European Commission

Recipe for change:

An agenda for a climate-smart and sustainable food system for a healthy Europe

Report of the EC FOOD 2030 Independent Expert Group




Recipe for change:

An agenda for a climate-smart and sustainable food system for a healthy Europe

European Commission
Directorate-General for Research and Innovation
Directorate F — Bioeconomy
Unit F.3 — Agri-Food chain
Contact Karen FABBRI
E-mail Karen.Fabbri@ec.europa.eu
RTD-PUBLICATIONS@ec.europa.eu
European Commission
B-1049 Brussels

Manuscript completed in 2018.

Luxembourg: Publications Office of the European Union, 2018

PDF ISBN 978-92-79-80356-7 doi: 10.2777/84024 KI-01-18-208-EN-N

EUROPEAN COMMISSION

Recipe for change:

An agenda for a climate-smart and sustainable food system for a healthy Europe

Report of the FOOD 2030 Expert Group

Directorate-General for Research and Innovation
Bioeconomy

2018

TABLE OF CONTENTS

PREFACE

Europe is on the move from the present to the future. The long financial and economic crisis made us focus on the immediate problems without much room to invest in our future. With improved economic growth this period is coming to an end, although I realise that many Europeans do not yet experience this personally and have not yet recovered from the setback. The economic crisis taught us that the systems that we have set up to organise the world are vulnerable.

Also our food system is far from resilient. It has too many negative effects on the environment and on our health. The system delivers more affordable food at larger quantities than ever, but this goes at the expense of future generations. This is an important insight for the direction in which we have to innovate the food system. At a global level this has been recognised by the adoption of the Sustainable Development Goals (SDGs) and the signing of the Paris' agreement on climate change (COP21).

Especially the last one creates a juridical obligation for member states that makes a redesign of our food systems unavoidable. Rethinking the use of soils and the role of livestock in the food system of the future is needed. But preparing the food system for the future is not only a challenge for agriculture. A sustainable world implies sustainable consumption of a healthy diet. And although individual consumers and farmers can make important contributions, it are also other players in the food system, like retailers, food processor and technology providers but also cities and financial institutions that can make a difference.

In its FOOD 2030 initiative the European Commission has recognised this challenge to make our food system future-proof. Several publications and conferences have been dedicated to the need for a food system approach with improved governance. In a next step DG RTD has asked a group of experts to appraise the current research from a food systems angle and to formulate missions that can direct the future research and innovation actions in Europe.

The report of that group of independent experts is now on your screen or in your hands. It was my pleasure to chair the group and I warmly thank my colleagues for their hard work and excellent collaboration. I extend my thanks to all others that contributed indirectly and to the Commission staff for their support and entrusting us with this challenging task.

In the coming year the European Union will discuss its investments for the future, in financial discussions and in allocating budgets to research and innovation programs. With this report we argue to recognise the resilience of our food system not only as a serious challenge but also as an opportunity to bring Europeans together at the table with diverse and healthy food from its many regions.

Krijn J. Poppe,
Chair of the Independent FOOD 2030 Expert Group

EXECUTIVE SUMMARY

Our current food system is not fit for the future....

....and in this paper a group of experts proposes a new direction

Introduction

In 25 years, our food system will look very different from now. Technology and social practices will have changed the way we produce and process our food, as well as how we shop. Even what we eat will be different.

Our current food system is not fit for the future. Farm practices are not sustainable, we eat less healthily than we should and we are unprepared for climate change. We also think about agriculture, the wider bio-economy and managing natural resources as being separate from the food system, while in reality they are all interconnected. We need to create sustainable, diversified, inclusive and resilient processes that can cope with the complex social and ecological effects of increased urbanisation, population growth, changing demographics, climate change and resource scarcity: our whole food system needs innovation.

In this report, a group of experts recommends orientations for innovation in the years to come at the request of the European Commission's DG RTD. The report will contribute to a Research, Innovation and Investment Strategy (RI&IS) in line with the Commission's FOOD 2030 initiative, which is based on four priorities:

- **Nutrition** for sustainable and healthy diets
- **Climate** smart and environmentally sustainable food systems
- **Circularity** and resource efficiency of food systems
- **Innovation** and empowerment of communities

Using food systems thinking, the experts have further elaborated and integrated these four priorities to develop a mission type approach.

SDGs are relevant to the food system and the Paris Agreement on Climate Change

More beans,

The grand challenge: a climate-smart, sustainable food system for a healthy Europe

Many of the 17 sustainable development goals (SDGs) set by the United Nations are relevant to the food system. These range from ending hunger and improved nutrition (SDG2), via halting land degradation and biodiversity loss (SDG15), to forging a global partnership for sustainable development (SDG17). Nearly 10% of the EU population are not able to afford a regular quality meal every second day. Europe is the continent most severely affected by non-communicable diseases. These are the leading cause of disability and death, and they are linked to the way we eat and drink. To put it another way, without fixing the food system, the SDGs simply cannot be achieved.

The Paris climate change agreement (COP21) commits Europe to reducing greenhouse gases (GHG) dramatically to keep the rise in

less beef…in 10 harvests	global temperatures below 2 degrees. Farming has to adapt to climate change and a world without fossil fuel. The food system (including on-farm energy use) accounts for around 26% of total EU emissions. The food system can help, for instance by partly substituting plant-based proteins for animal proteins, by reducing food losses and waste and by helping farmers to implement practices to reduce greenhouse gas emissions. Farmers only have about 10 harvests to adapt to the 2030 effort-sharing agreement. After 2030, with the easiest measures taken, the climate challenge will be much more daunting, with a clear risk of unprofitable, 'stranded' assets.
EU policies should be accompanied by an R&I policy	Meeting these grand challenges will have important societal benefits, ranging from major improvements in our health to safeguarding food production for future generations. These grand challenges fall under many current EU policies. We need a substantial, over-arching R&I policy to support them. Regulations and taxes can stimulate innovation and productivity, but research and innovation are crucial to achieve policy goals and integration. The transformation of the food system should make it more sustainable, resilient, responsible, diverse, competitive and inclusive[i]:
The food system cannot transform alone	• Sustainable: with respect to natural resource scarcity and planetary boundaries; • Resilient: adapting to climate and global change, including extreme events and migration; • Responsible: being ethical, transparent and accountable; • Diverse: being open to a wide range of technologies, practices, approaches, cultures and business models; • Competitive: providing jobs and growth; • Inclusive: engaging everyone involved in the food system, plus civil society, fighting food poverty, and providing healthy food for all. In achieving these objectives, we must realise that the complexity of the food system extends to practically all bio-economic sectors. Farming depends on the natural environment, which makes the interaction of primary production with natural habitat management a crucial factor. Therefore agro-ecological knowledge and approaches are very important.

Food system approach

Connected in a food system

Grand challenges cannot be met in isolation through a range of technical innovations: a more integrated approach is needed, linking food consumption and production, land and sea, farmers and consumers – and back. We call this a *food system approach*. This kind of approach helps identify which parts of the system are interlinked and which can make the difference. Who will be the game changers?

The food system incorporates all elements and activities that relate to the production, processing, distribution, preparation and consumption of food, as well as its disposal. This includes the environment, people, processes, infrastructure, institutions and the effects of their activities on our society, economy, landscape and climate.

Change needs an iterative approach

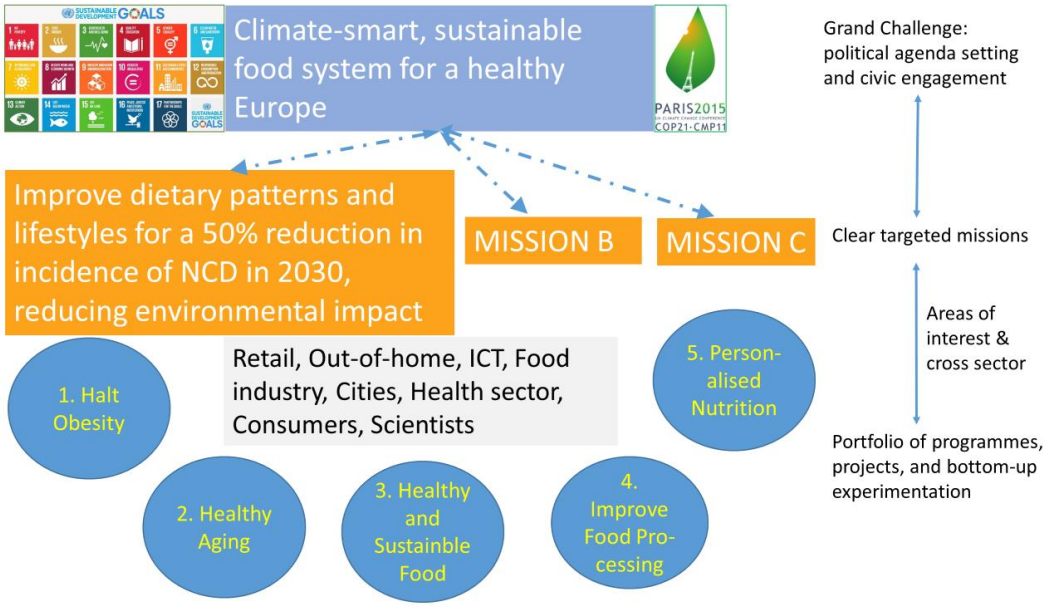
The food system is a complex adaptive system: complex, because there are many interrelations; adaptive, because external drivers (climate change, for example) as well as internal changes set chains of events in motion. It is only possible to understand the effect of changes after they have occurred. So, to transform the system we need a more iterative approach, using enhanced feedback loops.

Businesses that are parts of a food system are highly dependent on each other. Currently, retailers and food processors compete primarily on food prices but have few incentives to compete on quality, innovation or environmental impact. This means cost pressures on farms, with environmental consequences.

To provide affordable, high quality products and to increase the earnings of those who work in food, farming and fisheries, the food system has innovated successfully – but at the expenses of the environment, biodiversity and animal welfare. Food is now affordable and our lifestyles have changed so much that unhealthy diets contribute to obesity and non-communicable diseases. Some companies have responded and see innovations as business

Governments have strong reasons to intervene	opportunities. But that is not sufficient and governments need to intervene. Many small farming, fisheries, food processing and retail firms underinvest, as they are too small to reap all the benefits of risky innovations. This does not just represent classical market failure: it suggests the food system cannot become more sustainable without guidance and supportive policy frameworks. Right now, the food system is not responding enough to meet the great challenges. It seems that everybody is locked in and kept hostage by the current system. The powerful retailers, food processors and input providers (feed, chemical and machinery firms) compete with each other but do not have enough stimulation to work together in more sustainable ways – and this affects weaker farmers and consumers. We need to look at whether they need carrots as well as sticks.
Missions help to set a direction in the search for solutions.	**Missions** Successful innovations tend to have a clear direction. Governments can tell businesses to change, but they could also create a market for innovative products or (public) services, or a label explaining a certain type of sustainable farming. A mission type approach (in short: missions) is a powerful tool for this, as it promotes solutions from people on the ground. Missions are political in nature and require broad stakeholder engagement. We propose breaking down the grand challenge of ***"A climate-smart, sustainable food system for a healthy Europe''*** into three missions, using the frame proposed by Mazzucato (2018). These three missions, which further build on and integrate the four FOOD 2030 priorities, contain 17 focus areas.

A. Improve dietary patterns and lifestyles for a 50% reduction in the incidence of non-communicable diseases (NCD) in 2030, while reducing the environmental impact of food consumption



Direction: eat more diverse and healthier foods	Changing dietary habits and increasing physical activity could address major risk factors and reduce rates of obesity and Non-Communicable Diseases (NCDs) in Europe by 50%. Successful nutrition and lifestyle strategies will enable European citizens to live longer, healthier and more independent lives in a more sustainable environment, decreasing the costs of health systems. Changing dietary habits, for example, by switching to more plant-based proteins also has a large potential to reduce the environmental impact of food consumption. This mission builds on the FOOD 2030 priority of *Nutrition for sustainable and healthy diets*.
Innovation: cities, insurance companies and ICT as new players	Currently seven of eight major risk factors for premature death are linked to the way we eat, drink and exercise; we need to prevent diseases rather than just treating them. A quarter of greenhouse gas emissions come from the food system, where food choice and waste are critical. Scientists understand better than ever how our body functions, thanks to ongoing progress in areas such as neuro-science, genetics, omics-technologies and understanding the intestinal microbiome. In this context food safety will be improved to an even higher level. Businesses that offer food to consumers can play an important role in promoting healthy and sustainable choices. Cities are important as regulators and spaces – do they, for instance, encourage fast-food outlets or cycling lanes and urban farms? The health sector (from dietitians/nutritionists and doctors to health insurance companies) can also play a key role in facilitating sustainable food choices. The European industry could build up suitable, personalised nutrition technology (apps, food printing, food delivery) based on scientific and socio-economic evidence.

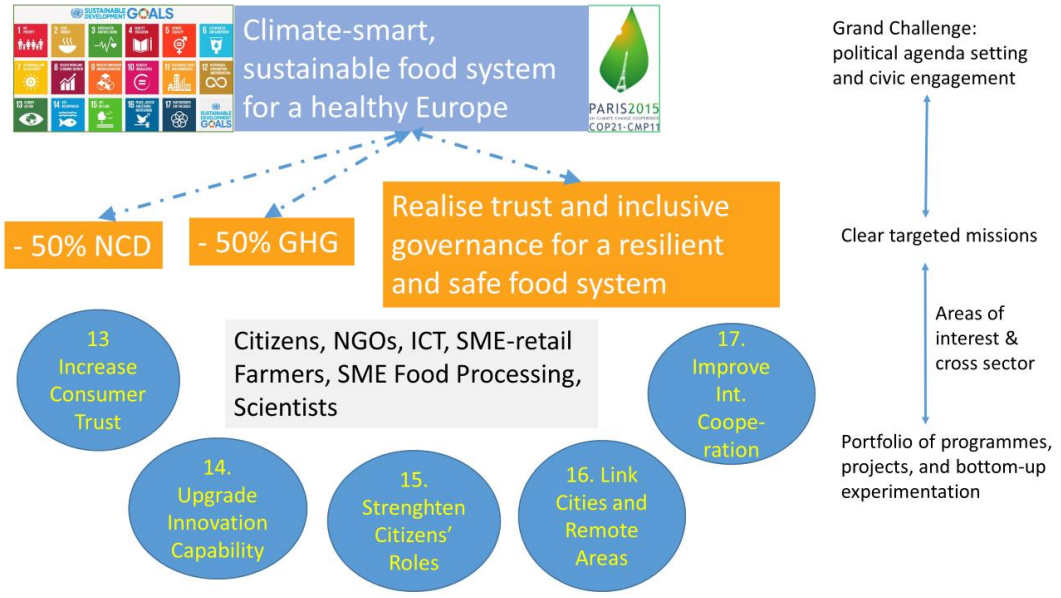
An example	Innovative food products with taste attributes for the elderly are developed that target malnutrition and are environmentally sustainable. Strategies are developed to deliver nutrition advice tailored to the individuals' biological readouts (dna, microbiome, neuro-science) that will also promote sustainable dietary patterns. These might be delivered in new ways (with personalised nutrition advice and food printing in smart kitchens). It will give European companies a competitive advantage.
Five focus areas	1. **Halt Obesity**: halt the rise in obesity levels in school-aged children, adolescents and adults by tackling complex causes via a food systems approach. 2. **Healthy Aging**: add healthy and independent years to the ageing population, halving the number of dependent adults. 3. **Healthy and Sustainable Food**: help more people eat a healthy and sustainable diet by making twice as many affordable energy and protein food sources available. Collaboration with Africa is useful. 4. **Improve Food Processing**: improve food processing for more nutritional and tastier products that are also safer and better for the environment. 5**. Personalised Nutrition**: use personalised nutrition strategies to improve dietary patterns and lifestyles, reduce the incidence of non-communicable diseases in Europe by 50% and decrease the environmental footprint of the consumption by 20%.

B. Create a resource-smart food system with 50% lower greenhouse-gas emissions by 2030

Direction: redesign a safe, lower-impact food production system	We need to redesign the food system to help solve Europe's climate challenge, respecting environmental limits on water quality and irrigation levels, air quality (ammonia, odour, fine particles), biodiversity (pesticides, natural habitats) and soil quality (no soil degradation and more carbon storage). The food system must not pose unnecessary risks for public health (fine particles, zoonosis, use of antibiotics and pesticides) and should respect ethical demands (e.g., animal welfare). Aquatic production should double and the use of feed from insects and algae should increase. Plant production should be strongly based on agro-ecological principles supported by reductions of fossil-based energy and pesticides. Integrated water resources management is needed. We must also reduce the negative impacts of packaging, particularly of plastics. This entire redesign should result in a food system built on sustainable diets and minimal waste, which is recycled in a safe way in accordance with circular economy principles. This diet should be affordable for all Europeans. Farmers and fishermen should also have a fair income that is not based on subsidies, but where needed on public contracts for public services. This mission builds on and integrates the FOOD 2030 priorities to make food systems climate-smart and environmentally sustainable as well as circular and resource efficient.
Innovation: redesign systems, ecology and working with local farmers	More ecological understanding of agro-ecosystems is now available to redesign food production. Innovative changes in the organisation of primary production and agro-ecosystems have been developed by groups of farmers and need support for upscaling. New technologies speed up breeding processes, while self-driving robots can farm with great precision, requiring fewer

	chemicals. Just as tractors and pesticides revolutionised production in the 1950s, modern techniques could completely redesign the food system and avoid negative environmental impacts. But such technologies do have negative aspects too, such as the impact on employment, or ethical and data ownership implications. We need a societal debate from the start to ensure responsible innovation in this area. Input industries and food processors are important, but innovation systems must also work closely with farmers, as many solutions are linked to local conditions. This is the case in the EU but also holds for joint innovation programmes with Africa and the Middle East, where demographic developments, climate change, war and migration often lead to food insecurity.
An example	On a territorial scale the farming system is redesigned with an integrated approach to animal and plant production, to reduce the diversion of biomass for animal feed, drive down GHG emissions and turn waste flows into fertility. Ecological principles are further developed and knowledge on proper soil management is enhanced, alongside advances in ict-driven precision farming. This makes a reduction of virgin minerals and chemical inputs possible - and affordable for smaller farmers. Such food is marketed on the basis of reducing waste and increasing sustainability, contributing to a shift in consumer preferences – just as consumers opt for the electric self-driving cars of the future over current diesel cars.
Seven focus areas	**Territorial systems**: develop sustainable and climate-resilient food systems on a territorial scale. **Diversified systems**: diversify fields, farms, landscapes and diets to use resources in a climate-proof, sustainable way. **Low impact animal systems:** redesign, integrate and encourage low-impact animal production systems. **Smart soil and virgin mineral use:** arrive at a fully sustainable and smart use of natural resources: zero land degradation by 2030, healthy soils, reducing the yearly input of virgin minerals (such as phosphate) by 50%. **Reduce impact packaging:** Reduce the environmental impact of food packaging by 2030 by 75%. **Halve food waste and losses:** Halve food waste and losses from the EU food and farming system by 2030. **Double food from aquatic systems:** Double the sustainable production of high-quality food from EU aquatic systems by 2030.

C. Realise trust and inclusive governance for a resilient and safe food system



Direction: empower small producers and foster open innovation	A resilient food system that copes with new challenges through responsible innovation needs fast feedback loops. Challenges should quickly provoke action. Current food systems are failing because they do not factor in negatives such as health and environmental impacts. Instead, food producers need to be empowered to take action. Vulnerable farmers, fishermen, consumers and small food companies as well as innovators benefit from open data and open innovation; this openness also helps people to accept new technologies. Remote rural and coastal areas also need links to cities and innovation centres in Europe's major food regions. This mission builds on the FOOD 2030 priority on *Innovation and empowerment of communities*.
Innovation: a shopping list, from sharing food data to keeping isolated places liveable	To make the food system more inclusive, we need to look at certain pressing issues. These include stimulating social innovation, including and empowering small food businesses, combining the modern and old, and creating new business and governance models. We also need to look at ways to engender a sense of community that keeps isolated locations feeling "liveable" in emptying rural/coastal areas with an ageing population. In this context food safety will be improved to an even higher level. Connecting communities of small businesses to innovation hubs (with ICT tools or otherwise) can improve knowledge flows. Engaging citizens through educational and social programmes can strengthen their role in the system, as can short supply chains. Urban food policy networks can play an important role in fostering knowledge exchange, civil society participation and the dissemination of good practice. New technologies and organisational arrangements (like e-platforms) make it possible to share data along the food chain, thereby promoting safety,

	transparency and trust. Methods to assess sustainability and to support true cost accounting can improve the governance of the global food system. We must also pay special attention to institutional development frameworks to upgrade local food systems in an urbanising Africa and the Middle East.
An example	Cities that aim to be carbon-neutral will adopt a food policy that promotes a healthy living environment and source their food from carbon-neutral food systems. Food outlets are spatially planned to nudge consumers into sustainable healthy products. Vulnerable (consumer) groups are empowered to take the lead in developing effective ways to gain control over their food intake. Such cities are innovation hubs to which farmers and small food businesses are linked, also through new technologies that efficiently deliver the food and provide farmers and fishermen with options to innovate. New technologies bridge the geographical distance between those cities and remote areas to connect distant populations and allow equal access to social advancements.
Five focus areas	**Increase food safety and consumer trust:** increase consumer trust by 50% by improving the authenticity, transparency and safety along the food system by 2030. **Upgrade innovation capability**: upgrade innovation capabilities of small firms in food systems. **Strengthen the citizen's role:** strengthen the different roles of citizens in a healthy, diverse and sustainable food system. **Link cities and remote areas:** link cities, remote rural and coastal areas to help them develop innovative food systems. **Improve international cooperation:** improve international cooperation in trade and development, especially with Africa and the Middle East.

Conclusions

Like a Michelin-starred menu, the food system has a lot of ingredients – individual farmers, multinational vendors, international governments and, of course, consumers, who may not equate what is healthy with what is tasty. There is no one switch for a sustainable system.

