externalities of each in use on a global scale

- **use evidence to establish how alternative uses of renewable resources can influence carbon emissions**

... in order to explore the extent to which the bioeconomy can decouple environmental degradation from economic growth. Exploring the potential reduction of carbon emissions is important, because while it is in general assumed that the use of renewable raw materials reduces the carbon footprint of products, this might only be partly true. In cases when the same raw material can be used for different purposes, the carbon emissions may differ significantly.

- **foster the demand for bio-based products from a consumers' perspective through gathering evidence on consumers' practices in relation to bio-based products and how these may form new market places**

... *in order to* establish how much customer acceptance will influence the replacement of fossil fuel based with renewable materials

- **new innovative and inclusive business solutions using bio-based services**

... *in order to* explore how much broader the bioeconomy concept can be, beyond mere reduced use of fossil fuels for production of goods and energy. The bioeconomy should also create new business opportunities (innovative) and generate jobs in rural areas (inclusive). There is a huge potential of better and more systematic use the market opportunities offered by bio-based services, which are currently not used or even understood - especially in rural areas such development could provide new opportunities and positively contribute to the rural renaissance.

- **understanding the impact of the global bioeconomy development on the availability of biomass resources on the global markets**

... *in order to* inform the implementation and success of the EU bio-economy, which strongly depends on the availability of resources and the market developments at the global level. Understanding these factors should help to steer the market development in the desired direction (considering threats and opportunities).

- **comprehensive mapping of the policy framework affecting the bioeconomy in the European Union and its Member States**

... *in order to* inform an approach to embed the bioeconomy in fiscal and regulatory policies enabling a better joined up approach in the single market, better alignment of EU research/innovation funding with the established priorities of bioeconomy based policies, and appropriate considerations of the potential of bio-based approaches at the onset of policy development

For the thematic category '*Demonstration plants/testbeds for cascading use of biomasses*' we recommend research to:

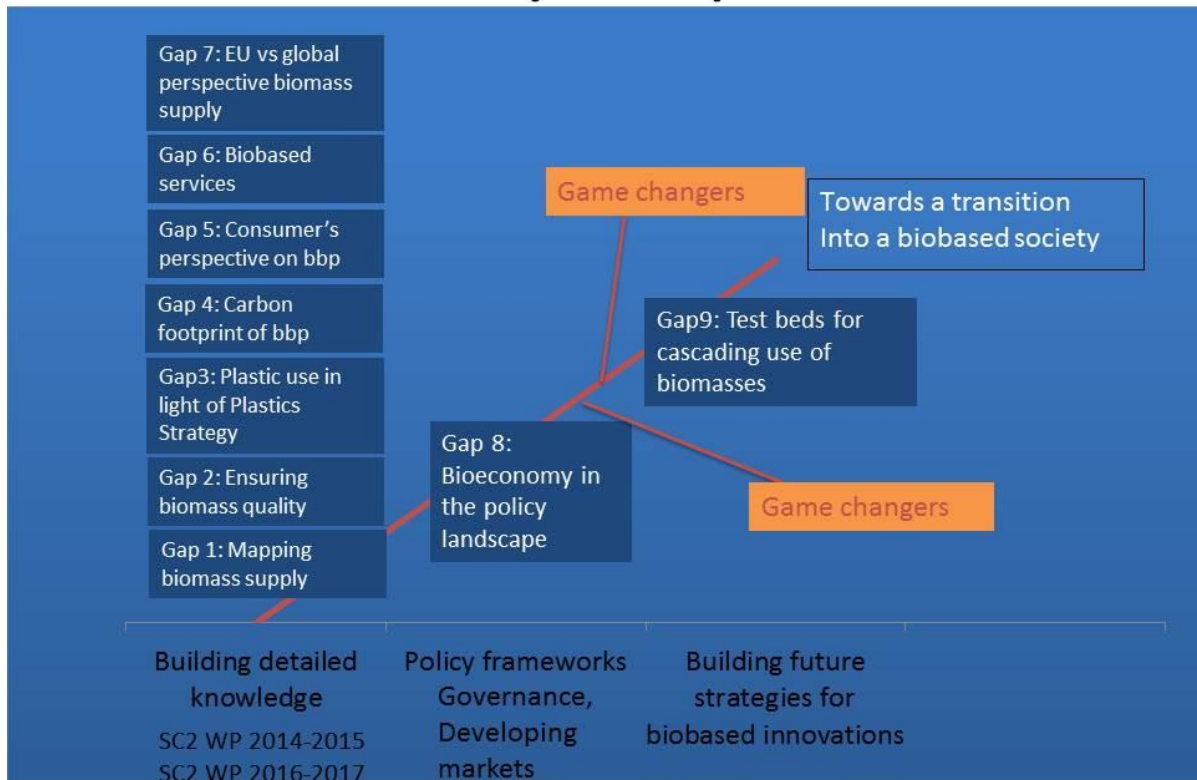
- **create an optimal network of laboratories supported by new infrastructure to form test beds that can develop process technologies and new products in a demo-scale that underpin the development of biorefineries (industrial scale) for maximising biomass use**

... *in order to* show how creating platforms for stakeholder and industrial collaboration projects will maximise the product output of different biomass streams and thus demonstrate the full potential of the expected transition into a bio-based society

For the thematic category 'Marine biomass use and production' we have not delivered specific recommendations at this stage.