Innovations make farm subsidies avoidable and reduce rising health costs

Interventions at the point where the problem occurs do not solve it: the taxpayer will continue to subsidize farmers and pay for the increasing costs of the health system. Meanwhile, small food companies, farmers and fishermen continue to lack incentives to provide sustainable and healthy food. So, we need a multi-objective and multi-actor drive for responsible innovation across the food system, with new partners like cities and health insurers. New technologies in genetics and preventive health (e.g., the microbiome, neuroscience) and ICT (artificial intelligence, precision farming, personalised nutrition) could also help to bring change, if applied in the right way. Social innovation and organizational changes are required to realize a climate-smart, sustainable food system for a healthy Europe.

Europe is well positioned

In the age of the bioeconomy, Europe is well positioned to take the lead and guide the world towards a food system that is future proof. We have a sense of urgency plus state-of-the-art food production systems, high levels of food safety and environmental quality standards and a first-class knowledge infrastructure. Europe has the capacity to lead the world in creating a sustainable food system and benefit from the business it will generate. In this way the European industry (food, health, ict) will improve its competitive position vis-à-vis other continents.

n investment of €10 billion

Tackling this grand challenge by completing the three missions will need major investment, way above the currently allocated framework funding. We, as experts, therefore call for substantial investment within the framework of the next EU budget in partnership with Members States, industry, foundations, civil society, and others. This investment should be deployed via a dedicated Research, Innovation and Investment Strategy (RI&IS) which engages all possible instruments and partnerships necessary to get the job done.

… has a high return on investment

Past investments in agricultural research have resulted in a large societal return: US data suggest that $1 invested was worth ten times as much, over time. Even greater results have been shown with non-communicable diseases: reducing salt intake by 30% in the high-burden population of sick people reportedly gave US society $19 of benefit for every $1 spent. In Europe, greenhouse gas emissions from the food system are currently around 1180 Mtonnes CO2-equivalents. Reducing that by 50% would save the equivalent of €20 billion a year.

Recommendations

European Union (Commission, Parliament, Council) Adopt the main conclusion of this advice to develop a unified, health-centric, climate-smart, sustainable and resilient food system for Europe based on a system approach to R&I and of a substantial investment way above the current allocation from the EU budget and beyond.

Directorate General RTD Lead by example and convene and organise the necessary critical mass within the European Commission as a first step to working together towards these common goals. Work closely with other EC services, and others, to deliver a food system that improves the social contract between agriculture and society on providing healthy, sustainable food at prices that are fair for farmers and consumers.

Member States (and regions in federated member states) Support the approach in the EU by making your own research and innovation programmes mission-driven, with the same grand challenge and three missions advocated here. You could choose from the 17 focus areas to represent your national priorities and specialisms. Work jointly in ministries and authorities across departments to implement a systems approach to R&I policy and governance on these missions.

Companies (in food processing, retail, input industries, ICT, health, and finance) Reconsider your business strategy in light of contributing to SDGs, given the challenges for the food system, scale up your innovation activities and link them to the research and innovation programmes of the EU and the member states.

Farmers, SMEs in the food chain and start-ups in the food system Realise that there are chances to improve your position in the food chain by pursuing innovation, stronger collaboration with different food chain actors and participation in multi-party innovation programmes.

Citizens and consumers Eat in a healthy and sustainable way; contribute ideas and engage in innovative projects to support the transition of the food system.

Cities and other local (water) authorities Introduce a proactive and evidence based food policy that creates healthy, sustainable urban environments to make healthy and sustainable choices appealing for consumers. Make sure that city neighbourhoods are connected with the surrounding green countryside and seaside for a healthy lifestyle. Multi-party innovation should be an important part of urban food policies.

Foundations, civil society and non-governmental organisations Your objectives can partly be realised by advocating for the proposed missions and aligning with or taking part in research and innovation programmes with the people you represent.

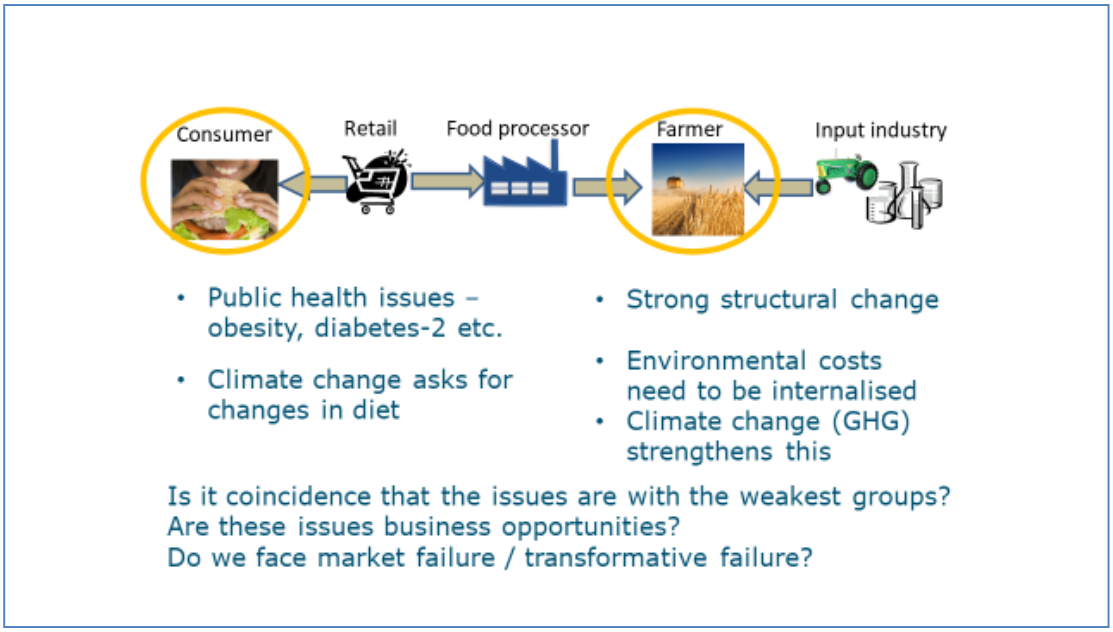
INTRODUCTION

Since the combined food, fuel, financial and fiscal crisis of 2007-8, which witnessed a dramatic increase of food prices, there has been an intensified and renewed interest in the complex and interconnected sets of multi-scaled challenges, vulnerabilities and inequities of European food systems. Such food systems are defined in this report as systems that embrace all the elements (environment, people, inputs, processes, infrastructure, institutions, markets and trade) and activities that relate to the production, processing, distribution and marketing, preparation and consumption of food and the outputs of these activities, including socio-economic and environmental outcomes[1]. In particular, the challenge of ensuring food and nutrition security (FNS) – having access to sufficient, safe and nutritious food for current and future generations – is very high on the global political agenda.

1 – FOOD SYSTEM APPROACH

Achieving Food and Nutrition Security (FNS) for future generations worldwide, faces multifaceted and interrelated global challenges such as climate change, urbanisation, population growth and natural resource scarcity. This raises the need for a more systemic approach to FNS that embraces all actors in the food system – not just producers and consumers, but also retailers, who heavily influence food demand, and processors, who can affect farmers' behavior through their food safety and sustainability schemes. The issues in the food system are concentrated with the smaller, most vulnerable part of the chain, suggesting that the governance of the food system does not provide enough incentives to other actors to transform the system to a more sustainable and inclusive performance (figure 1).

Figure 1 Weak spots in the food chain require better governance



[1]http://www.un.org/es/issues/food/taskforce/pdf/All%20food%20systems%20are%20sustainable.pdf

Food policy, research and innovation often depend on the joint effort of different partners in the food chain (farmers, processors, input industries, advisory services, water authorities, government agencies and others) – in other terms, on the capacity of multi-actor projects to take up an innovation challenge. In some cases, such projects require the contribution of new food players, such as, for example, public health institutions, health insurance, the financial sector, manufacturers of sensors and LED lighting, or Information and Communication Technology (ICT)-based commercial platforms given their role in food delivery, and the European Space Agency, which has been providing new data on land use patterns.

The food system is also more and more interrelated to the wider bioeconomy and to start-ups, which see investments in the food sector as a business opportunity – that is, as an opportunity to invest in innovations like the growing of algae or insects or develop systems for indoor farming or personalised nutrition. These new actors are especially of interest in the light of current actors' inability to solve problems (so called 'wicked problems') and to facilitate a re-configuration of the food system. Public actors like city and regional governments are also developing an interest in food, nutrition and attractive landscapes, given their contributions to healthy lifestyle, urban design and the quality of the retailing, green infrastructure and mobility systems in an urban area (Sonnino, 2016 and 2018).

These developments are making the food system more and more complex. Innovative research and technological advancements that are based on a food system approach and uses the principles of complex adaptive systems (detailed in Part 2 of this report) can actively shape and interlink future EU policies by strengthening and expanding knowledge of the complexity of the FNS challenge and provide workable solutions. By adopting a food systems approach that looks at multiple sectors and scales, a more comprehensive understanding of the interconnected drivers of FNS can provide robust evidence to support policy-making that moves beyond silo-based thinking to adopt coherent, long-term policy strategies that increase the efficacy of various food systems (industrial or 'alternative') for improving FNS.

In this sense, Research and Innovation (R&I) is particularly important in identifying strategic points where intervention can be the most effective in creating more sustainable food systems – that is, food systems that deliver FNS for all in such a way that their economic, social and environmental bases are not compromised for future generations[2]. By focusing on the interconnections between FNS and public and environmental health, R&I has the capacity to influence and link multiple policy areas (such as agriculture through the Common Agricultural Policy (CAP), aquaculture through the Common Fisheries Policy (CFP), in addition to energy, trade, and development [food aid] policy). For example, presently FNS R&I actions are supporting the implementation of relevant EU policies like the long-established CAP, which has implemented the EIP-AGRI, in an attempt to strengthen the science-policy-farm practice interface and foster bottom-up processes in innovation. The CAP is complemented by various environmental policy instruments like the Nitrate directive. Concerning aquaculture the Water Framework Directive and Marine Strategy Framework Directive (MSFD) are relevant. For food there are the food safety laws (which seek to protect consumer health through a farm-to-fork approach and improve traceability), and internal market rules covering the protection of human, plant and animal health. Implementing a food systems outlook to approaching the United Nations' Sustainable Development Goals (SDGs) could also potentially enable their timely and effective delivery. Furthermore, FNS is also an integral part of the European Commission's broader 2012 Bioeconomy Strategy, which has underpinned much of the R&I under Societal Challenge 2 of Horizon 2020.

[2]http://www.un.org/es/issues/food/taskforce/pdf/All%20food%20systems%20are%20sustainable.pdf

Furthermore, in light of the Paris Agreement on Climate Change limiting global average temperature increase to 1.5oC above pre-industrial levels, EU agriculture and food-related policies will need to be reformed to integrate this ambitious target and contribute to mitigation efforts to reduce greenhouse gas (GHG) emissions and build resilience with adaptation measures.

In conclusion, it could be argued that FNS R&I should play a strategic role in the development of a European-wide food and nutrition policy, which integrates environmental and health concerns across the whole food system into a coherent, coordinated and multi-dimensional policy to deal with the full complexity of FNS.

2 – FOOD 2030

With regard to innovation issues, it should be noted that the RISE High-Level Expert Group to EU Commissioner Carlos Moedas has recently suggested establishing a European Innovation Council (EIC) to attract and support talented innovators, promote open, collaborative and crowd-source modes of innovating and develop instruments that can support "breakthrough projects" until the up-scaling phase (EC, 2017a). Furthermore, the recently published Lamy report recommends doubling the budget for R&I programmes after 2020 to define R&I missions that address global challenges, involve citizens in the programmes and simplify the EU funding landscape for innovations (Lamy et al., 2017).

FOOD 2030 has been launched by the European Commission's DG RTD as a systemic approach that seeks to tackle these challenges with R&I policies designed to future-proof food systems and make them more sustainable, resilient, diverse and competitive for the benefit of society. It aims to do so by providing solutions to four overarching priorities (see European Commission 2017e for details):

- **Nutrition for sustainable and healthy diets.** This priority supports the development and implementation of EU safety policies, the EU Nutrition Policy Framework and relevant targets of the SDGs 2, 3, 8 and 10. This priority can be broken down in the following topics:
    - Tackling malnutrition and obesity
    - Improving nutrition for healthy aging
    - Healthy and sustainable diets, for example, supporting more plant-based sources or other protein alternatives to meat
    - Ensuring food authenticity and developing future safety systems
    - Recovering forgotten crops for nutrition and resilience
    - Promoting healthy and sustainable African diets
- **Climate-smart and environmentally sustainable food systems.** This priority is relevant to the CAP, the EU Strategy on Adaptation to Climate Change, EU environmental policies, the Paris climate agreement (COP21) and relevant targets of the SDGs 2, 7, 14 and 15. This priority can be broken down in the following topics:
    - Demonstrating sustainable aquaculture for Europe
    - Enabling precision farming for small farmers
    - Boosting photosynthesis for food & energy
    - Fighting climate change through healthy soils

- **Circular and resource efficient food systems.** The third priority supports the modernisation of the CAP, the EU Circular Economy Package (including the Waste Directive and Climate Action policies) and relevant targets of the SDGs 2, 8 and 12. This priority can be broken down in the following topics:
    - Achieving zero food waste
    - Tackling primary production waste streams
    - Converting food waste into bio-based products
    - Reducing food packaging
    - Sharing data for short-circuit food systems
- **Food systems innovation and empowerment of communities.** The fourth priority aims to support the Digital Single Market Strategy, the EU Urban Agenda, the Europe for Citizens programme and relevant targets of the SDGs 2, 9, 11 and 16. This priority can be broken down in the following topics:
    - Ensuring sustainable and accessible food in cities
    - Engaging citizens in food systems and science policy
    - Fostering a sharing economy for food production and consumption
    - Implementing data-driven food and nutrition systems

The systemic remit of FOOD 2030's approach will foster the development of R&I that makes food systems more resilient, more stable and more equitable through internalisation of negative external effects, diversification and localisation. In particular, the role of ICT and data sharing can help to ensure the proper functioning of food commodity markets and their derivatives, where timely access to market information can help to limit extreme food price volatility, as well as to develop customised, localised and diversified food supplies. Technological advances in precision farming also for smaller farms can also attract innovation into the industry and help to redesign arable production for better soil management. Information technology can also encourage urban-rural linkages and models of co-ownership in the sharing economy. Additionally, the quest of ensuring global FNS entails supporting protein alternatives to meat to reduce dependence on conventional animal-based farming (and its large carbon footprint). Climate change and the principle of the circular economy ask for a rethinking of the role of the animal sector in the food system, making use of waste streams and permanent grassland. This goal also includes recovering forgotten crops that can contribute to nutrition, resilience and the conservation of genetic diversity of seeds, cultivated plants and animals in the global food system.

Similarly, SDG16 prioritises equity in food systems, which challenges future R&I to engage citizens in food systems and science policy in order to promote responsive, inclusive, participatory and representative decision-making at all levels. SDG10 requires R&I that links improved nutrition outcomes with issues of intergenerational justice, spanning all four FOOD 2030 priorities in order to promote social, economic and political inclusion. Also spanning FOOD 2030 priorities are research projects that emphasise sharing and accessibility, including those addressing urbanisation and capacity for participatory, integrated and sustainable human settlement planning and management. An important aspect of this is the development of sharing economies for food production and consumption that can in turn create local food hubs and resilient infrastructure, supporting economic development and human wellbeing. Food system equity and social justice also points to R&I that prioritises healthy and sustainable African diets as a pathway to inclusivity. In this respect the issue of FNS and the need for R&I is

also linked to the issue of migration, from a European perspective especially in relation to Africa and the Middle East.

Linking concerns about low greenhouse gas emissions transitions with technological and social innovation can help to promote SDG7, which should include research to boost photosynthesis for food and energy to increase crop yields and boost alternative energy production. R&I for climate change should promote biodiversity, focusing in particular on healthy soils by improving management and governance of agricultural land and promoting a more holistic approach to linking primary production and end users. Climate-focused R&I should also concentrate on demonstrating sustainable aquaculture in order to reduce pressure on European fish stocks and promote sustainable management of coastal and marine ecosystems.

Linked with environmental concerns about sustainability are FOOD 2030 priorities that focus on innovation in dealing with waste associated with food systems operations. This includes the SDG12 aim to achieve zero food waste to reduce the sector's environmental footprint, tackling primary production waste streams to improve farm operation (especially in the aquaculture sector) and converting food waste into bio-based products to close nutrient supply circuits and create economic opportunities through value-added products. The FOOD 2030 priority of improving resource efficiency should also focus on R&I that promotes rethinking of food packaging and labelling to reduce household waste through prevention, recycling and reuse.

Finally, SDG3 focuses on good health and wellbeing, which points to several FOOD 2030 priorities, including tackling malnutrition and obesity, alongside the development of future food safety and authenticity systems, which will help to strengthen countries' capacities to reduce and manage health risks.

This overview of challenges for food and nutrition security that follow from the SDGs should not make us forget that the pleasures that citizens derive from the variety and diverse culture of the European food as well as the landscapes that over centuries have been shaped by agriculture. While R&I developments need to address the complex, socio-ecological challenges that face our interconnected food system – food is also about pleasure, conviviality and provenance, and therefore, is contextualized by a rich array of localized food systems that engage with communities in place-specific ways, intimately linked to regional identity. The quality and diversity of our food products is recognised all over the world and this has led to important high-quality export products and related employment. Although the challenges are global, Europe is well positioned to take the lead and guide the world towards a food system that is future proof. In Europe the sense of urgency is combined with a good knowledge infrastructure. The different cultures and variability in climates have resulted in variability in diets and food production systems that ensure that new concepts can be verified in practice on applicability and appreciation.

To safeguard this variety and culture and tackle the challenges in food and nutrition security, R&I calls upon all actors in the food systems (figure 2) and will play a critical role in making our food systems future-proof: more sustainable, resilient, responsible, diverse, competitive and inclusive (EC, 2016):

- Sustainable: with respect to natural resource scarcity and in respect of planetary boundaries;
- Resilient: with respect to being able to adapt to climate and global change, including extreme effects and migration;
- Responsible: with respect to being ethical, transparent and accountable;
- Diverse: with respect to being open to a wide range of technologies, practices, approaches, cultures and business models;

- Competitive: with respect to providing jobs and growth;
- Inclusive: with respect to engaging all food system actors, including civil society, fighting food poverty and providing healthy food for all.

Figure 2 R&I for Food Systems

3 – MISSIONS AS A NEXT STEP

The European Commission intends to base its R&I investments on missions (Mazzucato, 2018). The FOOD 2030 priorities, as summarized above, have therefore to be developed into missions. For this task a group of experts (see Annex 1 for the composition of the group) was installed by DG RTD and charged to develop and assess the impacts of possible R&I missions. The missions will be helpful as policy recommendations to increase R&I investment and R&I impact towards future-proofing our food systems, so that they become environmentally sustainable, resilient, responsible, diverse, inclusive, and competitive. Part 3 of this report presents these missions.

To develop the missions, the Expert Group has reviewed the progress and problems affecting the current European R&I landscape relevant to food systems and FNS and assessed the main drivers and barriers to high-impact R&I. This has been based on evaluations of the 7th Framework Programme and the Horizon2020 work programme. The findings of the Expert Group are reported in Part 1 of this report.

In part 2 the Expert Group focuses on the intervention logic of R&I under a food system approach, providing the evidence base and rationale for a Research, Innovation and Investment Strategy (RI&IS) aligned with FOOD 2030 objectives, as well as overarching EU and International policy objectives (SDG, COP21+, EU priorities, CAP modernisation, etc.).

PART 1. R&I ACHIEVEMENTS TO DATE

It is particularly important to disseminate successful European R&I initiatives to strengthen the science-policy dialogue in the area of FNS and also to demonstrate the potential of new collaborative endeavours that are needed to future-proof our food systems. In this part of the report the Expert Group reviews the progress and problems affecting the current European R&I landscape relevant to food systems and FNS and assesses the main drivers and barriers to high-impact R&I.

In the 7th Framework program the so called Cooperation Theme 2: Food, Agriculture and Fisheries and Biotechnology (Knowledge based Bio-Economy: KBBE) was organised around four axes (food, agriculture, fisheries and aquaculture and biotechnology). The total budget was €1.8 billion with 515 projects (with an annual budget increase of about 46%, in spite of the 2008 reduction in the wake of the global financial crisis). According to the assessment documents of FP7 (EC, 2014a), there are two periods with a distinct research focus. In the first period, the aim of the programme was to link science, technology and stakeholders to foster new research actions targeted to the support of efficient and environmentally-friendly renewable terrestrial and aquatic bio-resources. These actions sought to respond to the environmental, economic and societal challenges related to safe and quality food production, innovation and biotechnology, agriculture, aquaculture and fisheries and protection of the environment. In terms of budget allocation, food diminished its importance across the period, whereas biotechnology, fisheries and aquaculture increased notably. In the second period, from 2011 onwards, the FP7 programmes responded to the then recently launched Europe 2020 strategy, and in particular its flagship initiatives, 'Innovation Union' and 'A resource efficient Europe', which prioritised competitiveness, job creation, sustainable growth and social progress and the translation of research into innovation and market application (EC, 2017i). In the second period, coherence with EU policies was also prioritised (CAP, agriculture, CFP, fisheries, IMP maritime, CAHP Animal Health, KETs, environment protection regulations and resource efficiency and waste etc.) as well as international initiatives (MDGs) (EC, 2017c).

Horizon2020's Societal Challenge 2: Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Research and the Bioeconomy is organised around four call themes: Sustainable Food Security, Bioeconomy and Bio-based innovation, Blue Growth and Rural Renaissance (the latter was launched in the 2016-2017 programme). The budget doubled in the H2020-SC2 programme (relative to FP7) to €3.85 billion, with 49 topics in the first phase and 86 topics in the second, with a clear convergence towards technology (TRL) research and innovation and less focus on fundamental research (funded through H2020 Excellence Science, ERC grants, and Marie Curie Actions) (EC, 2017b, EC, 2017c). Responding to this trend, we can observe that, with regard to the type of participant, the H2020 programme has evolved with respect to the former FP7 by involving a higher proportion of enterprises (including SMEs) to assure knowledge and technology transfer. H2020-SC2 accounts for a higher participation of Private for Profit members when Bio-based Industries (BBI-JU) calls are included (50.3%) with respect to FP7-KBBE (46%), whereas FP7 accounts for a larger proportion of Higher Education Services (HES) (21%) than H2020 (17%) and Research Organisations (REC) (20% and 18% respectively) (EC, 2017g).