All these recommendations can be presented simply as elements that will deliver the desired transition to a more bio-based society (see below)

Bioeconomy development



ANNEX 6

Expert Advisory Groups

The Societal Challenge Group is just one in a series of expert advisory groups helping to shape the future research programmes under HORIZON2020 and beyond. The full list below has been used to test that sufficient thought has been given to the potential for integrated approaches, outlined in the main report.

1. Access to risk finance (debt and equity financing)
2. *Climate action, environment, resource efficiency and raw materials
3. European research infrastructures including e-Infrastructures
4. *Europe in a changing world – inclusive, innovative and reflective societies
5. *Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy
6. Future and Emerging Technologies (FET)
7. Gender
8. *Health, demographic change and wellbeing
9. Innovation in small and medium-sized enterprises (SMEs)
10. International cooperation
11. The Marie Skłodowska-Curie actions on skills, training and career development
12. Nanotechnologies, advanced materials and advanced manufacturing and processing
13. Science with and for Society
14. *Secure, clean and efficient energy and Euratom
15. *Secure societies – protecting freedom and security of Europe and its citizens
16. *Smart, green and integrated transport
17. Space
18. Spreading excellence and widening participation

ANNEX 7

Source material used in the preparation of the Advisory Group Recommendations

1. 10 political priorities of the Juncker Commission: https://ec.europa.eu/priorities/index_en
2. EC(2013/743/EU) 'Council Decision of 3 December 2013 establishing the specific programme implementing Horizon 2020 – the Framework Programme for Research and Innovation (2014 – 2020)'; http://ec.europa.eu/research/participants/data/ref/h2020/legal_basis/sp/h2020-sp_en.pdf
3. European Commission (2015) The role of science, technology and innovation policies to foster the implementation of the Sustainable Development Goals (SDGs): <http://bookshop.europa.eu/en/the-role-of-science-technology-and-innovation-policies-to-foster-the-implementation-of-the-sustainable-development-goals-sdgs-pbKI0415809/?CatalogCategoryID=Gj0KABst5F4AAAEjsZAY4e5L>
4. European Commission, Responsible research & innovation: <https://ec.europa.eu/programmes/horizon2020/en/h2020-section/responsible-research-innovation>
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23. Sustainable Agriculture, Forestry and Fisheries in the Bioeconomy - A Challenge for Europe. 4th SCAR Foresight Exercise.
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25. European Commission Directorate General for Health and Consumers. Scoping study 2013. Delivering on EU food safety and nutrition in 2050 - scenarios of future change and policy responses.
26. Consumer Futures 2020. Scenarios for tomorrow's consumers. 2011. www.forumforthefuture.org/project/consumer-futures/overview
27. Strategic Foresight: Towards the 3rd Strategic Programme of Horizon 2020. Directorate-General for Research and Innovation
28. Global Food Security 2030. Assessing trends with a view to guiding future EU policies. Joint Research Centre 2015. EUR 27252 EN Foresight Series.

ANNEX 8

Horizon 2020 Societal Challenge 2 Advisory Group members

Last Name	First Name	Organisation	Country
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Wakeford	Richard	Professor of Environment, Land Use and Rural Strategy at Birmingham City University	UK
Wiskerke	Han	Wageningen UR	NL

Meetings of the Horizon 2020 Societal Challenge 2 Advisory Group in 2016:

- meeting of the SC2 AG – 22 February 2016
- meeting of Sub-Group chairs – 18 April 2016
- meeting of the SC2 AG – 19 April 2016
- meeting of Sub-Group chairs – 3 June 2016

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Food security, sustainable agriculture and forestry, the bioeconomy and the management of marine, maritime and inland waters are among the most important elements influencing European society and the wider world. These elements are at the heart of sustainable development that delivers strong communities through a flourishing economy that respects the environment – development that the world’s children and grandchildren will thank us for.

Research under the heading of Horizon2020 Societal Challenge 2 should be hugely influential in delivering that goal. The 2016 report of the Horizon2020 Expert Advisory Group for Societal Challenge 2 provides strategic advice from an expert perspective on the priorities for European Commission funded research under the themes of food security, sustainable agriculture and forestry, the bioeconomy and marine, maritime and inland water research. It lifts our eyes to a further horizon – and embraced new priorities flowing from the rapid changes in the world and global agreements since Horizon2020 was designed.

Studies and reports

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