Analysis for this chapter focused on past, current and future research priorities in former and on-going EU Framework research programmes is based on two internal evaluation reports of FP7 and H2020 projects, an analysis of the project data of FP7 and H2020, the three relevant H2020 work programmes, a screening of on-going projects under Horizon 2020 related to circularity in the CORDIS database and relevant literature (see tables and figures in Annex 2).

The main R&I achievements to date have been analysed in relation to the **FOOD 2030 four priority areas**, using data for both FP7 and Horizon 2020 programmes.

A - NUTRITION FOR SUSTAINABLE AND HEALTHY DIETS

FP7 Funding and Achievements

The assessment of FP7 reports shows that there have been achievements in the following areas[3]:

Consumers (EU contribution: €40 million/11 projects): Progress has been achieved in understanding consumer behaviour and preferences. Areas of note include research into consumer perception and attitudes towards food and the determinants of food choice and communication strategies for influencing consumers toward more healthy lifestyles. Projects such as Nudge-it have applied an interdisciplinary approach to identify and understand the factors surrounding food choice, resulting in evidence-based solutions. EU Public Health policies advocate the achievement of healthier diets through population reductions in fat, trans-fat, sugar and salt intake; R&I funded through FP programmes has been instrumental in developing the evidence base to support these policies. Projects such as EATWELL have provided rigorous evaluations of healthy eating policies to create the evidence base for the development of policies such as the WHO European Food and Nutrition Action Plan (2015-2020). For example, EATWELL demonstrated that, at the EU level, voluntary reformulation has worked well with respect to reduction in trans-fat and salt. Many R&I projects such as EATWELL have been instrumental in providing recommendations on advertising controls, importance of nutrition labelling and the potential of school food provision - all of which now appear in the WHO's Action plan for Europe[4]. It is also noteworthy that many FP7 Nutrition projects dealt with consumer perceptions and beliefs surrounding food and nutrition and food products.

Nutrition (EU contribution: €142 million/25 projects): In FP7 significant work was undertaken to establish what are key beneficial dietary factors: specific reformulation studies were performed and tested in humans. Additionally, population work was performed to understand the impact of certain dietary components on disease risk. Projects investigating the development and applications of nutrigenomics also featured and now the majority of nutrition studies are employing such tools and the potential of biomarkers in nutrition and health is being realised. Understanding of food allergens was progressed through projects such as IFAAM and EFRAIM. Significant advancement in the knowledge of the interaction between diet and health/disease emerged from fundamental work performed in FP7 projects. For example, the HEALTHGRAIN project demonstrated the role of wholegrain and high fibre cereal diets in reducing the risk of chronic diseases such as Type 2 diabetes and cardiovascular disease. These and other FP7 projects form the basis for the development of reformulation of foods and provide an evidence base for health claims. Initial projects in the field of Personalised Nutrition revealed immense potential in this field and further work is needed to capitalise on the initial success (for example, Food4me). FP7 projects have been instrumental at providing scientific evidence for the development of dietary reference values for nutrients across Europe by the European Food Safety Authority (EFSA) – examples of such projects include ODIN. Furthermore, projects such as FoodRISC and FACET have been important for the development of strategies for communication of food risk and assessment of risk exposure respectively.

[3] See: An ex-post evaluation of the rationale, implementation and impacts of EU Seventh Framework Programme (2007-2013), Brussels, DG RTD, 2015.
[4] http://www.euro.who.int/en/health-topics/disease-prevention/nutrition/nutrition

The Networks of Excellence (funded through FP6) have had significant impact on the nutrition research field. Two examples of networks that still exist include NuGO and EuroFIR. Since cessation of funding in 2009, NuGO has grown and is now the leading organisation for Nutrigenomics. This network of researchers has been key to developing and implementing concepts such as Personalised Nutrition and to driving innovation in the nutrition community. EuroFIR has been instrumental in the harmonisation of food composition databases. The existence of such active networks 8 years after finalisation of the original EU projects is undoubtedly evidence of significant impact of the original funding.

Food processing (EU contribution: €123 million/35 projects): The focus has been on development of technologies to improve functionality, quality and nutritional value. This included more technical projects that focused on the development and demonstration of eco-efficient processing and packaging systems, smart control applications and more efficient valorisation and management of by-products, wastes, water and energy. Additionally, there were projects clearly focusing on health and nutrition and covering aspects like personalised nutrition and health value foods (3 projects), solutions to reduce contaminants, sulphites, salt, fat and sugar and improve satiety (4 projects) and development of functional foods and ingredients, including proteins from insects. Investments have also been made in a concerted action to enhance co-operation in food and health. The primary user of scientific results in the food processing area is the food industry, including Small and Medium Sized Enterprises (SMEs). In projects dealing with novel processing technologies, contaminants or reduction of salt, sugar or fat, the results are also relevant to regulators and policy makers and have had a significant impact on supporting the development of early career scientists.

Projects results in this area have often been patented or further developed in follow-up projects. For example, CONFFIDENCE was granted two patents for analytical tools to detect contaminants in foods, and commercial exploitation is already taking place. Another example is the continuous investments in research on High Pressure Processing, which may be associated with the start-up of new companies and the expansion of existing ones (e.g., Hiperbaric, TOP b.v, Ypsicon), new products in the market (e.g., fresh juices, tapas, duck liver, sliced ham), and new equipment (e.g., 0 to 400 machines, see Figure 1 in Annex 2). Projects in this area clearly allow the strategic development of European knowhow in emerging technological areas. Other examples are pick and place food packaging automation (PICKNPACK project), 3D printing of personalised foods (PERFORMANCE), customisable, eco-efficient, biodegradable packaging solutions (ECOBIOCAP), new technologies for more efficient energy usage and food storage (FRISBEE) and sustainable novel food processing technologies like CO2 drying (PRESERF).

In conclusion, the investment of only 7% of FP7 KBEE EU funds to food processing research (KBBE programme) increased the competence base of Europe, developed new companies, provided skilled resources and generated patents and market opportunities exploited by food industry, including SMEs. The economic effects are not easy to quantify with the metrics available, but time to the market may be 5-15 years -- depending on the technical and commercial bottlenecks.

Food quality and safety (EU contribution: €98 million/24 projects): Investments have focused on improving chemical and microbiological safety and improving food quality along the food chain. Human health safety aspects covered include: prions, perfluorinated compounds, biocides and antibiotic resistance, nano-particles, pesticides, effect of processing on food contaminants, seafood contaminants and parasites and food allergies. Tools for risk assessment and management of allergies and Genetically Modified Organisms (GMOs) have been supported. A Pan-European Total Diet Study has also been financed to research real dietary exposure to food contaminants consumption (heavy metals, mycotoxins, POPs) and estimate chronic exposure to pesticide residues in food and food additives intake.

The primary users of scientific results are regulators and policy makers or other public agencies. A large number of third country participation was involved in projects concerning food safety of produce, cereals, aquaculture or other products exported to the EU from third countries.

A large proportion of research did not expect to lead directly to innovation but was precompetitive or focused on providing a base for policy making to protect public health. Thus, the results provided data and databases to evaluate the risks associated with both chemical and microbial contamination of foods and scientific evidence of prevalence, in addition to improved detection methods, as well as software and analytical tools. The societal impact is the direct or indirect contribution to food safety or quality, which also has an economic impact on a range of stakeholders from the producer to the consumer. Social innovation results often in processes that support public awareness through dissemination and labelling.

A number of EU projects have provided inputs into EFSA scientific opinions (e.g., ASFRISK, CALLISTO). In addition to the scientific publications, the projects provided skills and resources for contribution to EFSA expert panels or working groups. Training of researchers and students in relevant analytical tools is another clear output of these projects.

H2020 Funding and Achievements

In H2020, there has been a dearth of projects in the nutrition field that deal with the examination of links between nutrition and health/disease or perform mechanistic studies or public health nutrition interventions – all of which are imperative to the development of a healthier Europe (see Figure 2 in Annex 2). An examination of funded projects (greater than €2m) revealed that the majority of projects were in the Food Safety area and SMEs or MSCA individual fellowships (see Figure 3 in Annex 2).

Other funding mechanisms such as the JPI-Healthy Diet Healthy Life (JPI-HDHL) should not be considered as an alternative source – indeed, they have only been able to fund very focused areas of the Food and Nutrition area. Furthermore, the concept behind the JPI-HDHL is that it addresses such an important societal challenge that it needs investment from both the EC and national funding agencies. Unfortunately, the reduction in funding during H2020 for Nutrition and Health projects will limit Europe's ability to reach SDGs 2 (Zero Hunger) and 3 (Good Health and Well-Being). Furthermore, of the 6 WHO regions, Europe is the one most severely affected by Non Communicable Diseases (NCDs), which, in turn, are the leading cause of death. Key risk factors for NCDs include being overweight/obese and a poor quality diet. With these facts in mind, it is imperative that future R&I focus on reducing obesity, promotion of healthier diets and understanding the optimal intervention strategies to reduce NCDs. Given the emergence of the importance of the microbiome, the JPI-HDHL has funded this area well, with two recent calls and a further one planned – a joint action call (€6.4m over 6 projects) and ERA-net co-fund call (€9.5m for 11 projects). Further coordination at an international level will be important for this field.

The Food Systems Africa topic in Work Programme 2019 (€21m for 3 projects) is part of the EU-African Union R&I Partnership on Food and Nutrition Security and Sustainable Agriculture.

In the Work Programme 2014-2015, one sub-area within "Sustainable Food Security" is "Safe Food and Healthy Diets" that is tackled through four RIAs, one CSA and one IA to address food safety, sustainable and competitive food production. Investments on development of food processing technologies have been limited to activities within BBI (focus on food side streams/waste), ERA-net SUSFOOD (sustainable technologies) or a few IAs aiming to apply knowledge built in previous research. ERA-net SUSFOOD is a successful initiative with a clear focus but its dependence on national funding limits the European impact of these projects. Nevertheless, success stories have been identified (for example, within the IA project HIPSTER, which focused on scaled-up development

and full implementation of High Hydrostatic Pressure in combination with Temperature (HPT) to extend the shelf life of foods while preserving the sensory properties). This project may not have been possible without previous projects in FP5 and FP6 on development of High Pressure processing (e.g., FAIR CT96-1175, FAIR CT96-1175; FP6_ NOVELQ).

B - CLIMATE-SMART AND ENVIRONMENTALLY SUSTAINABLE FOOD SYSTEMS

Within the FOOD 2030 priorities, climate and sustainability has been subject to very clear prioritisation and targeting over previous framework programmes, particularly SC2 of H2020. Climate and sustainability related projects (including e.g. Climefish and CERES for fisheries and aquaculture) have achieved notable successes, performing well in terms of addressing relevant challenges, delivering key outputs (scientific publications, innovative products/value chains) and building internal and external coherence (EC, 2014a; EC, 2017c; EC, 2017i). However, the most notable success may have been to evolve the intervention logic between and within programming periods (see below).

FP7 Funding and Achievements

Climate and Sustainability targeted research under FP7 is a cross-cutting issue in the overall FP7 programme; therefore, it relates to specific thematic areas, calls and projects across the entire programme. From the 'Project Funding in FP7 KBBE thematic areas these have been selected from the call themes and from the projects' database and add to a total budget of €773 million (42% of total budget of the FAFB programme, which was €1,837 million), with 246 projects (48% of total 515 in the PF7 KBBE programme) across the following thematic areas (EC, 2014a; EC, 2014b):

Agriculture (EU contribution: €347 million/125 projects)[5]: This area has been primarily focused on farming practices and business -- although there has been progress in research related to innovation and market applications as well as in international research. Even if the scale of research is mainly individual, technologies or shifting practices at the level of the plot/farm (e.g., genomics and plant breeding for the control of pests), socio-economic and policy research under this heading has increasingly linked these technologies to the sustainable management of terrestrial resources involving stakeholder engagement (EC, 2014a). Some projects (AGRIPOLICY, ERA-Net RURAGRI) have adopted a broad geographical scope and focused on supporting policy-making, creating networks and building coordinated research agendas in support of rural development. Others have focused on linking sustainable production systems to local industries and stakeholder involvement across a territory (e.g., greenhouse cultivation systems under EUPHOROS). The FACCE-ERANET plus on Food Security, Agriculture, Climate Change adaptation is an example of building research synergies and boosting cooperation with national research programmes through inputs to the research agenda of the analogous Joint Programming Initiative (FACCE–JPI). Within the international dimension of the programme, several projects have focused on the socio-economic and environmental effects of improved practices and innovations for the sustainable use of natural resources in climate change hotspots -- e.g., the Mediterranean and MENA regions, Africa (AQUAMED, SIRRIMED, SUSTAINMED, EAU4FOOD). In all cases, community networking has proven to be essential for addressing climate and sustainability goals in the remit of international development (EC, 2017g).

[5]Increased sustainability of all production systems. (KBBE 1-2: FP 7 contribution €224 million/59 projects). We include here socio-economic research and support to policies (KBBE 1-4: FP 7 contribution € 123 million/66 projects). The areas under the agriculture heading are not clearly defined research guidelines, especially the 'increased sustainability area' that covers thematic issues scattered across all FP7 KBBE themes, like sustainable development in the agriculture and forestry sectors. Likewise, sustainable production includes a full array of agricultural sciences, such as technology systems, monitoring, plant and soil protection, sustainable low input farming, forestry and ecosystem sciences for the provision of public goods.

Fisheries and aquaculture (EU contribution: €165 million/46 projects)[6]: Responding to productivity, environmental and socio-economic goals, a significant body of research under this heading has focused on addressing aquatic ecosystems through holistic, bottom-up and policy-oriented approaches. Major projects working across multiple member states and fisheries have developed, monitoring toolboxes for supporting the application of EU policies[7] in the marine environment (MARIABOX), evaluating fish management systems using multidisciplinary GIS tools with respect to the requirements of the Common Fisheries Policy (CFP) in various regions (ECOFISHMAN), and developing a multi-stakeholder operational dialogue framework for supporting technological innovation along the chain, participatory governance and aquaculture research and innovation in relation to fish management systems (AQUAINNOVA). Combining top-down management strategies with bottom-up co-management and multi-stakeholder participation, as required by the CFP, these projects reflect evolving trends in maritime research for sustainability (EC, 2017c; EC, 2017g).

Biotechnology (EU contribution: €251 million/62 projects)[8]: This research area experienced a notable evolution away from biomass sources towards industrial projects and product development. Sustainability concerns have resulted in environmentally-proofed products and processes, marketable biotechnology products and projects supporting related policies along the novel bioeconomy value chain, including toolkits for bio-based economy transitions, focused on systems analysis (SAT-BBE) and the development of regional bioeconomy potential (BERST[9]) (EC, 2017c; EC, 2017g).

H2020 Funding and Achievements

Climate and Sustainability have been addressed across various R&I programmes of H2020, accounting so far for 239 projects with a total budget of €459 million, of which 133 (55.6%) fall under SC2 (EC, 2017f). Climate and Sustainability projects are distributed in the two programmes: H2020 2014-15 (total contribution €482 million, 3 call themes, 49 topics) and H2020 2016-17 (total contribution €757 million, 4 call themes, 86 topics), the latter accounting for a larger variety of topics, calls and consequently a more scattered budget distribution (EC, 2015b; EC, 2017i; EC, 2017d; EC, 2017c). These are:

Sustainable Food Security (total EU contribution: €721.5 million)[10]: 'Resilient and resource-efficient value chains' is the largest area in terms of budget allocation and projects. It aims at securing high quality, sustainable, resource-efficient production, low-greenhouse gas emissions supply chains, fostering biodiversity and related ecosystem services and takes into account stakeholder-based and socially inclusive participation and policy support actions (EC, 2017c; EC, 2017h). Several projects have developed this

[6]Increased sustainability of all production systems. (KBBE 1-2: FP 7 contribution €99 million/27 projects). We include here socio-economic research and support to policies (KBBE 1-4: FP 7 contribution €20 million/12 projects). The ocean of tomorrow (KBBE 1-5: FP 7 contribution €46 million/7 projects).

[7]For example the Water Framework Directive (2000/60/EC) and the Marine Strategy Directive

[8]Increased sustainability of all production systems. (KBBE 1-2: FP 7 contribution €3 million/1 project). Marine and fresh-water biotechnology (blue biotechnology (KBBE 3-2: FP7 contribution €126 million/29 projects). Industrial biotechnology novel bioproducts (KBBE 3-3: FP 7 contribution €61 million/16 projects) Environmental biotechnology (KBBE 3-5: FP7 contribution €115 million/28 projects).

[9]The project has proven to be a key reference project for the EU Bioeconomy strategy in Europe and for the EU Bioeconomy Observatory.

[10] SFS: H2020 2014-15 contribution €251.5 million (52%); H2020 2016-17 contribution €461 million (61%).

integrated, multi-scalar, multi-actor approach. The FATIMA project developed integrated agri-environmental management for water and energy in cropping systems, from farm-level irrigation schemes to river basins in 8 different EU and non-EU countries. The DIVERSify project has brought together a consortium of different types of stakeholders (scientists, farmers, advisors, breeders and SMEs) to develop tools for assessing the benefits of cropping and environment interactions, providing an example of collaborative actions and experiments for developing diverse, sustainable and resilient cropping management decisions using a co-innovation and knowledge exchange approach. Other projects have developed transition pathways in cropping patterns, focusing in particular on shifting to protein-rich legume production systems through multi-actor approaches, case studies and evidence-based policy advice (TRUE-VERDADERO) and developing innovative technical solutions through stakeholder involvement across the entire production chain (PROTEIN2FOOD). Under this call, territorial multi-scale, multi-stakeholder approaches have also been applied to aquaculture development (AQUASPACE) and assessing the environmental and socioeconomic impact of the aquaculture industry (TAPAS) (EC, 2017e; EC, 2017f).

Blue Growth (total EU contribution: €274 million)[11]: 'Unlocking the potential of Seas and Ocean'/ 'Demonstrating an ocean of opportunities' are cross-cutting focus areas for marine and maritime research on technologies for market applications, one of the key drivers of H2020 (EC, 2017c; EC, 2017i). Projects have covered Arctic research and international region-specific research (e.g., the Mediterranean BLUEMED), while focusing on climate change and developing tools to project regional impacts on fish populations under a range of socio-economic and policy scenarios (CERES). Strategies are scaled-up to define drivers of change and adaptation measures in close cooperation with the industrial sectors and relevant stakeholders to anticipate risks, barriers to adaptation and potential responses to assist fish and aquaculture production industries and policy makers (EC, 2017c; EC, 2017f).

Innovative Sustainable and Inclusive Bioeconomy/ Biobased Innovation for Sustainable Goods and Services (total EU contribution: €125 million)[12]: This call is focused on the development of bio-based industries and sustainable bio-productions, with technological and social innovations and strong involvement of stakeholders along the entire value chain (EC, 2017c). Within a broad transnational vision, FACCE SURPLUS is an ERA-NET-Cofund to support different food and non-food biomass production systems and transformations for sustainable and resilient agriculture. It is framed into the FACCE-JPI and its Strategic Research Agenda (SRA) for enhancing cooperation and alignment of the national research programmes in the field of sustainable agriculture and resilient production systems. The project DIABOLO is a larger scale project that develops a Europe-wide monitoring platform in the context of international initiatives (UNFCC, UNFF) for supporting European forest policies and for a variety of international end-users (FAO, JRC, IIASA) (EC, 2017f).

Rural Renaissance (total EU contribution €127 million)[13]: Fostering innovation and business opportunities is a new thematic call, launched in the last programme (2016-2017), that paves the way for supporting the integration of applied science, climate actions and socio-environmental sustainability and policymaking -- an essential objective in the FOOD 2030 'Climate and Sustainability' priority (EC, 2017d; EC, 2017c). For example, the CERERE project is based on dynamic interactions between science and

[11] This figure represents the total funding for the two periods: BG: H2020 2014-15 contribution €144 million (30%); H2020 2016-17 contribution €130 million (17%).

[12] This figure represents the total funding for the two periods: each under a different name and acronym: ISIB: H2020 2014-15 contribution €86.5 million (18%); BB: H2020 2016-17 contribution €38.5 million (5%).

[13] RUR: H2020 2016-17 contribution € 127 million (17%).

practice, addressing sustainability problems encountered in the agri-food sector by supporting non-conventional, decentralised and local solutions. This includes innovations to improve the sustainability of cereal production systems (e.g., rotations, use of germplasm, soil fertility) via a multi-stakeholder network, collaborating with EIP-Agri along the production and processing systems. Similarly, the AFINET project studies the interactions of forest, crop and animal productions by creating a novel platform of regionally-based and multi-stakeholder Agroforesty Innovations Networks across several European regions with varied agro-climatic conditions (EC, 2017f).

Bio-based Industries Joint Undertaking (BBI-JU) (EU contribution: €445.5 million)[14]: BBI-JU is a separate programme within H2020-SC2, which amounts for a considerable share of the SC2 budget (€ 800 million, about 21% of the total SC2 budget) (EC, 2017f). The programme's objective is to develop a Joint Technology Initiative to foster investments and sustainable development of the bio-based industry in Europe. It supports the development of new technologies, materials and consumer products of fossil-replacement biomass and new business models that integrate all actors along the entire value chain (EC, 2017c).

SME Instrument (SMEInst): The SME Instrument funds high-potential innovation developed by SMEs. The SME instrument offers entrepreneurs support for breakthrough ideas with the potential to create entirely new markets or revolutionise existing ones. These projects have substantially lower funding, but comprise a large number of projects focused on resource-efficient production systems, biodiversity conservation and the delivery of ecosystem services (EC, 2017c; EC, 2017f). WATER4FOOD provides local-scale sustainable solutions to mounting water scarcity in Europe's island Mediterranean countries (aggravated by climate change) by developing small-scale desalination plants. In a wider perspective, the SCALING UP NOVIHUM project has developed an innovative technology to reduce soil erosion using brown coal to produce environmental benefits to degraded soils (EC, 2017f).

Conclusions

The FP7-KBBE assessment concluded that policy coordination had to be strengthened across sectors (e.g., agriculture, energy, transport, etc.), to support linking research, innovation and education programmes via specific strategic programmes (EC, 2014d; EC, 2014c). In the following H2020-SC2 programme emphasis was also placed on the **integration of research** across thematic areas (such as Climate and Sustainability research themes present in the SC2 programme), together with a relatively lesser focus of fundamental research with respect to FP7-KBBE (as other research initiatives take the lead, such as ERC) (EC, 2017f; EC, 2017g). In particular, **marine research** has achieved notable levels of integration across different areas and projects that reflect the tendency to focus on multi-species, locally-based ecosystem-level challenges and solutions – underlining the value and potential for adopting territorial approaches in overall agricultural research. With 106 academic papers (including in high-impact journals), the LIFECYCLE project – researching the early development, growth and environmental adaptation of a range of fish species – is considered one of the most impressive success stories (EC, 2017c).

External coherence of SC2 with other EU policies has also been reinforced, particularly with the Common Agricultural Policy (CAP), as well as Fisheries, Maritime and Climate policies. This has been achieved through different mechanisms, all with a high leverage potential for sustainability: i) agricultural research in H2020 is shared between DG RTD and DG Agriculture; ii) the second pillar of the CAP includes a commitment to foster knowledge transfer and innovation in agriculture, forestry and rural areas; iii) the

[14] H2020-BBI JU 2014, contribution €51.5 million, one call, 16 topics; H2020- BBI JU 2015 contribution €206 million, two calls, 10 topics; H2020 BBI JU 2016 contribution €188 million, one call, 27 topics).

European Innovation Partnership for 'Agricultural Productivity and Sustainability' (EIP Agri) seeks to pool different funding streams (under CAP and H2020) to support bottom-up innovation linked with coherent delivery. SC2 activities, however, show little or no synergy with some other policies (employment, environment, energy), which may reflect the limited scope of EU-level policies in areas like employment (EC, 2017c) and imply that some missed synergies cannot be addressed by realigning research priorities alone. Looking at the **internal coherence** of SC2 with other societal challenges in H2020, links are strong with regards to the technology-related challenges (SC3-energy, SC4-transport and SC5-environment), but less so in relation to socially-focused innovation areas (SC6-inclusive societies) (EC, 2017c) evidencing the need to strengthen more integrated socially-based research. Most significantly, new forms of research - more territorial, more integrated, more policy-focused - have established a strong foothold. Building on the second phase of FP7 and its cross-cutting 'The Oceans of Tomorrow' initiative, H2020-SC2 gave a major impulse to cross-sectoral research for marine and maritime challenges by launching the new 'Blue Growth' focus area (see above). Emphasis was also placed on investment in developing sustainable bio-based industries in Europe, throughout the new programme BBE-JU which focusses on integrated value chains as compared to more fragmented vision of the former FP7-KBBE Industrial and environmental biotechnology programmes. This initiative has proven to be successful for reinforcing the links between research agencies and the bio-based industrial sector as well as for building a stronger network throughout bio-based industries in Europe (EC, 2017h; EC, 2015a). Alongside, international cooperation is present across the entire H2020-SC2 programme related to Climate and Sustainability projects within strategic calls (e.g., the BLUEMED initiative for the Mediterranean region). Agricultural research is shared between DG RTD and DG AGRI and is geared toward supporting knowledge transfer and innovation in agriculture, forestry and rural areas. It is linked to the recent reform of the CAP and follows a multi-actor approach, integrated farm value-chain, private sector investments and the support of the European Innovation Partnership on 'Agricultural Productivity and Sustainability' (EIP Agri) (EC, 2017c; EC, 2017h). Overall, these new initiatives have created a strong basis for responding to the Climate and Sustainability priority of FOOD 2030.

In particular, research aligned with the **territorial, landscape/ecosystem-level and governance-based nature** of the climate and sustainability challenge is gaining prominence, particularly in the 2016-2017 work programme of SC2 (e.g., the Rural Renaissance call, links with FACCE JPI and EIP Agri) (EC, 2017d; EC, 2017c). **Involvement of all food supply chain stakeholders** has also been reinforced all along FP7 and H2020, as well as increased **dialogue with society** in general (increasing levels of open innovation practices, stakeholder conferences organised by DG RTD on Bioeconomy (EC, 2017h) or FOOD 2030, involvement of SMEs and Industries in Research (EC, 2016; EC, 2017d), even if some barriers still need to be overcome). These two shifts constitute a good basis on which FOOD 2030 could build to enable a larger stream of food system-scale climate and sustainability research in the future.

C - CIRCULAR AND RESOURCE-EFFICIENT FOOD SYSTEMS

This section addresses the circularity and resource efficiency of food systems, with a focus on R&I along the food chain (for example, food processing, food packaging and waste reduction). Circularity and resource efficiency at the level of farms, fisheries and aquaculture are covered under the theme *Climate and Environmental Sustainability*. There is a strong overlap between the priorities of Climate & Sustainability on the one hand and Circularity and Resource-efficiency on the other hand, making classification of projects difficult. Additionally, a considerable number of projects and budgets that could be classified under *Circularity and Resource Efficiency* were related to the wider bioeconomy (including biofuels and other non-food applications of agricultural products) and not to food; these projects were excluded from this analysis.

FP7 Funding and Achievements

One of the main themes of the FP7 (2007-2013) was the management and protection of biological resources to secure food and non-food economies. In total, €411 million (EU contribution) was spent on 'food' related issues (ranging from nutrition to climate), whereas around €110 million (EU contribution) was spent on the non-food bioeconomy. There was a strong financial contribution for the development of more sustainable and competitive primary production and the emerging bio-based technology industries. In the food sector, there was a strong focus on health and functional food.

The EU internal evaluation report of FP7 projects mentions a number of positive achievements relevant for the circular economy and resource-efficiency (EU Com, 2014a). This includes, for example, "improvements in biological resource-use efficiency lead to net gains that flow through the supply chains, ultimately leading to lower food prices, improvement in the trade balance, or opportunities to use biological resources in other ways such as ecosystem protection or the expansion of the bio-based sector" (EU Com, 2014a, page 87). However, at the time, the focus was on using biotechnology to serve emerging bio-based industries and on food processing, while food waste and circular economy issues were covered less overall. Below is a summary of some of the focus areas and achievements of projects relevant for Circular Economy and Food Waste.

Food processing, food packaging and labeling (EU FP7 contribution: €49 million/17 projects): These projects aimed at process optimisation, improving product quality and exchange of knowledge, especially for SMEs. Almost all projects involved the food industry as a direct user. Only one relatively small project (COMPETE) listed policy as a main user. For example, the largest project (PicknPack, €8 million) aimed at cost reduction, greater hygiene and more efficient use of resources by improved packaging technology. Most projects were aiming at improving the competitiveness of the food sector. Two projects (TRADEIT and TRAFOON) were aiming at traditional foods as well as traditional processing techniques that are applied by SMEs, thus adding to the diversity and inclusiveness of the food sector. Few projects directly addressed circularity and improving resource efficiency.

Food waste (EU FP7 contribution: €1 million/1 project): FUSIONS (CSA) was the only funded project on food waste. It estimated food waste in the EU, developed a common food waste policy framework and analysed the feasibility of social innovative measures for optimised food use. It helped to formulate future research issues for the H2020 programme.

H2020 Funding and Achievements

The Horizon 2020 programme aims to address stronger societal challenges compared with FP7. The in-depth interim evaluation of H2020 projects (EU Com, 2017a) concluded that 67.7% of the projects have a specific impact related to more efficient use of raw materials and reduction of waste. 51% of the projects are expected to have an impact on 'Climate action, environment, resource efficiency and raw materials' and 41.9% on 'Food waste and eating well'.

When analysing the current on-going projects under H2020 in the CORDIS database, around 50 on-going projects were identified (of quite different types, also for SMEs) which can be related to "Circularity" (or Circular Economy). Of these, 14 projects (period 2014-17) are dealing with food waste and 22 more generally with biogenic waste. Analysis of the distribution of the budget for medium and larger projects linked to circularity shows that a significant part of the money goes to industry-oriented projects (32%) and to food waste and other biogenic waste projects. Only a small share of funding goes to projects with a territorial focus on cities or a specific rural area. More details can be found in Figure 7 in Annex 2. Of these projects related to circularity, only a few focus on the farm level or on fishery/aquaculture.

When looking at other H2020 projects in the CORDIS database, which have been categorised as "Climate and Sustainability" or "Innovation" focused, the number of projects with a strong focus on agricultural production is much higher. Many of these agricultural projects are partly contributing directly or indirectly to better resource efficiency. The same can be said regarding fish and aquaculture projects, which are mostly categorised as "Climate and Sustainability" projects and are not listed under "Circularity" projects; several might also have an impact on resource-efficiency (in particular, water use in Recircular Aquaculture Systems). Below is a summary of some focus areas and achievements of projects funded under H2020.

Food processing, food packaging and labeling (EU H2020 contribution: €7 million/4 projects >€1 million): In H2020, much less has been spent on food processing and food packaging -- only about €7 million. There was a clear shift in attention towards the reduction of food waste and losses, waste valorisation, wastewater treatment and cleaning,

Food Waste (EU H2020 contribution €38 million/10 projects >€1 million): A number of projects with ca. 10 medium and larger projects with more than €38 million were funded until 2017 within H2010 with a clear focus on food waste. The REFRESH project aimed to develop a "Framework for Action model" based on strategic agreements across all stages of the supply chain and to develop a consumer food waste behavioral model as well as a compositional waste database. However, challenges remain to collect sufficient reliable data to calculate food waste and to develop new transformational business models.

Projects with a socio-economic focus have explored household practices in Nordic countries (FOODWASTE), the potential of food sharing initiatives (SHARECITY) and tackling food waste through the collaborative power of ICT networks (SAVING FOOD). Several projects focus on the valorisation of specific food waste sources through specific processing techniques. For example, the AgriMax project is concerned with agricultural and food waste valorisation based on flexible multi-feedstock biorefinery processing technologies for new high added value applications. Other projects focus on revalorisation of by-products of the food processing industry into high-value functional proteins and other food ingredients (e.g., use of whey in SYBAWHEY and WHEY2VALUE; vegetable by-products in GreenProtein project).

The project AgroCycle focuses on the use of agricultural waste, co- and by-products both inside and outside the agriculture sector, leading to the realisation of a circular economy. One difficulty facing these kinds of projects is the lack of more integrated Life Cycle Assessment (LCA) systems (e.g., social LCA and Life Cycle Costing methods), which better address social and economic issues of multiple uses of agricultural products and by-products.

Projects on circularity and resource-efficiency (other than food waste): Under H2020 there are three projects that deal with the role of cities in waste reduction and valorisation. This includes decentralised management schemes for urban biowaste in DECISIVE and RES URBIS projects, resource management in peri-urban areas in REPAIR and cooperating for circular economy in FORCE project. A few projects deal with improved waste water management with a technological focus (e.g. INCOVER, LT-AD, MADFORWATER). Another growth area was the use of algae for food, energy and in the chemical industry (INTERCOME).

Conclusions

The projects analysed showed that there is still huge potential for food industry projects to **use waste streams** from the food and beverage industry sectors to produce added value bio-based products: food supplements, feed, sustainable nutrients for agriculture, bio-based chemicals, bio-polymers, bio-based food packaging, etc.

The important role of **social innovation** when dealing with food waste has been documented and should be prioritised in future projects. This will require a more systemic approach to solve problems and find practical solutions, which often are multisectoral (e.g., multiple uses for food, feed, energy). For the development of new products or by-products it is important to have **close cooperation with the industry**, while also taking the demand side into account. More socio-economic research should be integrated in technologically-oriented projects, for example regarding consumer acceptability of new by-products, and the creation of incentives and governance frameworks.

D - FOOD SYSTEMS INNOVATION AND EMPOWERMENT OF COMMUNITIES

FP7 Funding and Achievements

Scientific and technological innovations in the food production chains were mainly addressed through projects funded in the context of *Theme 2: Food, Agriculture, Fisheries and Biotechnology* (FAFB) of the FP7 programme, whereas social innovation and the challenge of resilient communities were the core of the theme *Social Sciences and Humanities* (SSH).

Food, agriculture, fisheries and biotechnology (FAFB) (EU FP7 contribution: €721 million): The FAFB programme (Theme 2 of FP7) set out to support Europe in a global economy while protecting our environment and social model. FAFB work programmes are indicative of the evolution of the R&I subjects and approach as FP7 progressed. With respect to agriculture and food production research, there was an emphasis on agricultural research, and the topics covered in the calls ranged from food originating from wild catch (fisheries) and primary production activities (aquaculture and terrestrial farming systems) to key target areas of technical innovations and safety in the food value chains. As the programme progressed, there was increasing emphasis on the participation of SMEs (which was made mandatory in many topics), linked to a drive from the EC to support innovation. Additionally, in the second half of FP7 the theme "The Ocean of Tomorrow" was introduced and paved the way to the Blue Growth theme in H2020.

FAFB of FP7 catered for the different food-producing communities shaping distinct priorities. The food industry was ranked first for R&I investments of €300 million. The food and drink processing industry of the EU employ 4.2 million people with an annual turnover of more than €1.05 billion (1.8 % of the annual value added of the EU). Despite the presence of large multinational companies, the food supply chain of the EU is characterised by the presence of more than 280,000 SMEs in food production and food processing. However, the food industry shows a low R&I intensity, with annual investments of 0.2% of the industry's turnover (FoodDrink Europe, 2017).

Research projects targeting farmers (in the sense of all persons who cultivate plants and keep livestock, including fish) were supported with €241 million. Other relevant primary users were the plant and animal breeding industry and fishermen, who received funding for €177 and €3 million respectively (EC, 2017i). Primary production activities take place in rural or semi-rural areas represent about 88% of EU territory and account for 46% of the Gross Value Added and 55% of jobs, resulting in a market worth €40 billion and 90,000 new jobs. These communities, besides carrying out the primary food production, live outside cities and exhibit different consumption patterns from city dwellers. Moreover, they rely heavily on ecosystem functioning and natural resource management to secure production. Their activities are governed by the CFP and the CAP. As a result, the policy community was the largest group of direct users in terms of FP7 funding with €481 million, or 27% of total expenditure (EC, 2017i).

Besides, the mainstream research themes, KBBE also included projects that addressed forward-looking issues as the sustainable modes of urban and peri-urban food

provisioning (SUPURBFOOD) and ways to valorize food waste to produce low cost feed of suitable nutritional properties (NOSHAN).

Social Sciences and Humanities (SSH), innovation and participatory approaches (EU contribution: €94 million): The SSH work programme sought to build a better understanding of the key dynamics of change. This includes multiple geographic levels: the economic, social and political conditions for satisfying the world food needs (FOODSECURE), the adjustment process in rural areas in the light of the reformed CAP (CAP-IRE) and participatory approaches to urban planning and management (CHANGE2SUSTAIN). It also addressed different types of actors: from the obstacles and prospects for sustainable lifestyles and green economy in Europe (GLAMURS), changes in consumption and consumer markets and consumer behavior, the importance of social entrepreneurship for innovative and inclusive societies (EFESEIIS), and the role of multinational companies in addressing global development challenges (GLOBINN).

By 2013, Activity 8.2 of the SSH work programme was set to define the objectives and factors for an effective transition to a more sustainable society, underlining the important role of the private sector through the development of new technologies but also through responsible business practices that support local development.

Framework Programme 7 made great efforts to foster innovation activities in the agri-food value chains, putting a great emphasis on sustainability, which represents one of the key dimensions of any Responsible Research and Innovation (RRI) process (Stilgoe et al., 2013). RRI is the driving framework of R&I EU-wide since 2014 and, as a concept, rests on the idea of sharing responsibility across all actors implicated in the R&I process (citizens, researchers, industries, policy makers and educators).

In addition, the EU has supported networking activities, the function of stakeholders' platforms such as the European Technology Platform Food for Life, TP Organics, the European Aquaculture Technology and Innovation Platform and Animal Task Force and the European Innovation Partnership for agricultural productivity and sustainability (EIP-AGRI) in order to promote new structures of interaction and new multipliers of knowledge and innovation. EIP-AGRI promotes innovation by organising actors into groups and thematic networks that share information to foster competitive and sustainable farming and forestry that "achieves more and better from less" (EC, 2015c).

Developing new solutions to pressing community needs, such as the 'Zero Hunger' and 'Good Health and Wellbeing' SDGs, and promoting transitions to responsible food production and consumption asks integral to empowering and engaging producers and consumers. However, the impact of former Framework Programmes on establishing the notion of a systemic approach and promoting food system innovation is generally considered to be low, due to the lack of holistic approaches and social innovation to create bridges between actors.

Social innovation applies to many fields, including environmental and nutritional education of new generations (school gardens, pedagogical practices, etc.), environmental safeguarding (biodiversity, landscape, renewable energies, etc.), participatory governance experiences (food planning, common goods management, urban-rural solutions, etc.), social justice (food access, social farming, critical consumption, poverty reduction, etc.), urban planning (community gardens, farmers' markets, etc.). Additionally, social innovation plays a key role in facilitating and strengthening rural, coastal and urban communities' ability to achieve food and nutrition security (AiCARE 2015). However, changing views and discourses is a long process, in particular for traditional communities such as fishermen, and might require a significant effort to change practices that support policy reforms.

The EU R&I frameworks have made significant investments in social innovation projects (TEPSIE, SI Drive, SINGDOM) to identify and implement solutions that are economically sustainable, encourage social change and, importantly, engage the public in discussions on social improvements (European Social Innovation Research, 2017). It is by now

widely recognised that such participatory approaches work well only when citizens' involvement starts at the very beginning of the process. This has rarely been the case in FP7 funded projects. Participatory approaches were encouraged in some agricultural topics, but few projects prioritised stakeholders' engagement as an ongoing activity. Although pluri-disciplinarity was a key feature of the Framework Programme, only some projects fully integrated social science disciplines within their own research plans. Furthermore, policy specialists and economists were under-represented in these research partnerships.

Turning to the food industry, according to the ex-post evaluation report of FP7, there was limited impact achieved relating to the innovation activities of food SMEs. Although SMEs constituted 24% of the participants in food-related research projects, their "participation was often not focused on the generation of commercial impact from results" (EC, 2014b) but they were mainly used for service activities in the projects (EC, 2014a). Thus, SMEs in the food value chain have rarely benefited from innovative ideas or outputs of research projects funded under the EU Framework Programmes up to FP7.

H2020 Funding and Achievements

Scientific and technological innovation is the expected outcome of the projects funded in SC2, whereas the dynamics of communities are explored in SC6:

Societal Challenge 2 (SC2): SC2 follows very closely the FP7 FAFB theme by aiming at scientific and technological innovations to meet the challenge of increasing demand for food in an environmentally sustainable manner. Technological advances are also central to unlocking the potential of the seas and oceans and to boosting Blue Growth. The trend towards innovation, established in FP7, is reinforced with the introduction of instruments specifically for this purpose. This includes the reintroduction of the SME instrument (used in FP5) to allow SMEs to lead relatively small innovation projects focused on their individual needs for specific products and services (see Table 2 in Annex 2). The participation of SMEs in all Horizon 2020 projects and innovation-related activities (e.g., patent applications, prototypes), have increased compared to the FP7 Programme (European Social Innovation Research, 2017).

Societal Challenge 6 (SC6): The SC6 Work Programme for 2014-2015 was built to support actions in the three intertwined areas of inclusive, innovative and reflective societies. This resulted in a theme of calls (INSO) to the development of new forms of innovation in the public sector, enterprises and society, including young entrepreneurs (DOIT), incubators, universities and innovation centres (Science2Society) and other relevant actors.

The CO-CREATION calls of 2016-2017 work programme shifted the focus towards the potential for societal and innovative development through co-creation in all sectors of society, engaging citizens, users, academia, social partners, public authorities, businesses (including SMEs), creative sectors and social entrepreneurs in processes that span from identifying problems to delivering solutions.

SUMMARY AND EVALUATION OF R&I ACHIEVEMENTS ACROSS THE FOUR FOOD 2030 PRIORITY AREAS

The achievements of European R&I through Framework Programme 7 and Horizon 2020 indicate the importance of systemic approaches to problem-solving and innovation that are multi-disciplinary and participatory – prioritising the experiences and expertise of all stakeholders within the agri-food value chain. In addition to a multi-perspective/multi-actor approach, R&I that work across territorial contexts and promote knowledge transfer between them helps to promote creativity and can open up opportunities for scaling up resulting innovations.

FP7 R&I achievements addressing 'Nutrition and sustainable healthy diets' have focused in particular on expanding knowledge around consumer behaviour and factors influencing food choice, contributing to a deeper understanding of how to implement diet changes and providing an evidence base for healthy diet and lifestyle policies such as EATWELL. FP7 achievements also include testing and evaluating beneficial dietary factors linked with the development of nutrigenomics and assessing food allergens and chronic disease risk. Factors contributing to the successes of FP7 R&I impacts in nutrition and health include the **continued success of formalised organisational research networks**, including EuroFIR and NuGO, which have driven innovation and harmonisation in research across the nutrition field. Impact achievements in food processing research, including tools for detecting food contaminants and processing equipment and packaging innovations, have led on from a **limited funding stream** (7% of FP7 KBBE funds) but has contributed to Europe's competency base, supported the creation of new companies, patents and market opportunities and provided skilled resources. In contrast, H2020 R&I achievements have been limited by a failure to link nutrition and health/disease, leading to a dearth of projects, studies or public health interventions contributing to innovation on this issue, and compromising Europe's ability to address SDG2, SDG3 and SDG6.

The 'Climate-smart and environmentally sustainable food systems' priority has benefited in substantial ways from the FP7 focus on **research synergies and community networking**. Collaborative research has involved linking sustainable resource management and production systems with multi-stakeholder involvement, individual technological innovation and farm/plot-level practices across territories. This territorial focus has also promoted achievements in policy-making, network and research agendas supporting rural development and sustainable resource management innovations in climate change hotspots. Maritime research innovations on sustainability and climate (e.g., those informing the CFP) were achieved through experimenting with both top-down and bottom-up management strategies that prioritise co-management and participatory approaches across territorial contexts. H2020 R&I on climate and sustainability also prioritised a multi-level, multi-stakeholder and socially inclusive approach to its sustainable food security focus. Such approaches include integrated environmental management schemes for water and energy in cropping (FATIMA) and multi-stakeholder assessment of tools to evaluate cropping and environmental interactions, taking a co-innovation and knowledge exchange approach (DIVERSify).

Synergy across R&I has allowed for **deeper integration of applied science, climate action and socio-environmental sustainability** priorities, resulting in several impactful projects such as CERERE, which focused on decentralised, local solutions to problems facing the agri-food sector, and AFINET, which formed regional multi-stakeholder networks to study interactions between forestry and crop and animal production. This focus on research integration across H2020 areas also precipitated innovations in marine research by addressing multiple challenges at a multi-species and ecosystem level. R&I achievements in climate and sustainability related to FNS have distinctly benefited from knowledge sharing and integration, particularly relating to the sharing of relevant research between DG RTD and DG Agri, an explicit commitment to knowledge transfer and innovation embodied within the CAP and the contributions of networks like EIP-Agri. The types of research fostered by this synergistic approach are **more territorial, more integrated and more-policy focused**, creating more productive links between research and industry, food supply chain stakeholders and society and innovative research that is aligned with the territorial, landscape/ecosystem level and governance-based nature of climate and sustainability challenges.

R&I on 'Circular and resource efficient food systems' is less visible due to the overlap between this and other priority areas – most notably 'Climate and sustainable food systems'. FP7 R&I projects on circularity and resource efficiency have focused on optimising food processing/packaging/labelling processes, enhancing product quality and improving knowledge exchange for SMEs. However, many projects fail to explicitly address circularity, with only one project engaging with food waste (FUSIONS). Through H2020, projects explicitly working on circular economies are heavily weighted toward

industry, with little territorial focus on either urban or rural areas specifically and few focusing on farm level issues or fisheries/aquaculture. H2020 does, however, focus more explicitly on food waste through projects that aim to create frameworks and models for understanding food waste behaviour and composition (REFRESH), food sharing (SHARECITY), ICT networks as tools for tackling food waste (SAVING FOOD) and the re-valorisation of food waste and by-products (AgroCycle). R&I on circular food systems and resource efficiency would benefit from a renewed focus on a **socially innovative and systemic approach** to these issues, as demonstrated by other FOOD 2030 priority action areas.

R&I in the priority areas of 'Food systems innovation and empowerment of communities' has allowed for the **one of the largest proportions of R&I investment** to flow into the food and drink industry. Projects in this area have focused on understanding the dynamics of change to explore solutions to challenges facing the food system, resulting in a stronger emphasis on sustainability and knowledge-sharing. In particular, this featured the development of **knowledge transfer networks** such as the aforementioned EIP-Agri, which provides structures of interaction that act as multipliers of knowledge and innovation. Participatory approaches also featured in FP7 R&I projects that focused on exploring social innovations for environmental conservation, governance, social justice and urban planning. Multi-actor approaches to food system innovation did, however, suffer from a low impact on SMEs, which have often failed to benefit from R&I in this area. In contrast, H2020 projects more readily utilised tools to boost SME participation and open up opportunities for them to pursue small-scale innovations focused on their individual needs for products or services. Additionally, H2020 prioritised community transitions with a focus on 'inclusive, innovative and reflective societies' as part of its SC6 programme. This included CO-CREATION, a project that took a multi-actor approach, including SMEs, creative sectors and social enterprise, to **co-create solutions to the challenges of community transition and empowerment**.

Amongst other things, R&I has been instrumental in empowering local communities to become advocates for policy change at the local level, in collecting the necessary evidence to inform EU policies on food safety (e.g., food labeling) and in providing recommendations on advertising controls and the potential of school food provision – all of which now appear in the WHO's Action Plan for Europe. R&I will also be essential for developing future EU policies that can improve the quality of life of future generations of citizens and safeguard the needs of older people.

PART 2. EVIDENCE BASE AND RATIONALE FOR RESEARCH

The achievements of European R&I through Framework Programme 7 and Horizon 2020, as reported in the previous chapter, indicate the importance of systemic approaches to problem-solving and innovation that are multi-disciplinary and participatory – prioritising the experiences and expertise of all stakeholders within the food system. In addition to a multi-perspective/multi-actor approach, R&I that work across territorial contexts and promote knowledge transfer between them helps to promote creativity and can open up opportunities for scaling up resulting innovations. These R&I activities have contributed to improve and adapt the food system but have not been disruptive enough to make the food system fit for the future and be able to cope with new challenges.

In this chapter, we first report on the FNS challenges for the next decades. This is followed by an analysis of the complexity of the food system, that effects tthe innovation needed. Based on this we discuss of the role of the government and especially the European Union in research and innovation.

A. Challenges for Food and Nutrition Security

The grand challenges for the future of humankind have been listed by the United Nations in the SDGs. These 17 development goals summarize 169 targets in an agenda for 2030. Many of them are relevant for the food system: Zero hunger (SDG 2), Good health and well-being (SDG 3), Affordable and clean energy (SDG 7), Decent work and economic growth (SDG 8), Industry, innovation and infrastructure (SDG 9), Reduced inequalities (SDG 10), Sustainable cities and communities (SDG 11), Responsible production and consumption (SDG 12), Life below water (SDG 14), Life on land (SDG 15) and Peace, justice and institutions (SDG 16). *Healthy, sustainable and climate-smart food for all* is probably a good summary of these challenges for the food system.

One aspect of sustainability deserves special attention: the Paris climate change agreement (COP21) that binds Europe to strongly reduce greenhouse gasses (GHG) to keep the rise in global temperatures below 2 degrees. The agreement states that food production should not be threatened but that does not mean that the food system cannot share in the mitigation effort, for instance by partly substituting plant proteins for animal proteins. And farming surely has to adapt to climate change. Farmers have only about 10 harvests to adapt to the 2030 effort sharing agreement and the climate challenge becomes much more daunting after 2030, with a clear risk of stranded assets.

These grand challenges are supported by many EU policies, like the EU Food Safety policies, the EU Nutrition Policy Framework, the Common Agricultural Policy, the EU Strategy on Adaptation to Climate Change, EU environmental policies (like the Nitrate directive), the EU Circular Economy Package (including the Waste Directive and Climate Action policies), the Digital Single Market Strategy, the EU Urban Agenda, the Europe for Citizens programme and several others.

One of the effects of these policies is that they can induce innovation from businesses in the food chain as they are forced to change practices. It would of course be attractive if they innovate to solve issues before regulations force them to do so. A substantial Research & Innovation policy should accompany these policies. Regulations and taxes can induce innovation and productivity, but research and innovation policies are often preferable to prevent such government interventions in the economy.

B. Need for transformative innovation

To provide affordable and good quality food and to increase earnings of those who work in food and farming activities, the food system has innovated successfully, but at the expense of the environment, biodiversity and animal welfare. Food is now so affordable

and our life styles have changed so much that unhealthy diets contribute to obesity and non-communicable diseases. Food is cheap, and we do not pay the true costs; it is easily wasted. These problems are recognised by some actors in the food system and lead to innovations, as the problems of today are the business opportunities for tomorrow.

Studies (e.g. Schutter, 2017) and high-level policy advice suggest that powerful actors in the food chain like retailers, food processors and input providers, compete strongly with each other but do not yet take enough responsibility to internalise the sustainability aspects that are manifest with small-scale actors such as farmers and consumers. This is especially prevalent in those parts of the food chain where unsustainability is persistent.

Transforming the food system to a desired future state requires that all actors (including consumers) take themselves responsibility for sustainable food production and consumption, including responsible innovation to address new challenges. The risk is that food chain actors continue to work as they do, leaving it to governments to compensate or subsidise low incomes of farmers, try to solve the environmental issues by governmental regulations and some public research and have governments and insurers pay for health and environmental costs. Therefore research and innovation, in coherence with other policies, should address the transformation of the full food system to a resilient, sustainable system. The food system should become more sustainable, resilient, responsible, diverse, competitive and inclusive:

- Sustainable: with respect to natural resource scarcity and in respect of planetary boundaries;
- Resilient: with respect to adapting to climate and global change, including extreme events and migration;
- Responsible: with respect to being ethical, transparent and accountable;
- Diverse: with respect to being open to a wide range of technologies, practices, approaches, cultures and business models;
- Competitive: with respect to providing jobs and growth;
- Inclusive: with respect to engaging all food system actors, including civil society, fighting food poverty, and providing healthy food for all (European Commission, 2016).

To achieve such a food system with a more resource-efficient and sustainable farming and food sector, it is important to recognise different types of bottlenecks. Some are institutional, other are technical or economic bottlenecks; some are knowledge gaps. Research, related knowledge exchange, investments in innovative business applications and a supportive regulatory environment can help to reduce bottlenecks.

Economic bottlenecks: Many problems are caused by low prices for fossil fuels, fertilisers, pesticides and packaging material on the one hand, and high labour costs on the other hand. As incomes increase in the rest of society, the quest to mimic this in farming and prevent rising food prices, innovation is geared to higher labour productivity. As not all farmers can increase their land area, this often leads to intensification of farming, resulting in high environmental direct or indirect costs (e.g., loss of soil fertility through erosion, loss of nitrates in rivers and lakes, residue of pesticides in environment and food, decline of landscape and species diversity and loss of landscape attractiveness for citizens). Today these externalities are not sufficiently taken into account.

Legal framework bottlenecks: In many cases legal framework conditions pose challenges, for SMEs in particular, e.g. to develop new products from food industry by-products. For example, stringent food safety standards (e.g., using food waste as a source of insect protein) resulting from legitimate consumer concerns may make it difficult to implement more sustainable practices in the feeding of non-ruminants or fish.

Institutional bottlenecks: In many cases, the inefficient or unsustainable use of natural resources is related to institutional contexts. This can include the inadequate protection of resources such as land and fish stocks, inadequate implementation and control of environmental legislation and insufficient cooperation between different actors in food systems. Additionally, current R&I creates institutional barriers because it is often aimed at technical, mono-disciplinary research. New and more effective governance models need to be developed.

Another important institutional bottleneck is the fact that for many innovations different actors in the food chain have to act in collaboration. Indeed, sustainability problems are complex and persistent as they cannot easily solved within one firm. A farmer can switch to a more sustainable production method, but probably this only works if his cooperative or a food processor is willing and able to market the product and can convince current clients to buy the product or find new ones.

Lack of knowledge bottlenecks: Information and awareness about the real environmental status (e.g., soil fertility, biodiversity) is still insufficient. Systematic monitoring is needed to periodically assess the health status of ecosystems, animals and humans. Research can help to develop appropriate monitoring systems.

Social bottlenecks: Consumer preferences, including buying and eating habits, are significant barriers towards more sustainable consumption and diets. Consumer research can contribute to a better understanding of consumer choice and behaviour and help to develop strategies for more sustainable consumption.

Given such bottlenecks in transforming the complex food system to a sustainable food system, there is a need for a different approach, compared to simple or complicated systems where causality is known, stable and linear (Kurz and Snowdon, 2003). In complex systems, the relationship between cause and effect can only be understood retrospectively. In a complex, adaptive system, "Probe – Sense – Respond" is a better strategy for intervention than the "Sense – Analyse – Respond" approach used for complicated systems. In complex systems, the self-responsibility of all the actors is crucial.

In relation to innovation and research, a food system approach entails (and is based on) the following interrelated tenets:

- Extra attention has to be paid to the systemic aspects of an unsustainable situation and its potential innovative solutions. Problems have to be detangled / broken down / decomposed before solutions are created;

- An unsustainable situation needs to be investigated from different perspectives to capture changes in viewpoints and roles and perform stakeholder analyses. This calls for a multi-disciplinary approach;

- Different governance levels (company, regional, industrial sector, national, global) as well as different actors' perspectives need to be taken into account;

- A systemic approach is based on the inclusion of weaker actors in the food system. Part of the food unsustainability problem is due to the fact that the system does not provide incentives for more powerful actors to feel responsibility to look at the whole system including problems that emerge elsewhere in the food system with weaker actors;

- Under a systemic approach, food consumption is not only seen as a matter of individual choices, but also as a result of influences exercised by the larger setting (food environment, culture, education, city design, time restrictions, etc.);

- Innovations often die out/are not scaled up as the food system can be hostile and inflexible institutional arrangements do not change, or only very slowly. Hence, research and innovation can benefit from trials and examples from different countries with different institutional settings (comparative research);

- Given the importance of institutional arrangements for the success of an innovation, forms of action research with actors, including citizen science, can be very useful to create room for (regional) experimentation with alternative policies. This stressed the importance of social innovations;

- Issues and potential solutions need to be evaluated over their impacts over the whole food system. For example, many forms of current food processing lead to waste streams (beer and wine production, production of white flour and rice, oils and fats, etc.), which are currently mainly being used as feed, while they contain many healthy, human-edible components (proteins, minerals, vitamins, fibres, etc.);

- It can help to think in terms of "niches" when innovations are created (sometimes with new actors) and in terms of "scaling up" when the institutional 'landscape' provides a window of opportunity (based on the use or breaking of the power of important actors);

- To overcome standardised and dogmatic ways of thinking it might be helpful to formulate missions that embody ambitious objectives that aim to address the tripartite dimensions of sustainability and address planetary scale socio-ecological challenges (Mazzucato, 2018). For example, design a glasshouse that is a net energy supplier, create an arable farm on ecological principles (without pesticides) with light machinery (strip farming), make agriculture an important carbon sink, etc.

C. Role of the government

Given the complexity of the food system challenges identified and the evidence base and rationale for RI&IS aligned with each of the four FOOD 2030 priorities outlined above, the complexity and necessity of R&I draws attention to the crucial role government intervention should play in funding, supporting and nurturing R&I through a systemic approach that creates outcomes that are socially, environmentally and economically beneficial to communities.

Innovation (and to a lesser extent research) is inherent to the food system and crucial for transitioning towards more sustainable, resilient and diverse socio-ecological futures. Private companies have an incentive to innovate in order to stay competitive in diversified economic markets. In this context, innovation is driven by the need to develop better products for the market or reduce expenditure and become more cost-efficient. A crucial component to this innovation impulse is increasingly related to ecological dimensions of sustainability that reduces the (carbon, water etc.) footprint of their food products, which can in turn be economically advantageous (i.e. reducing production costs). Furthermore, given their large investments and reliance on raw material inputs, food companies also have an incentive to help farmers to become more sustainable, as otherwise they can run into sourcing problems. With their brands and reputation vulnerable to criticism, with consequences in the product, labour and capital market, they also have an incentive to pay attention to the social dimension of sustainability, like fair trade.

There are three main reasons why government - or public - investment in R&I is crucial in an innovation landscape dominated by private sector interests.

First, in reality, the private sector often innovate less than is needed from a societal point of view and private sector innovations are motivated predominately by creating a profit.

Companies do not reap all the benefits from their investments; since the protection of their intellectual property is not guaranteed and has a cost, others might copy their innovations. Part of the benefits also quickly leaks to others in the system. The uncertainty about the success (or value) of R&I and development trajectory could result in that innovation being deemed too risky for companies to invest significant resources. Advances focused on diversification and system redesign do not tend to produce patentable technologies, offer few profit-making opportunities and profit incentives for industry-led innovation. Such market failure is especially the case with small companies such as food and farming related enterprises, and therefore requires intervention by the government. This aligns with the notion that social innovation is a public good that should benefit consumer-citizens, and therefore, be supported by significant governmental investment in which profit is not the singular driving force.

Second, there is a need for public action in relation to R&I due to system failure: the behaviour of the private sector is linked with profitable investments. Therefore, effects of unsustainable practices at present are not necessarily solved by innovations of current actors given other priorities. Crucially, there are complex societal problems that raise the need for innovation that place the health and wellbeing of communities at the centre of R&I agendas and may not have short-term or immediate benefit, and therefore, require a long-term perspective in terms of investment.

And finally, the lack of transformative capacity of an interconnected system that privileges dominant or established pathways is another barrier to R&I. Systems tend to strengthen their own performance based on strong relations and neglect weak links with other systems, creating longer-term problems (e.g. between food and health). Moreover, systems might be neglecting interesting innovations in other domains. Therefore, linking or integrating systems is particularly attractive from an innovation perspective, providing new synergies and potentially important systemic solutions to complex, multifaceted problems. However, given the ingrained trajectories of the current globalised food system, it could be difficult for food system actors to develop such innovative connections without intervention. These factors highlight the need for holistic and strategic government intervention based on a food system approach that recognises the inherent complexity, and crucial role, of vertical and horizontal integration, within food system innovation.

Market failure is the classical reason for governments to invest in R&I in agriculture. This has contributed to higher welfare with lower food prices and to the sustainability problems discussed above. More important than such classical market failure is the fact that the transformative capacity of the food system for systemic change is too low, the system is not resilient. The current food systems are not resilient and run a risk of collapsing. They have to be transformed to another state.

Government involvement in innovation raises the question: which government(s)? Is there a role for the EU instead of or in addition to the Member States? There are a number of reasons to have the EU involved, especially in agriculture and food. Firstly, because the member states benefit from spillovers as well as a level playing field within the EU. Furthermore, different agricultural sectors can benefit by connecting to European knowledge and innovation infrastructures. In the common market, the production of certain products is more and more concentrated (such as sugar) and so are R&I for these products. That makes it attractive, certainly with the current communication technologies, to link producers in other regions to the hot spots of innovation. It makes (public) Agricultural Knowledge and Innovation Systems more efficient.

In the Common Market many input suppliers, food processors and retailers operate across national borders. It is inefficient to nationally finance the same innovation projects within one country that are also conducted and nationally financed in other Member States, with the same international companies as partners. By pooling resources such as within the ERA networks and the JPIs for research, the budgets can be used more efficiently and strategically.

In focusing on the food system, it is important to realise that parts of the system are closely linked with other sectors in the bioeconomy. Policies and innovation in those sectors are important for the food system too, even with a general principle as 'food first'. As important is that farming very much depends on the natural environment, implying that the management of natural habitats is often interacting with agriculture. Through import of raw materials (feed) and tropical products as well as export of quality products in food, machinery and services, the European food system has clear links with countries outside Europe.

Special attention is needed to support food systems in Africa and the Middle East where climate change and population growth create problematic situations linked with war and migration. The global population is expected to increase from 7 to 9 billion by 2050, and the majority of this increase will occur in Africa. International collaboration between Europe and Africa is important to reduce global nutritional and economical inequities. Thus, there is a need to support the long term development of food safety and nutritional security and further develop the diversity of sustainable food systems in Africa.

Member-states, regions and even cities can play an important role in the transformation, but it is hard to see how this could be done without EU leadership. Europe is also well positioned to take the lead and guide the world towards a food system that is future proof. In Europe the sense of urgency is combined with a state-of-the-art food production system and a first-in-class knowledge infrastructure.

In the past such investments in food and agricultural have led to very high rates of return on the long term. An American meta-analysis concluded that "most studies that have estimated the aggregate social rate of return to research consistently found rates of return between 40 and 60 percent" (USDA-ERS, undated). A related meta analysis (Fuglie et al, 2007) reported work over 1965-2005 by Huffman and Evenson concluding that the median estimate of the social rate of return was 45 percent per year. This roughly implies that each euro spent on agricultural research returns about € 10 worth of benefits to the economy.

These results are partly based on important breakthroughs in plant and livestock breeding, investments in basic research seems to have a higher return than in extension, and such data on investments in social issues like biodiversity or environmental challenges is much scarcer. Often such benefits are only accumulated after the many years that are needed from the basic research in the lab to the field. Which is another reason why governments are involved in agricultural research. As with all investments, past performance is not a guarantee for the future, but at least the past shows that important welfare gains can be gained by taking up challenges with research and innovation.

PART 3. POTENTIAL FUTURE R&I MISSIONS, FOCUS AREAS AND THEIR IMPACTS

Innovation needs a direction of search. Successful innovation systems make that direction explicit (Hekkert et al, 2007). Missions are a powerful tool for this, as they also solicit bottom-up solutions. The choice of these missions is political in nature and deserves a wide stakeholder engagement. We propose to break down the grand challenge of *"healthy, sustainable and climate-smart food for all''* into three missions, using the frame proposed by Mazzucato (2018) in her advice to the European Commission. We have based those three missions on the analysis of FP7 and Horizon 2020 results as reported in Part 1 of this report, literature on the grand challenges and a first list of 17 potential focus areas for the first half of the next decade. This list of 17 potential focus areas is presented in this chapter, clustered under the missions. Mazzucato (2018) suggests five key criteria for the European research and innovation missions:

1. Bold, inspirational with wide societal relevance.
2. A clear direction: targeted, measurable and time bound,
3. Ambitious but realistic research and innovation actions,
4. Cross-disciplinary, cross-sectoral and cross-actor innovation,
5. Multiple bottom-up solutions.

Missions are derived from a societal agenda and do not prescribe a specific solution or technology. Although it is clear that developments in information and communication technology or genetics could provide important contributions to the missions, they are not in themselves a future to be desired. Furthermore, Part 2 shows a clear diagnosis of bottlenecks and blocking factors restricting food systems' transformative capacity, that are often linked to the fact that acting only on one component of the system will not enable the desired change to happen, and that conjoint innovation in all components of the food system are necessary. Unlocking this innovation and transformation potential of the food system is at the heart of the motivation for public investment in R&I, and explains the focus chosen in this part to particularly direct public EU R&I funding to those areas of innovations that are transversal and would unlock transformation capacity. Based on this we propose three missions in the domain of food systems:

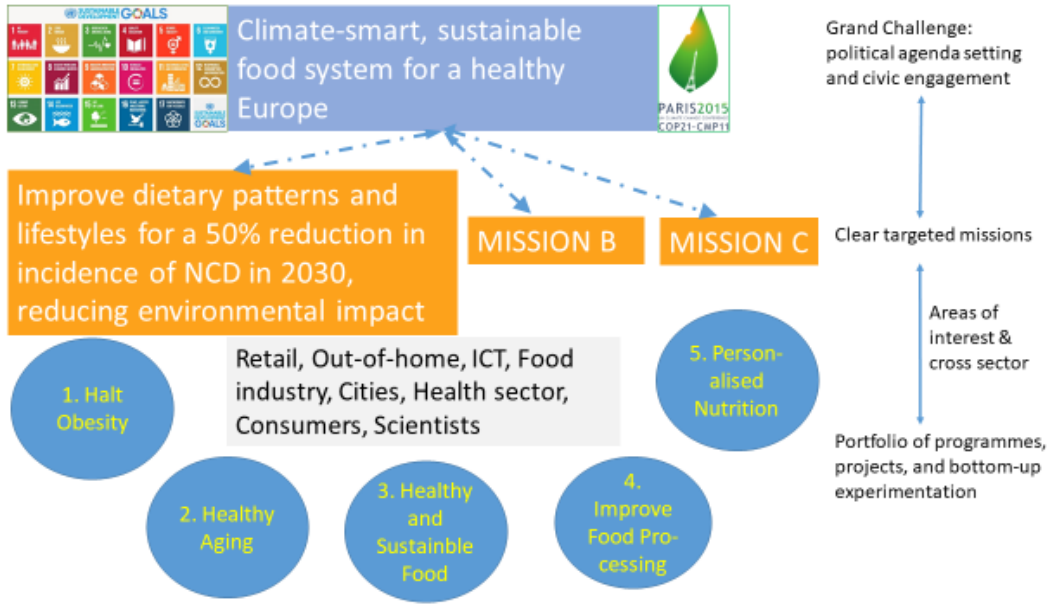
A. Improve dietary patterns and lifestyles for a 50% reduction in incidence of non-communicable diseases in 2030, while reducing the environmental impact of food consumption.

B. Create a resource-smart food system with 50% less greenhouse gas emissions by 2030.

C. Realise trust and inclusive governance for a resilient food system

The first one is more oriented to the consumption and the second to the production side, although there are many synergies that should be managed in the focus areas of these missions. These missions are multi-actor approaches that also renew the governance of the food system. Nevertheless, we see the need for a third mission that focusses on the governance itself and improves the transformative capacity of the food system by empowering new and small actors. These missions are described below, using the key criteria set out above.

A. Improve dietary patterns and lifestyle factors for a 50% reduction in incidence of non-communicable diseases in 2030, while reducing the environmental impact of food consumption



Inspirational and relevant: Changing dietary habits and increasing physical activity has the potential to address the major risk factors and reduce the incidence obesity and of NCDs in Europe by 50%. The impact of nutrition and lifestyle strategies that promote healthy ageing will enable European citizens to live longer, healthier and independent lives which in turn will decrease the burden on the health systems. Changing dietary habits, for example, moving to more plant-based proteins, has also a large potential to reduce the environmental impact of food consumption.

Direction: Currently seven out of eight major risk factors for premature death are linked to the way we eat, drink and our sedentary lifestyle (high blood pressure, high cholesterol, high blood sugar, excess body weight, inadequate fruit and veg consumption, physical inactivity and excessive alcohol intake). Of the six WHO regions, the European region is the most severely affected by NCDs, which, in turn, are the leading cause of disability and death. The four major NCDs together account for 77% of the burden of disease and 86% of premature mortality1. Alarming trends in obesity, due to an imbalance of energy intake and energy expenditure, necessitate that different strategies are used for different population groups tackling multi-facets of the problem. Healthy aging, with the number of over 80s almost set to triple, is another point of attention. More diverse diets and careful food processing is needed to increase consumption of healthy and sustainable diets. Attention to a healthy lead food culture like the Mediterranean diet in Europe and dishes based on specific African crops could be of interest.

Ambitious but realistic: Science understands better than ever how our body and brain functions, thanks to ongoing progress in areas such as neuro-science, genetics, omics-technologies and the gut biome. Behaviour of consumers can be better understood by exploring data from ICT-applications, social science and neuroscience. This supports more emphasis on preventive health. At the same time, sustainability aspects of our food consumption can be integrated. Food awareness is increasing amongst consumers and policy makers alike.

Cross-actor innovation: Business that offer food to consumers, like the retail and the out-of-home (catering, restaurants) can play an important role in improving healthy food consumption. Our food consumption is very much shaped by what food is offered and how. For the same reasons cities can be important actors regulating what, how and where food is supplied, but also because the design of the cities in terms of green areas (that reduce heat stress and provide options for exercising) and transport (walking, biking) influences a healthy life style. The health sector, from dieticians/nutritionists and doctors to health insurance companies, also play a key role. Fostering linkages between health research, food science, social sciences and citizens science contributes to a culture of a healthy diet in Europe and overseas in international partnerships with Africa (Food Systems Africa). It is obvious that the European ICT sector could use these diverse sectors and data sources to build up suitable personalised nutrition apps based on scientific evidence and artificial intelligence methods.

Cross-disciplinary research is essential from areas like nutrition, food science, medical research, social sciences, behavioural economics, marketing, architectural and urban design, psychology, sociology, and computer science. The research should not only address the consumer but also how actors that influence consumer eating behaviour, such as retailers, catering companies, food processors, media and policy makers can contribute. There are options for citizen science to empower consumers. As a relatively new area of government policy, data and research infrastructures that enable longer-period observations in this area lag behind those on primary agriculture.

Multiple bottom-up solutions: A serious improvement of the health situation of the European population that is not only based on curative but also on preventive actions can only be realised by a systemic approach in innovation that is linked with policy measures and recognises that several research and innovation pathways exist and should be tested. Diets vary between European regions and different groups in terms of e.g. age and social class. Most likely there is a lot of variation in individual responses to food intake and lifestyle. This makes different research and innovation actions necessary that have to be aligned to multiply impact.

This mission can be supported by a portfolio of 5 Focus Areas:

1. **Halt Obesity:** Halt the rise in overweight and obesity levels in school-aged children, adolescents and adults through tackling the multi-faceted drivers in a food systems approach.

2. **Healthy Aging:** Add healthy and independent years to the ageing population reducing by half the number of dependent adults.

3. **Access to Healthy and Sustainable Diets:** Increase the consumption of healthy and sustainable diets by doubling the diversity of accessible energy and protein food sources.

4. **Improve Food Processing:** Improve food processing for better outcomes for nutritional and sensory food quality as well as the environment.

5. **Personalised Nutrition:** Implement personalised nutrition strategies to reduce the incidence of non-communicable diseases in Europe by 50%.

We discuss these Focus Areas in detail below.

1. ***Halt the rise in obesity levels in school-aged children, adolescents and adults through tackling the multi-faceted drivers in a food systems approach***

Vision

At the core of obesity is an imbalance of energy input and energy expenditure. Almost 50% of the European adult population is either overweight or obese. Of particular concern, is the rise in childhood obesity with estimates indicating that following global trends there may be 60 million obese children by 2020 worldwide. The alarming trends in the global obesity necessitate that different strategies are used for different population groups tackling multi facets of the problem. Therefore the vision is to develop strategies to tackle obesity that are tailored for different population segments and as a result stop the rise of obesity in Europe. Of particular note is the ability to target pregnancy and early childhood periods with the objective to stall the growth of childhood obesity and its associated complications in later life.

Development of new policies and recommendations that promote healthy dietary habits and weight gain that include a number of actors in the field such as public procurement, food industry, governmental agencies and citizens are essential. The ultimate vison is one of a Europe where obesity rates are not growing at an alarming rate.

Bottlenecks

A key bottleneck is that evaluation of interventions is difficult in the current funding cycles; long-term interventions are necessary to evaluate optimal strategies. Better intermediate measures are necessary. Obesity is a multi-faceted problem and needs different strategies for the various population segments.

Synergies with other Focus Areas

This mission has a number of potential synergies with other Focus Areas, as outlined below:

- *Implement Personalised Nutrition strategies to reduce the incidence of Non Communicable Diseases in Europe by 50%:* Tackling obesity in adults could benefit from application of personalised nutrition approaches.
- *Strengthen the different roles of citizens in healthy, diverse and sustainable food systems:* Empowerment of citizens through measurable reduction of disease risk factors such as obesity.
- *Food processing with better outcomes for nutritional and sensory food quality as well as the environment:* Cooperation with this Focus Area could lead to the healthier less energy dense options and food based options to tackle malnutrition in obesity.
- *To reduce food insecurity and increase the consumption of healthy and sustainable diets by doubling the variety of energy and protein sources produced:* Potential for connection here to ensure development of healthy products that contribute to a reduced energy intake.
- *Halve food waste and food losses from the EU food system by 2030:* Promotion of a healthy diet and education pertinent to appropriate portion sizes will lead to a reduction in food waste.
- *Reduce the environmental impact of food packaging by 2030 by 75%:* Nutrition and health information is essential on food labels- innovative options for packaging could incorporate health and nutrition messages.

- *Increased consumer trust by 50% by improving the authenticity, transparency and guaranteeing safety along the Food system by 2030:* Any re-formulation of foods will have to be done with taking food safety into account.

Trade-offs with other Focus Areas

Development and retailing of foods that are energy dense and of little nutritional value.

Contribution to SDG and other (EU) policies:

This mission contributes to the following policies:

- *SDG2 (End hunger, achieve food security and improved nutrition and promote sustainable agriculture).* Reduction in the obesity levels will
- *SDG3 (Ensure Healthy lives and promote well-being for all ages).* Obesity is a key driver of an unhealthy lifestyle and strategies to halt the rise on obesity will be part of ensuring healthy lives.
- *SDG4 (Gender Equality).* Opportunities for and engagement in physical activity is lower amongst girls. Addressing this specifically will help deliver this SDG.
- *SDG12 (Responsible Consumption and Production).* Promotion of healthier diets, lifestyles and food environments will contribute to achieving this SDG.
- *WHO European Food and Nutrition Action Plan 2015–2020.*
- *WHO Investing in children: the European child and adolescent health strategy 2015–2020.* The present Focus Area can contribute to the improvement in child and adolescent health by tackling the growing obesity crisis.
- *Rome Declaration on Nutrition.*
- *EU Action Plan on Childhood Obesity 2014 – 2020.*

What needs to be done

Strategies need to be implemented that target different population segments with a particular focus on childhood obesity. Progress can be achieved in the following areas:

Childhood Obesity:

- Development of sustainable and healthy dietary recommendations for pre-natal, pregnancy and infant periods. Research should include impact of different dietary regimes in this key window. This will provide evidences to optimise recommendations on nutrition before and during pregnancy, the breastfeeding period and childhood, with special reference to later health development of offspring.
- Development of the evidence base to support the development of policies dealing with food provision in schools and hospitals to ensure that healthy and sustainable options are available to all.
- Development and implementation of innovative strategies to incorporate physical activity into daily lives. Redesigning food environments to promote healthy food options. Incorporation of physical activity into the school day to ensure that children are meeting the recommendations. Redesign of the built environment to promote physical activity.

- Reformulation of foods to make them healthier and tailored to their nutritional needs.

Adolescents:

- Innovative strategies to use marketing and social media to promote healthy eating in adolescents. Co-development of strategies with consumers of this age category have the best chance of success.
- Development of gaming approaches to increase healthy lifestyle choices.
- Development of school policies to tackle the significant drop in physical activity in adolescent girls.

Adults:

- Reformulation of foods to make healthier less energy dense options.
- Food based solutions to tackle malnutrition in obesity.
- Re-design of food environments to encourage and promote healthy and sustainable dietary patterns.
- Development of effective campaigns for reduction of alcohol intake.
- Redesign the architecture of the urban environment to promote physical activity.

Actors to be mobilised

The key actors to enable delivery of this vision are as follows:

Scientists: The building of a substantial evidence base to support the development of effective interventions to tackle childhood obesity including a focus on maternal health is essential. Further understanding of the drivers of obesity in adolescents and the development of scientifically proven prevention strategies in the age group are necessary.

Scientific advances need to be made in the reformulation of foods to make healthier less energy dense options and the production of food based solutions to tackle malnutrition in obesity. Further understanding of the link between obesity and chronic diseases is essential to develop further prevention strategies.

Policy Makers: Urgently need the development and implementation of specific policies to reduce childhood obesity by targeting prenatal, pregnancy and early childhood. The development of policies dealing with food provision in schools and hospitals to ensure that healthy and sustainable options are available to all is urgently needed.

Incorporation of physical activity into the school day to ensure that children are meeting the recommendations.

Urban Planners, Food Producers, Food Retailers, and Food Sector: A transformative redesign of food environments to promote consumption and purchase of healthy and sustainable food options is essential.

Interaction with urban planners is also necessary to redesign of the built environment to promote physical activity at all ages.

Citizens: Co-design of strategies for promotion of healthy eating and increased physical activity amongst adolescents.

Metrics / Indicators

Obesity rates are on the rise so a key metric would be to halt the rise in obesity in children, adolescents and adults.

2. Add healthy and independent years to the ageing population reducing by half the number of dependent older adults

Vision

In the next 50 years, the number of Europeans over 65 will double and the number of over 80's will almost triple. This changing demographic of Europe brings with it a number of challenges to the Food Systems and how we deal with an ageing population. Furthermore, as life expectancy will continue to increase there is an urgent needs to develop strategies and solutions to promote and support healthy ageing. The impact of development of nutrition and lifestyle strategies that promote healthy ageing will enable European citizens to live longer, healthier and independent lives which in turn will decrease the burden on the health systems. The definition of healthy ageing adopted herein is the process of optimising opportunities for physical, social and mental health to enable older people to take an active part in society without discrimination and to enjoy an independent and good quality of life. Good nutrition plays a central role in achieving this and implementing nutrition strategies in a food systems manner has the potential to deliver the vison of a society (both city and rural dwelling) that supports and enables the older populations to live healthy independent lives.

Bottlenecks

Lack of awareness of new solutions amongst this demographic is likely to be high and will need suitable implementation and promotion plans. Development of plans will require a multi-sectorial approach that may hamper progress.

Synergies with other Focus Areas

There are potential synergies with a number of other Focus Areas:

- *Halve food waste and food losses from the EU food system by 2030:* adjustment of portion sizes and development of food solutions adapted to the elderly have the potential to impact on food waste. Potential for the extraction of bioactive ingredients from food waste streams and re-use in functional foods for the elderly.

- *Strengthen the different role of citizens in healthy, diverse and sustainable food systems:* Empowerment of the elderly is central to this nutrition Focus Area that could have synergies with this.

- *Upgrade innovation capabilities of actors in food systems:* capitalising on the need for specialised food products for the ageing population has the potential to lead to significant innovations in for the food industry.

- *Food processing with better outcomes for nutritional and sensory food quality as well as environment:* The development of new food products tailored to the nutritional needs of the elderly is an excellent opportunity.

- *Diversify fields, farms and landscapes to achieve climate-proof and sustainable resource use, for healthy people, healthy environment and a healthy planet:* Inclusion of the potential to develop new ingredients to support healthy ageing will complement the present Focus Area.

- *Halt the rise in obesity levels in school-aged children, adolescents and adults through tackling the multi-faceted drivers in a food systems approach:* Tackling obesity will help promote healthy ageing.

- *Implement personalised nutrition strategies to reduce the incidence of Non Communicable Diseases in Europe by 50%:* Implementation of personalised strategies has the potential to deal with some of the nutrition issues faced in the older population.

- *Increased consumer trust by 50% by improving the authenticity, transparency and guaranteeing safety along the food system by 2030:* Any development of new bioactive ingredients will have to done with food safety at the forefront.

Trade-offs with other Focus Areas

The ageing population have requirements of high quality animal source protein, which may be conflicting with the desire to reduce the reliance on animal-based protein.

Contribution to SDG and other (EU) policies

This Focus Area contributes to the following:

- *SDG2 (End hunger, achieve food security and improved nutrition and promote sustainable agriculture).* Addressing nutrition in healthy ageing through a food systems approach can help achieve improved nutrition and reduce malnutrition in this population group.

- *SDG3 (Ensure healthy lives and promote well-being for all at all ages).* Clear strategies and innovations to deal with Europe's ageing population are essential for the delivery of this SDG.

- *SDG5 (Achieve gender equality and empower all women and girls).*

- *SDG10 (Reduce inequality within and among countries).* Development of strategies that result in an independent older population will contribute to reducing inequalities.

- *SDG11 (Make cities inclusive, safe, resilient and sustainable).* Inclusion of solutions and strategies to promote independent living of older adults will support reaching targets involved in this goal.

- *SDG12 (Ensure sustainable consumption and production patterns).* Clear solutions to deal with the nutrition requirements of the older population in a sustainable fashion.

- *European Innovation Partnership on active and healthy ageing*[15]*:* addressing nutrition needs of the ageing population through a food systems approach will help deliver this policy.

- *Developing the new European policy for health – Health 2020*[16]*:* tackling the nutrition aspects through a food systems approach has the potential to contribute the European Health Policy.

[15] https://ec.europa.eu/eip/ageing/home_en

[16]http://www.euro.who.int/__data/assets/pdf_file/0007/147724/wd09E_Health2020_111332.pdf

- *WHO Europe Policies and priority interventions for healthy ageing*[17]*:* Addressing healthy ageing from a nutrition viewpoint will contribute to the delivery of the goals of this policy.

What needs to be done

The following are areas of priorities where potential solutions could be developed:

- Development of efficient nutrition and lifestyle evidence based prevention programmes that are accepted and used by the elderly. These need tailoring for men and women. Further research is needed to define the programmes, evaluate the success and tailor for men and women.

- Development of innovative food products that target malnutrition in the elderly. A food systems approach to the development of new food products that specifically target malnutrition in the elderly. There is also the potential for extraction of bioactives from for example waste streams and incorporation into specific foods to create value added foods.

- Development of innovative food products with taste attributes that address the loss of taste in the elderly, thus making foods more pleasurable for this population group.

- Improved city environment for the ageing population with a focus on the food environment. Development of new innovative approaches for food environments to ensure older people have access to fresh, healthy and sustainable produce.

- Development of tools for evidence-based (direct diagnostics tools for use by the elderly) personalized nutrition and lifestyle programmes.

- Development of accompanying diagnostic and ICT systems useable by the elderly at home to assist in the delivery of nutrition strategies.

- High quality house environment for the elderly for long-term independency and care.

- Development of personalised 3D printing of foods and new food products to support the needs of the elderly especially when throat muscle deterioration has occurred.

Actors to be mobilised

Scientists: Development and implementation of nutrition and lifestyle advice for the elderly population based on strong scientific evidence. Development of key recommendations and resultant potential food product solutions.

Environment and Innovation Actors: Work is needed to ensure that cities are adapted to the ageing population. Home environments need to be enhanced to ensure long-term independency and care for the elderly. Development of accompanying diagnostic and IT systems are essential to enable independent living. All solutions should be co-developed with the elderly population to ensure acceptability and usability.

[17]http://www.euro.who.int/en/health-topics/Life-stages/healthy-ageing/publications/2012/policies-and-priority-interventions-for-healthy-ageing

Policy Makers and Public Authorities: Development of new policies that are driven by evidence based nutrition advice. Engagement with public authorities to make urban environments more ageing friendly.

Food Producers and Food Industry: Development of new products that address malnutrition in the elderly. Potential to develop high value foods by linking with for example waste streams. Extraction of bioactives could be used in the development of food products that target healthy ageing.

HealthCare Providers: Engagement with healthcare providers to ensure that nutrition aspects are an integral part of elderly care.

Consumers: Co-development of any potential solutions is essential in order to ensure that they fit the needs of the elderly population.

Metrics

In the next 50 years, the number of Europeans over 65 will double and the number of over 80's will almost triple. A key measure of success will be the number of older adults living independently: by 2030, a key aim will be to increase the average healthy lifespan by 4 years.

3. Increase the consumption of healthy and sustainable diets by doubling the diversity of accessible energy and protein food sources

Vision

The vision is to double the diversity of locally available food leading to healthier diets and more sustainable food systems. Accessibility to more diverse, nutritious and locally produced foods has the potential to reduce health problems associated with poor nutrition (e.g. undernutrition, over-nutrition and/or micronutrient deficiencies) and promote consumption of more sustainable diets. Fewer than a dozen plant and animal species account for 80% of our diet. For example, out of 5,538 plants used for human food, just three – rice, wheat and maize – provide more than 50% of the world's plant-derived calories[18] . The main source of protein in our diets consists of meat, that account for 15% of greenhouse gas emissions, consumes 10% of the world's fresh water and use more than one quarter of the planet's ice-free surface[19]. On the other side, there is a large diversity of crops and other protein sources suitable for human consumption with relevant nutritional profile and sustainability footprints that are not produced or processed in sufficient amounts. Examples are: underutilised crops (e.g., lupin, peas, quinoa, teff), alternative proteins sources in our daily diets (e.g., plant proteins, mycoprotein, in-vitro lab meat, algae, seaweed, insects) or alternatives to unsustainable food sources (e.g., soya, palm oil).

More research is needed along the food chain, to support the primary production, processing and consumption of more diverse foods, including (i) identification of alternative food sources and criteria for their selection, (ii) sustainable production at farm or sea of more diverse food sources (e.g. crop diversification, production of algae or

[18] https://www.bioversityinternational.org/research-portfolio/diet-diversity/

[19] Food and Agriculture Organization of the United Nations, Livestock's long shadow: Environmental Issues and Options, 2013, http://www.fao.org/docrep/010/a0701e/a0701e00.htm

insects, other livestock well adapted to local climate conditions or making better use of resources available), (iii) processing at farm or food industry will need to be scale down processes, adapt existing processes or develop new processes to extract or transform the new food sources into ingredients or tasty, nutritious and tasty diets, (iv) retailing and distribution to interact with producers and consumers making healthy and sustainable diets more available.

Bottlenecks

Production of alternative food sources is underdeveloped and new supply chains have to be developed from production to consumption. Consumer acceptability of some products, for example alternative protein sources is low and product quality needs to be improved. New processing approaches are required and therefore collaboration along the food system is needed. There is a disconnection between current dietary recommendations in terms of meat consumption and a reduction in livestock for environmental impact.

Synergies with other Focus Areas

Research developed under this Focus Area will benefit or have positive effects on:

- *Tackling obesity* –more diverse diets can provide new routes to tackle obesity, making more healthy foods and some of the alternative food sources may have positive effects on control of appetite.

- *Personalised nutrition* – the new food sources will contribute to a large variety of solutions and ready to eat foods for personalised nutrition.

- *Healthy aging* - Elderly have often of malnutrition and alternative food sources can tackle malnutrition by proving a variety of texture, flavours and availability of nutrients that will be more suitable for them, thus increase the food choices

- *Increase safety and transparency* – the new food chains need to be safe and transparent. Research activities in collaboration with Focus Area 5 is need to speed up novel food approval (when relevant) or to guarantee safety (e.g. allergenicity is relevant for alternative proteins; new microflora may dominate in other food sources)

- *Diversify fields, farms and landscapes to achieve climate-proof and sustainable resource use* – The agricultural strategies for diversity at the scale of farms, landscapes, production areas and regions will complementary this mission at system level provide support for selection of the most suitable crops for specific regions

- *Double the availability of high quality food production from EU aquatic systems* – The integration of exploitation of food sources from aquatic systems that are underutilised or have not been consumed previously (e.g. algae or seaweed in sustainable diets has large potential by creating sustainable diets).

- *Reduce food waste* - development of new chains will reduce waste by taking in account state of the art knowledge regarding circularity and better use of resources

- *Food processing with better outcome for nutritional and quality* – The novel processing solutions and equipment that will be developed will be useful for the new food sources

- *Upgrade innovation capabilities of actors in food systems* – The use of new food sources will support the development of completely new food chains.

Contribution to SDG and other (EU) policies

- *SDG2:* Diets that are more diverse will improve nutrition, and ensure food security and promote sustainable agriculture. It will contribute to the eradication of hunger and ensure access by all people, in particular people in vulnerable situations to safe, nutritious and sufficient food all year round. Promote access to and fair and equitable sharing of benefits between farmers, producer and retailers.

- *SDG3:* Availability and high consumption of more diverse and healthy diets will contribute to ensure good health and well-being.

- *SDG6:* More adapted crops can improve water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.

- *SDG8:* Agriculture is the single largest employer in the world – promotes agricultural growth.

- *SDG 11:* Consumption and production of more sustainable and nutritious diets will contribute to improve sustainability of cities and communities.

- *SDG 12:* Ensure sustainable consumption and production of foods that make the healthy choice the easy choice. Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production. Sustainable management and efficient use of natural resources.

- *SDG13:* Promote more sustainable chains with better capacity for effective climate change-related planning and management. Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries.

- *SDG17:* Enhance North-South, South-South and triangular regional and international cooperation on and access to science, technology and innovation and enhance knowledge-sharing on mutually agreed terms, including through improved coordination among existing mechanisms, in particular at the United Nations level, and through a global technology facilitation mechanism.

Trade-offs with other Focus Areas

Promoting more biodiversity could create a trade-off with the vision of Focus Area 8. Redesign, re-integrate and encourage low impact animal production systems and Focus Area 9 - Arrive at a sustainable and efficient use of natural resources where single culture or livestock may provide a more cost effective system.

What needs to be done

Progress can be achieved in the following areas:

- Promoting agricultural and aquatic production of nutritious, sustainable, consumer attractive, well adapted but scarcely consumed foods/potential nutrient sources.

- Developing an interdisciplinary approach to define a healthy sustainable diet that incorporates nutritional needs, environmental impacts, biodiversity and cultural preferences.

- Devise food based guidelines that will ensure the consumption of a more diverse, healthy and sustainable diet.
- Assessment of the suitability of the new nutrient sources for feed versus food.
- Assessment of the safety, allergenicity or pathogen transmission risks.
- Generating research data to support the assessment of EFSA regarding novel foods.
- Explore international collaboration, e.g. Africa that is home of a huge diverse range of crops.
- Developing strategies for an effective production systems for new crops/raw materials.
- Refresh crop gene pools and existing crops by increasing yield and/or disease resistance.
- Develop and adapt food processing operations to small-scale production to enable add-value activities at farm or SME level. This will may also include creating new intermediate products and using digital technologies for distribution and communication with the end-users.
- Molecular understanding of the new raw/food materials (composition, functionality, nutritional value, etc.) and how they can be converted into ingredients or tasty, healthy, sustainable foods.
- Scale up or scale down sustainable processing and manufacturing solutions adapted to the new raw/food materials as well as production in short food chains.
- Re-evaluate and advance food processing of the new crops/raw materials to avoid waste and exploit the full nutritional potential.
- Nutritional validation, i.e. digestion of macro/micronutrients in the gastro-intestinal tract and human studies to demonstrate efficacy of any new food products.
- Improve consumer perception and behaviour regarding new crops and raw materials.

Actors to be mobilised

To implement the vison for increases consumption of healthy and sustainable diets by doubling the diversity of energy and protein food sources accessible, a multi-actor approach should be adopted:

Food/Raw Material Producers, including Farmers: increase production of a large variety of crops, livestock or other aquatic food sources. Integrating the new food sources in their existing production schemes or developing new strategies.

Food Industry, Equipment Suppliers, and Seed Developers/Suppliers: to implement solutions to process the new food sources into nutritious, tasty, and sustainable food products and diets. New equipment solutions will be developed. New seeds well adapted to local climate will be identified.

Retailers, Supply Chain Experts: some of the new food sources will support the development of local and short food chains. Retailers and supply food chain experts will therefore be needed too.

Consumer Organisations: consumer acceptance is critical for implementation of new food sources. Knowledge about acceptance and preferences is important for the success of this mission.

Other Organisations: such as those that have worked longer with aspects of biodiversity and/or have knowledge to support this mission are: FAO, CGIAR, EU AFRICA RTD High Level Dialogue.

Indicators

Progress can be measured with the following indicators:

- % of new crops introduced as population's dietary energy and protein sources (today rice, maize and wheat provide almost 60%).
- % of people suffering of malnutrition: categorised by social groups such as elderly people, children and adolescents, in addition to groups in specific geographic regions (e.g. % of children in Africa).
- % of sustainable diets or foods commercially available.

4. Improve food processing with better outcomes for nutritional and sensorial food quality as well as the environment and food safety

Vision

The overall vision is to guarantee that food processing complies with circular economy and sustainability principles, while maintaining the nutritional value, safety and taste of the foods. Convenient and processed food will respond both to health challenges (less fat, sugar, salt, additives, rich in bioactive components and fibres) and sustainability challenges (reducing or upgrading by-products, reducing packaging, energy and water). Food processing will be transparent and better respond to different expectations of consumer segments with regard to food quality and safety.

There is a growing consumer demand for minimally (often named mild) processed food with naturally derived ingredients and additives instead of chemically synthesised additives, flavours and colorants (e.g. organic food). Traditional and handcraft type of processing gains momentum, as well as short food chains, although food safety risks might be increased. Therefore, it is worth to rethink food processing in a food system as well sustainability and nutrition perspective.

Furthermore, novel technologies, often developed for large-scale companies, are also available for SMEs. Research supports equipment suppliers on development of food processing at different scales. Food processing unit operations are downsized for smaller operations with local sourcing, responding to the growing demand for local, diverse and authentic food. Technologies suitable for on-farm processing or SMEs to produce final food products or semi-fabricated/intermediate products empower farmers and support the development of short and local food chains.

The food system of the future should also aim to reduce the chemicals "on" and "in" food. The ambition would be to integrate the tools at hand (e.g. robotics for precision farming, -omics, new breeding techniques, agro-ecology) and allow an increase in the safety of food (particularly when considering the "cocktail effects" or vulnerable categories of people) by decreasing the number of chemicals throughout the food chain. This addresses the social concerns (on chemicals used in the food chain), medical concerns (e.g. on potentially carcinogenic compounds present in the food chain) and environmental concerns (loss of biodiversity) which ultimately lead to the lack of trust.

Bottlenecks

The major bottleneck is that the food system is dominated by large companies. Furthermore, they make most profit on over-processed food products, which are promoted by strong branding and marketing. A bottleneck is price competition, which leads to food processing companies buying the cheapest raw materials on the global market. Furthermore, most of the companies do not use the full potential of by-products from processing, often resulting in loss of raw material streams with high nutritional value. Another bottleneck is the relatively low importance given to the nutritional value of foods and a tendency to over-processing to increase safety margins and reach far markets. Food supply chains for many products are too long and products and ingredients may be twice or three times processed before assembled into a final food product. The rising sales of more convenient foods with longer shelf life, which may be more sustainable, results often in a loss of nutritional value. Ingredients such as sugars, proteins, and starches are often highly purified and fractioned, which makes them universally applicable in many products. However, fractionation and purification affect the sustainable use of raw materials, energy and water.

Synergies with other Focus Areas

- *Tackling obesity* – Solutions to reduce sugar, fat and improve the nutritional value will contribute to tackle obesity.
- *Personalised nutrition* – Innovative processing solutions like 3D printing will enable implementation of personalised nutrition.
- *Healthy aging* – Tailored processing to needs of aging population regarding texture, flavours and availability of nutrients will be an important contribution for healthy aging.
- *Increase safety and transparency* – the processing solutions to be developed have to be transparent and better respond to different expectation of consumer segments with regard to food quality and safety.
- *Develop sustainable and climate-resilient food systems on a territorial scale* - The development and downscaling of mild processing techniques, which combines traditional with appropriate high tech approaches, can support more handcraft and small-scale type of processing.
- *Double the availability of high quality food production from EU aquatic systems* – Processing solutions to be developed here are also relevant for food from the sea, in order to increase accessibility.
- *Reduce food waste* – Processing foods and reducing/upgrading side streams can have a direct impact on waste reduction.
- *Upgrade innovation capabilities of actors in food systems* – processing at small scale and at the farm can empower innovation capacity of farmers and SMEs.

Contribution to SDG and other (EU-) policies

Food processing with better outcomes for nutritional and sensory food quality as well as environment addresses the following SDGs:

- *SDG2:* High availability of sustainable and nutritious processed foods will improve nutrition and ensure food security. It will contribute to end hunger and ensure access by all people, in particular people in vulnerable situations to safe, nutritious and sufficient food all year round. Promote access to food and fair and equitable sharing of benefits between farmers, producer and retailers.

- *SDG3:* Availability and high consumption of more nutritious foods will ensure good health and wellbeing.

- *SDG6:* Sustainable food processing requires reduction of water use. This will address water scarcity and substantially reduce the number of people suffering from water scarcity.

- *SDG7:* More sustainable production systems will reduce energy use per food consumed.

- *SDG8:* Agriculture is the single largest employer in the world – food processing, e.g. preservation and transformation of agricultural products, promotes agricultural growth. The solutions to be developed for processing at farm level will improve revenues of farmers.

- *SDG 12:* Re-evaluating and developing food processing with better outcomes for nutritional and sensory food quality as well as environment ensure sustainable consumption and production of foods.

- The European food processing industry has profited from significant support from the EU Framework Programme for Research and other EU initiatives like the Innovation Partnership. Furthermore, it responds to the EU Action Plan on Circular Economy (COM 215/0595 final) taking into account that solutions and supportive research and innovation must be adapted to the region and context.

- The Regulation (EU) 2015/2283 on novel foods is also addressed.

Trade-offs with other Focus Areas

Upgrade innovation capabilities of actors in food systems - There is often a trade-off between large food processing companies, which can invest in technically advanced food safety control systems and energy saving systems whereas small artisanal producers cannot make such investments for cost reasons.

To reduce food insecurity and increase the consumption of healthy and sustainable diets by doubling the variety of energy and protein sources produced - Processed plant-based protein rich products, if sourced from unsustainable practises (e.g. soya from former high nature value rainforest) and origin are not always more sustainable as meat products.

What needs to be done

Progress can be achieved in the following areas:

- Development of more integrated assessment systems of a) the multiple impact of processing technologies on characteristics of products including food structure, composition and stability, safety, nutritional and sensory quality, as well as b) of the impact on all sustainability dimensions (environmental, social, economic), public health and labour safety for different product groups.

- Development and validation of new technologies with regard to high consumer acceptance and little environmental impact and high nutritional quality. Support EFSA with evidence based data for assessment of novel technologies.

- Continuation of investments and efforts to reduce salt, sugar and fat in processed foods.

- Evaluate current processing practices and supply chains in terms of improvement of sustainability and nutritional value and impact on health of processed foods.

- Develop technologies to produce new food ingredients from by-products or improve existing ones.
- Innovative and sustainable processing solutions, e.g. process intensification, combining technologies for short food chains.
- Understand how to keep and naturally enhance taste in processed foods.
- Process control with ICT to improve and control food quality including nutritional value.
- Processing closer to the consumer, e.g., retailers, restaurants, catering, etc. to make healthier foods more available.
- Further development of traditional technologies (fermentation, cooling, drying, etc.) with less energy and water use while optimising the nutritional benefit (bioactive substances, etc.) based on new knowledge (e.g. nutrigenomics, human microbiome, food digestion).
- Development of advanced technologies, based on the "cradle–to cradle" and circular approaches, to make better use of the diversity and complexity in raw materials and to facilitate their total use.
- Scaled-down processing technological solutions for small-scale processing with local ingredient sourcing.
- Lower energy and water consumption and increase of water re-use during food processing.
- Stronger linking agricultural production methods (choice of varieties, terroir, type of soil) with food quality parameters and processing requirements.
- Linking sensory quality research to agronomic research with regard to the choice of varieties and cultivation system (e.g. processed fruits or cereals for biscuits or berries for yoghurts) and to consumer research (communication concepts).
- Development of processing solutions to tackle public concerns on chemicals and carcinogenic compounds.

Actors who should be mobilised

A multi-actor approach should be adopted, involving the researchers, industry, consumers and other actors in the agri-food chain.

Food Processing Industry: Evidence based criteria and decision support system for selection, design and development of processing technologies based on further developed sustainability assessment methods. Novel technologies available for natural structuring foods improving taste and optimal nutrients bioavailability. Further development of processing solutions to reduce sugar, fat and salt in ready to eat foods.

Retail, Food Service: More tasty and nutritious protein-rich processed food products instead of animal-derived meat responding to the VEGAN trend. Development of processing solutions to make healthy food more easily available in cities, schools, elderly homes, etc.

Equipment Manufacturers: Further development of sensing technologies for on-line quality control during processing to minimise product losses. Advanced and smart robotics solutions to improve use of raw materials/ minimise waste.

ICT Technology Developers: ICT supported tools (apps) for quick consumer information on health and sustainability impact of processed food types. Adapt food processing to scale by using digital technologies (e.g. Internet of Things) for process control systems.

Farmers and Artisanal Processors: Downscaling and development of processing methods to small-scale operations (SMEs, on-farm processing, households groups) will contribute to job creation and job retention in rural areas.

Regulators and Policy Makers: Data on food safety of minimal or mild processing methods for different product groups (e.g. less use of additives for milk and meat products for shelf life, sensory quality and food safety) will help to adapt food safety regulations.

Consumers: Better access to easy understandable data on the impact of processed food both on nutrition and sustainability will strengthen consumers' role in the food system. Better understanding of expectations and acceptability of specific consumer groups with regard to food processing technologies, which are perceived critically e.g. by dealing with organic food (nanoparticles in packaging, microfiltration and heating process for ESL-Milk, use of animal product-derived additives in wine like gelatine, etc.). New ways of communication and interaction between consumers and processing companies.

Indicators

- Multi-criteria sustainability assessment systems (e.g. FAO-SAFA guidelines) linked with holistic food quality parameters with relevance for human well-being and health.
- Reduction of environmental impact of food processing measured with some key indicators (non-renewable energy use in different processing operations, CO2, water footprint, etc.). Target: Reduction: 50 % until 2030.
- % of non-utilised waste (or by-products) not used for food for different product groups.
- New processing technologies merging in the market assessed for sustainability and health.
- Consumer acceptance (social research) for different novel food processing technologies in different countries and for different product groups.

5. Implement personalised nutrition strategies to reduce the incidence of Non Communicable Diseases in Europe by 50%

Vision

Personalised nutrition that fits people's needs, preferences, lives, health status, phenotype and genotype, has the potential to have major impact by empowering people to follow lasting healthy sustainable diets, which will lead to optimal health and well-being and prevent diet related diseases.

There is substantial evidence that the one-size fits all approach to nutrition advice is not effective and that there is significant inter-individual differences in response to food intake. In order to improve the diet of EU citizens it is critical that dietary advice is tailored to the individual. Development of smart personalised nutrition is necessary as unhealthy and unsustainable diets have a negative impact on health, the economy and the environment. 7 out of 8 major risk factors for premature death are linked to the way we eat, drink and exercise (high blood pressure, high cholesterol, high blood sugar, excess body weight, inadequate fruit and veg consumption, physical inactivity and excessive alcohol intake). Of the six WHO regions, the European region is the most

severely affected by NCDs, which, in turn, are the leading cause of disability and death. Recent figures quoted by the WHO report that the four major NCDs together account for 77% of the burden of disease and 86% of premature mortality[20].

The vision therefore is one of a Europe with a healthier population with reduced disease incidence enabled through consumption of sustainable diets tailored to the individual.

Bottlenecks

A bottleneck in realising this vision is that the systems for collection and translation of data into nutrition advice are not yet available. Furthermore, privacy issues for personal data and the potential use of such data by health insurance companies needs to be considered. Other bottlenecks include our lack of understanding of the personal physiological response to foods, lack of data in terms of bioavailability of nutrients and matrix effects and lack of understanding of drivers of food intake . Furthermore, delivery of personalised nutrition involves a complete re-shaping of the food retail environment to one that can guide the shopper based on their personal biological passport. Finally, personalised nutrition advice is not aligned to current national dietary guidelines and solutions to overcome this are necessary.

Synergies with other Focus Areas

Solving the challenges of this vision has positive effects on:

- *Reduce food waste:* Personalised Nutrition advice has the potential of reducing food waste by suggesting recipes/concepts for waste food. The smart algorithms could be dynamic enough to ensure food waste in the household is minimal.
- *Food processing with better outcomes for nutritional and sensory food quality as well as the environment:* Personalised nutrition will need to incorporate new novel food processing ideas and as a result there is synergy with this Focus Area.
- *Upgrade innovation capabilities of actors in food systems:* Significant innovation is needed at the food retail level for Personalised Nutrition so the synergies with the innovation Focus Area should be exploited.
- *To reduce food insecurity and increase the consumption of healthy and sustainable diets by doubling the variety of energy and protein sources produced:* Implementation of personalised nutrition will lead to consumption of healthy and sustainable diets.
- *Strengthen the different roles of citizens in healthy, diverse and sustainable food systems:* Implementation of Personalised nutrition has the potential to engage citizens and promote citizen science.
- *Diversify fields, farms and landscapes to achieve climate-proof and sustainable resource use:* Through personalised nutrition approaches that advocate for consumption of foods that are produced from climate friendly and sustainable systems.

Trade-offs with other Focus Areas

Personalized nutrition advice may recommend an increased consumption of animal derived food products to certain individuals. There could be trade-offs with the focus Area to increase consumer trust, if personal health data are not sufficiently protected and if

[20] http://www.euro.who.int/en/health-topics/disease-prevention/nutrition/nutrition

big companies (health insurances companies or retail chains) determine personalised nutrition of individuals only based on their commercial interests.

Contribution to SDG and other (EU) policies

This Focus Area can help address the following:

- *SDG2 (End hunger, achieve food security and improved nutrition and promote sustainable agriculture).* Implementation of personalised nutrition strategies will deliver improved nutrition and ensure food security for a larger proportion of the population.

- *SDG3 (Ensure Healthy lives and promote well-being for all ages).* Implementation of Personalized Nutrition strategies has the potential to ensure that by 2030 there is a reduction by one third in premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being.

- *SDG 11 (Sustainable Cities and Communities).* Promotion of food environments that enhance personalised nutrition will in turn lead to sustainable cities and communities.

- *SDG12 (Ensure sustainable consumption and production patterns).* Adoption of Personalised nutrition approaches will support the adaptation of sustainable consumption patterns.

- *WHO European Food and Nutrition Action Plan 2015–2020.* Implementation of Personalised nutrition has the potential to aid the delivery of this action plan[21].

- *Rome Declaration on Nutrition.*

- *WHO Global action plan for the prevention and control of NCDs 2013-2020[22].* Personalised nutrition has the potential to contribute to this.

- FOOD 2030 for a food and nutrition security[23.]

- White paper on a strategy for Europe on nutrition, overweight and obesity related health issues.

What needs to be done

Progress can be achieved in the following areas:

- Developing strategies for Personalised Nutrition that are based on physiological responses incorporating omics technologies, diet related behaviour, motivation and decision making. Work needs to incorporate metabolic phenotyping, genomics, gut microbiome, nutritional requirements, preferences, lifestyle, socio-cultural factors, wearable sensors and new biomarkers in order to determine the optimal nutrition for an individual.

- Better understanding of the biology underpinning individual responses and translation into personalised nutrition advice.

---

[21]http://www.euro.who.int/__data/assets/pdf_file/0008/253727/64wd14e_FoodNutAP_140426.pdf

[22] http://www.who.int/nmh/events/ncd_action_plan/en/

[23] EC Staff working Document SWD (2016) 319.

- Inclusion of parameters to ensure that personalised advice facilitates a shift to more sustainable diets. Recommendations could be delivered at a food level incorporating the environmental impact of the food production.

- Understanding the impact of the food environment and the incentives and factors influencing motivation and behaviour change and developing strategies for incorporating them into commercially independent dietary advice at a personal level.

- Development of natural structured convenient and nutritionally personalised ready to eat food products that incorporate learning on food matrix effects and variability in bioavailability. Furthermore it is possible that such food products could also be delivered in "healthy vending machines".

- Development of new processing solutions to provide personalised foods (e.g. 3D printing for elderly or young adults), while ensuring protection of personal data.

- Re-design of food retail sector to enable a consumer to shop based on analysis of their personal profile incorporating physiological data, behavioural, cultural and financial data. Delivery of systems that would provide weekly meal plan to families based on their personal data.

- Innovative measures to link food producers with personalised nutrition providers.

Actors who should be mobilised

For the implementation of personalised nutrition strategies, a number of different actors need to be involved:

Nutrition Scientists: Significant work is needed to understand the physiological responses to food in order to develop personalised nutrition. Work needs to incorporate metabolic phenotyping, genomics, gut microbiome, wearable sensors and new biomarkers in order to determine the optimal nutrition for an individual.

Food Retailers: re-design of the supermarket in partnership with consumers to deliver a technologically advanced supermarket where on entry one would be guided through based on their personal profile. Development of on-line food shopping tailored to personal needs, incorporating consumer desires and family menu planning. New ICT solutions will be necessary to enable links between personal data and food delivery/shopping options.

Food Producers: opportunities to link with producers with short supply chain to deliver sustainable options for consumers.

HealthCare Providers: Delivery of personalised nutrition solutions that can be delivered as part of routine healthcare. Evaluation of potential options and demonstration of efficacy in terms of health improvement.

Food Processing: development of innovative processing approaches, for example 3D printing, for delivery of personalised foods for the elderly. Enhancement of our understanding of the bioavailability of nutrients from different foods and impact of food matrix. Development of natural structured convenient and nutritionally personalised ready to eat food products could also be delivered in "healthy vending machines".

Consumers: Personalised nutrition solutions have the potential to be transformative; however, consumers need to be at the centre and involved in co-design of solutions/strategies in order to ensure success. Understanding the impact of the food environment, incentives and factors influencing motivation and behaviour change.

Scientists in Circularity and Climate: Development of algorithms to deliver personalised nutrition advice incorporating climate impact of the food as a factor.

Policy Makers: Interaction is needed to align personalised nutrition approaches with the national dietary guidelines and to ensure protection of personal health and dietary data.

Indicators

Progress can be measured with the following indicators:

- By 2030 30% of consumers that make use of personalised nutrition advice
- The incidence of Non Communicable Diseases in Europe. Target value: reduction by 50%.

B. Create a resource-smart food system with 50% less greenhouse gas emissions by 2030

Bold, inspirational with wide societal relevance: Coping with climate change is an important challenge for our food system. Farming has to adapt to the effects of changes in the weather patterns that will effect diseases and yields. Aquaculture and fisheries have to deal with different species and threats such as more frequent storms and harmful algae blooms. Being responsible for roughly a quarter (1180 Mtons) of the emissions of CO_2-equivalents in the EU, the food system can also contribute to the mitigation target of the Paris agreement. In the future resource smart food system, food waste and food losses will be minimal. Circular economy principles bring waste (including bone meal, swill, phosphate from human excreta) back in the production cycle in a safe way. Soils store carbon. The role of animals in the food system will be reduced: following current trends in demand as well as in order to fulfil nutrition and environment objectives, future diets could be much more based on proteins from crops and aquaculture, and animal systems could be redesigned to low impact systems based on waste streams and non-edible plants (grass) grown on places where feed production does not compete with food production. New types of feed from insects and algae could help. Food systems should not only be redesigned for strongly reduced CO_2 emissions but should become resource-smart in general (UNEP, 2016). The negative impacts of packaging (plastics) need to be reduced. The transition from the fossil-energy to the renewable energy era, combined with advances in ICT and precision farming techniques, will lead to more sustainable food production systems better exploiting innovative technologies and agri-ecological principles. Crops diversification (like in strip-farming), will help to reduce use of pesticides and fertilisers and will promote territorial solutions better adapted to local environmental conditions, preserving biodiversity, soil fertility and the availability of water.

A clear direction: targeted, measurable and time bound: This mission calls for a redesign of the food system that results in a production system with a full-fledged contribution to the European climate challenge, that respects environmental limits concerning water quality and quantity (use of irrigation), air quality (ammonia, odour, fine particles), biodiversity (pesticides, natural habitats on farms), soil degradation, does not pose unnecessary risks for public health (fine particles, zoonosis, use of antibiotics) and respects ethical demands (e.g. animal welfare). Production systems should stay at the safe side of the maximum sustainable yields. Multiuse of the marine space should lead to a win-win situation among different economic activities at sea. Reduced production and

consumption of livestock products would free up a large area that is currently used for feed production, allowing highly sustainable and resilient production models to be prioritized and put in place without compromising total food production in the short-term, and in a way that secures the long-term production capacity of soils and agro-ecosystems. A growth of the marine and fresh water production systems, healthy proteins for food and feed (algae) helps too. The redesign should also result in a consumption system that is characterised by sustainable diets with minimal waste, which is recycled in a safe way. Such a diet should be affordable for all Europeans. Farmers and fishermen should have a fair income that is not based on subsidies, other than agri-environmental contracts to supply public goods (like landscape or water management).

Ambitious but realistic research and innovation actions: Science understands better than ever how plants grow and how ecology works, thanks to progress in (system) biology and genetics. New technologies therefore can help to ensure that crops better cope with climate change or diseases. The internet of things and artificial intelligence make precision farming with a sharp reduction of chemical inputs a realistic option and developments in machinery (tractors, smart fishing gears, smart real-time sensors, drones for underwater inspection) will partly mirror those in the car industry: self-driving robots and electrification. This opens up options for a full redesign of the production system, comparable to the introduction of the tractor and the pesticides in the 1950s. But such technologies do have negative aspects too, such as the impact on employment, or ethical and data ownership implications. We need a societal debate from the start to ensure responsible innovation in this area.

Cross-disciplinary, cross-sectoral and cross-actor innovation: More ecological understanding of agro-ecosystems is now available to redesign food production. Innovative changes in the organisation of primary production and agro-ecosystems have been developed by groups of farmers and need support for upscaling.

The way that farmers produce is heavily influenced by the input-industry and food processing, more than by environmental and agricultural policies. Innovations delivered by the input-industry (machinery, installations, pesticides, feed) helps farmers to raise labour productivity and the potential to earn an income comparable to increasing wages in the rest of the economy. Labour productivity leads to farm enlargement and intensification. However, this intensification process can occur to the detriment of the environment, and to farmers themselves, in a context of low food prices and high input costs, unless steps are taken (by the food industry, by governments) to ensure that it pays to farm sustainably. Research and innovation are therefore cross-actor and include input industries, ICT and food processors. Food processors and retail have an important role in increasing the consumption of healthy, sustainable diets (see mission A for details).

Cross-disciplinary research is needed here between areas like animal and plant science, food science, environmental science, computer science and social science including economics. There is a need to redesign innovation systems and work much more closely with farmers in a co-creation mode, as many solutions are linked to local natural circumstances. Linking those local and regional experiences in European thematic networks can speed up innovation. Special attention is needed for joint innovation programs with Africa and the Middle East (EU-African Union priority on Food and Nutrition Security and Sustainable Agriculture) as demographic developments and climate change lead to food insecurity in those regions, a situation linked with war and migration. The FAO "Scaling up Agroecology Initiative" is relevant too.

Multiple bottom-up solutions: Given the different pathways that contribute to the mission and the local or regional territorial aspects of the innovations in which one size will not fit all, multiple bottom-up solutions exist and are needed for a resilient food system.

This mission can be supported by a portfolio of 7 Focus Areas:

6. **Territorial systems:** Develop sustainable and climate-resilient food systems on a territorial scale.

7. **Diversified systems:** Diversify fields, farms, landscapes and diets to achieve climate-proof and sustainable use of resources.

8. **Low impact animal systems:** Redesign, re-integrate and encourage low impact animal production systems.

9. **Smart soil use:** Arrive at a truly sustainable and smart use of natural resources: zero land degradation by 2030, healthy soils, reduction of the yearly input of virgin minerals (such as phosphate) by 50%.

10. **Reduce impact packaging:** Reduce the environmental impact of food packaging by 2030 by 75%.

11. **Halve food waste and losses:** Halve food waste and food losses from the EU food and farming system by 2030.

12. **Double aquatic production:** Double the sustainable production of high quality food from EU aquatic systems by 2030.

We discuss these Focus Areas in detail below.

All these Focus Areas are linked with one another. It is only conjointly that they make a relevant and coherent programme for innovation: for instance, diversification in crop production and re-integrated animal production systems within territorial approaches to innovation are possible only when implemented in interaction with one another. They also need the changes in diets and nutrition presented in Mission A to lead to the expected performance on the economic, social and environmental performance dimensions of sustainability.

6. Develop sustainable and climate-resilient food systems on a territorial scale

Vision

There is growing evidence that technological innovations will need to be complemented by major social and organizational innovations in order to respond to the scale and urgency of sustainability challenges (SCAR, 2011; IEEP, 2017; IPES-Food, 2016). Humanity has already exceeded the 'safe operating space' in the domains of biodiversity loss and disturbance of phosphorous and nitrogen cycles - all closely linked to agriculture (Rockstrom et al., 2009, Steffen et al., 2015). Many of the severest environmental risks in food systems are linked to the de-territorialization of food systems and the spread of input-intensive monocultures, highly concentrated animal production, and the resulting disruption of ecosystems and the crucial services they provide, both in the EU and in third countries where EU demand for agricultural commodities helps to drive unsustainable land use patterns (Witzke et al., 2010).

Calls for a more fundamental redesign of food and farming systems have therefore been growing. Notably, after a 4-year process involving over 400 international experts, the International Assessment of Agricultural Science and Technology for Development called for a wholesale reorientation of agricultural science and technology towards more holistic, multi-sector approaches including agroecology, diversification and sustainable intensification (IAASTD, 2009); similar concerns have been reiterated in recent international studies, with the re-diversification of agriculture increasingly seen as a prerequisite for environmental performance and climate resilience at various levels (Godfray et al., 2010; Meynard et al., 2013; OECD, 2016, HLPE, 2015).

In particular, redesigning food and farming systems in a way that maximises synergies across a given territory holds major potential to support this shift (e.g. synergies between different forms of production, between local food supply and local food demand, between waste flows and re-use opportunities, between the ability to supply eco-system services and the need for those services). Reconnecting actors and rebuilding infrastructures on the local/territorial level can facilitate the sequenced shifts (in production, processing, consumption, waste management etc.) that are required to drive change in a context of highly interconnected actions along the food chain (see Part 2). Territorially-focused food systems innovation connects actors at a local or regional level to find a first layer of solutions to close fertility gaps, to reuse waste, promote complementary land uses and to reduce environmental externalities and maximize ecosystem services to the extent possible - rather than mainly relying on externalizing problems to other ecosystems, regions or countries.

Innovation focused on rebuilding sustainable territorial food systems can complement steps to increase sustainability in global supply chains, allowing the respective efficiencies to be maximized across the food system. Where incentives and infrastructures have previously been missing, territorial innovation approaches can help to bring short supply chain models to fruition, e.g. via innovative tools for aggregating producers and connecting them to local markets, alongside public procurement policies that provide opportunities for local, seasonal production. This can unleash virtual circles: as some supply chains become shorter, more sustainable and more transparent, people become more willing to pay the true cost for sustainable food production; this in turn allows small-scale farmers to stay in business, helping to maintain production diversity and avoid regional monocultures. Furthermore, cooperative territorial governance structures (e.g. local food policies and food policy councils) can be formed on the back of newfound alliances between farmers, environmental campaigners and consumer/health groups. Meanwhile, the re-emergence of short supply chains and small and mid-sized food processors and retailers applies pressure from below, forcing mainstream actors to move further and faster to align with best practices in terms of offering opportunities to local suppliers and ensuring equitable distribution of the costs and benefits of delivering more sustainable supply chains. Power in food systems is gradually rebalanced, paving the way for more democratic decision-making and wider trust and engagement in food systems.

Bottlenecks

- Current economic and political incentives (e.g. CAP subsidies, non-capture of externalities) work in favour of economies of scale, large-scale production of agricultural commodities and export-orientation. Innovation focused on diversification and system redesign does not tend to produce patentable technologies, requires longer time periods to deliver results, and is ill-adapted to the publishing constraints of major academic journals, which tend to focus on breakthroughs at the plant, cell and molecular levels (Vanloqueren and Baret, 2008).

- Based on economies of scale (see above), food chain activities such as processing plants and slaughterhouses have been consolidated into large-scale centralized operations, and are now absent in many regions.

- Policy tools for sustainability tend to focus on the individual farm (e.g. diversification requirements under CAP), but sustainability challenges cannot be solved only at this scale due to interlinkages between farms through ecosystems but also through supply chains and markets.

Synergies with other Focus areas

Promoting territorial food systems innovation could draw on major synergies with several other Focus areas.

- It would support achievement of Focus area 1 (Obesity) by incentivizing access to fresh foods via short supply chains, and the creation of healthier food environments as an aspect of redesigning territorial food systems.

- It would help to achieve the goals of Focus area 7 (Diversification) and Focus area 8 (Livestock) by helping to create the governance frameworks and modes of supply-side and demand-side collaboration required to support the re-diversification of agriculture and relinking of crops and livestock.

- It would support all Focus areas focused on promoting circularity and resource efficiency i) by helping to provide the local governance structures to manage those resource flows; and ii) by promoting synergies between different types of production within a territory (e.g. crops and livestock) in a way that maximizes available resources and minimizes waste.

Contribution to SDGs and other (EU-) policies

- SDG2: Territorial food systems will help to rebuild food production capacity in all regions, while relieving the pressure on overstretched ecosystems in commodity-exporting regions; by promoting short supply chain initiatives, they will provide additional opportunities for small-scale food producers.

- SDG12: Territorial food systems will pave the way for complementary land uses and resource flows.

- SDG13: Territorial food systems will facilitate major GHG reductions by promoting agri-diversification and reducing the external impacts of EU food systems; particularly through a reduction in protein feed imports.

- SDG15: By promoting diversification and the re-integration of agriculture with ecosystems, territorial approaches will help to rebuild biodiversity and sustainable land management.

Trade-offs with other Focus areas

This Focus area could lead to some trade-offs with Focus area 4 (doubling the variety of energy and protein sources used on food production) and Focus area 13 (increasing consumer trust by 50% by improving transparency and safety along the chain). Increasing the sustainability of protein sources could be achieved via territorial food systems, but increasing the variety of protein sources is a goal that would need to be met primarily via international trade. Likewise, steps to increase traceability typically entail costs and requirements that are more easily met by larger operators working with big volumes; this cannot be easily reconciled with territorial food system approaches aimed at facilitating short supply chain initiatives. To manage these trade-offs, policies would need to take account of the diversity of supply chains, ensuring that both are duly prioritized, and allowing both to flourish and to deliver their respective efficiencies.

What needs to be done

To develop sustainable and climate-resilient food systems on a territorial scale and address the bottlenecks described above, R&I would need to be increasingly focused on overcoming organizational and governance-based challenges. Progress can be made in the following areas:

- Supporting innovative projects involving actors across territories to redesign the food system and the local bioeconomy for triple performance (climate and environment, social, economic), ideally combining technological, social and institutional innovation;

- Developing and piloting new territorially-based governance models such as urban food policies, food policy councils, city-region food system planning;

- Developing and piloting innovative solutions to allow processing/slaughter facilities to be re-regionalized (e.g. mobile slaughterhouses; shared processing hubs);

- Promoting technological and organizational innovations (e.g. new cooperative, cost-sharing models) for transferring compost, manure, urban organic waste etc. to farms requiring fertility;

- Developing and piloting new integrated toolkits to support farmers to diversify production (e.g. new subsidy approach, new forms of credit and insurance, new extension services) via close cooperation between research, agriculture and rural development policies;

- Gathering evidence and promoting experimentation in terms of relocalising food supply chains in commercial settings (e.g. supermarkets) and public canteens (e.g. schools, hospitals);

- Furthering developing and refining full-cost accounting and lifecycle carbon footprint methodologies in order to demonstrate the sustainability of relocalised, reintegrated food systems.

Actors who should be mobilised

By definition, R&I focused on delivering sustainable territorial food systems requires the involvement of multiple food system actors in order to be successful. This includes:

Farmers: Territorial food systems require farmers to collaborate with each other and with other food chain actors in redesigning food systems and targeting new markets.

SMEs in Food Processing and Distribution: Small businesses in the food processing and distribution sector would need to work closely with farmers and with each other to offer a well-functioning alternative to the efficiencies of mainstream supply chains.

Municipal Authorities (including Public Procurement, Health, Waste Management, Environmental Protection Services): Local authorities at the city and regional levels have a key role to play in developing integrated territorial food policies that create the conditions for maximizing synergies across territorial food systems.

Farm Advisory/ Extension Services and Researchers: Farmers would need to be supported with the relevant knowledge, information and training services to undertake major shifts in production and marketing; case studies of successful transition would need to be documented and brought to light to embolden others to undertake similar initiatives.

Civil Society Groups: Given the importance of social and organizational innovations in building sustainable solutions at the territorial scale, civil society groups from across the spectrum of interests (consumer rights, health environment etc.) have a key role to play, and can pool their knowledge of how to drive durable behavioural change as part of emerging territorial governance structures (e.g., urban food policy councils).

Indicators

- Reduced dependence on protein feed imports and reduction in virtual land area required for EU food consumption

- Share of value of final product going to farmers (in all supply chains)

- Share of direct sales relative to total food sales
- Share of food in public canteens sourced regionally
- Implementation of sustainable public procurement policies and action plans
- Number of crops and their shares in the total amount of arable land in a farm holding (crop diversification measures: EC- JRC (EC, 2015)
- Reduction of stocking densities in sensitive livestock areas and watersheds
- Maintenance of permanent grasslands

7. Diversify fields, farms, landscapes and diets to achieve climate-proof and sustainable use of resources.

Vision

Diversification is being considered at the centre of future food production systems across scales (farm, field and landscape) and a pillar for environmental protection and the conservation of biodiversity. Under a food system approach, it will face the multi-facet challenge of balancing the **trade-offs between providing human food and nutrition needs and halting the degradation of the natural resource base**, GHG emissions and biodiversity loss (FAO, 2012; FAO, 2017; EC, 2017, UNEP 2016). Particularly, diversification of agricultural systems is a necessary condition to reduce intensive use of production inputs (pesticides, chemical fertilizers, water) to expand integrated agroforestry and livestock systems and for enabling the expansion of vegetal protein crops and legumes. These play a major role in the nutrient cycle of agro-ecosystems and in human diets to substitute or complement animal protein sources. In this direction, diversified production systems are being increasingly perceived as a major condition for augmenting resilience to climate change, for achieving environmental sustainability and for preserving biodiversity (Maynard, 2013; Godfray et al,. 2010; OECD, 2016). However, diversified low-input crop supply chains and more complex agronomic practices and crop rotations are not sufficient to achieve environmental objectives as it will be necessary to complement diversification with other types of improvements in the crop production systems (e.g. precision farming, new breeding technologies). For this to be achieved, public investment in R&I will be necessary to support diversification strategies considering that these actions go against the economies of scale of the specialized intensive mono-crop cultivation areas of many EU regions. In turn, diversification enlarges the opportunities for **decoupling food production from environmental degradation** (UNEP, 2016; EC 2017). This decoupling trend is further strengthened by spatial-specific farm and field diversification strategies promoting sustainable intensification of food production. Equitable access of food producers (small and large) to knowledge and technical developments and to financial markets will be geared to augment efficiency in soil use, adapted breeds, water use and management and overall effective governance. In addition, there is a need to strengthen local and regional programs for promoting effectiveness in the use of ecosystem services, such as regulation services (e.g. water), preservation of landscapes and biodiversity and for supporting climate change adaptation programmes.

Policy responses and governance systems should be better aligned, multidimensional, spatially integrated, (to take account for diversified systems at farm, fields and landscape levels) and with a strong multi-stakeholder participation and representation along the policy process. Policy support, (EU and international trade agreements) will need to be strengthen and focused to encourage expansion of protein rich legume production to reduce environmental impacts and a balanced diet transition towards more vegetal protein-rich intake. These bottom-up approaches are necessary to scale-up innovations -technical, social and institutional- undertaken at diversified local

contexts (OECD, 2016; EC, 2017). Policy coherence will need to be reinforced, linking actions and regulatory frameworks across agricultural and environmental polices (e.g. CAP, WFD, CC) as well as fiscal and social policies.

Multi-actor inclusiveness and participation along the entire value chain of food production is a crucial step for diversification purposes. Actors that manage food systems are managers of natural resources and therefore are important agents of change that preside the dynamic pathways for transition towards diversified sustainable food systems and its intervention logic (Hammond & Dubé, 2012).

In international trade policies, there will be new initiatives along the food system value chain for linking food production and food consumption, where all actors, farmers and processors, as well as governments will be major players augmenting cooperation and coordination, and to internalize environmental externalities not reflected in food prices

Bottlenecks

- Current CAP Pillar 1 incentives for crop diversification in the Greening scheme are not sufficiently developed for delivering environmental and climate goals and are an impediment for encouraging diversification. Along the same line, Biodiversity-based payments are not adequately supported.

- Economies of scale: specialization and mass production as well as information and dissemination of innovation are more profitable for unified large farms. This results in spatial concentration of single-crop productions rather than promote diversification for climate resilience, environmental protection and biodiversity conservation.

- To consolidate and support crop and farm diversification (to reach environmental and climate proof objectives) a variety of technological options in production and transformation must be available for farmers. However, investments are not easily affordable for small diversified farmers (e.g. precision farming for small scale requires downsizing of machinery, minirobotics). Ongoing market concentration in the upstream input and breeding industries represents a potential obstacle in terms of promoting innovations that are specific to and appropriate for the local ecological and socio-economic conditions faced by primary producers.

- As new trends in technology are knowledge-intensive, public investment in knowledge production is necessary and could become an impediment for some small farmers. Furthermore, more knowledge of agro-ecological and organic farming best practices is needed.

Synergies with other Focus Areas

The vision of the Focus Area on Diversification, could draw upon synergies with several Focus Areas:

- *Territorial scale (6):* Diversification of farms, fields and landscapes that are scale and context-specific will enhance the role of the territorial scale and local governance systems to attain decentralized and efficient food production, resilience of farming systems, environmental sustainability, climate adaptation and human health.

- *Low-impact animal production (8):* will benefit from diversified crop production systems enabling the integration of extensive, low-input, low environmental impacts of integrated animal-vegetal-forestry productions systems. It will enhance the opportunities for decoupling food production from environmental degradation.

- *Reduce food insecurity (4):* Strategies for attaining diversity at the scale of field, farm and landscape areas and regions, will permit access to a greater variety of protein sources used in food production. Thus, it will complement the global vision of this Focus Area to meet nutrition demands and consumer preferences by crop diversification adapted to EU regions and reduce greenhouse emissions.

- *Sustainable and smart use of natural resources (9):* Diversification strategies will have the potential to support resource use efficiency and circularity by strengthening the synergies across various types of productions (mixed vegetal-animal productions, low-input use legume productions), diminishing environmental impacts and managing resource flows.

- *Upgrade innovation capabilities of actors in food systems (14):* Synergies with this Focus Area would enhance the capabilities of actors in the food production system to engage in innovation and technology processes to implement diversified, local-specific agricultural production strategies. These synergies will support the scaling-up of technical and social innovations (e.g. precision farming, new modes of governance) undertaken at diversified farms and landscapes.

Contribution to SDGs and other (EU) policies

SDG2. Diversification of farms, fields and landscapes will contribute to the sustainability and climate-resilient food production systems, by encouraging sustainable intensification increasing productivity and reducing the use of chemical inputs. Diversified agro-ecological production systems encourage the maintenance of natural landscapes and biodiversity (SGD2.5). Diversified farming and the adoption of low-input technologies needs to ensure equitable access to technological developments and extension services to all types of producers and therefore it will contribute to the development of rural infrastructures and local farming communities (SDG2.6).

SDG6. Diversification and climate-resilient farming will contribute to supporting low water demand cropping systems and therefore an efficient use of water resources, being irrigation agriculture one of the major drivers of farming diversification (SDG6.4). One important characteristic of diversification of farms and fields is the necessary adoption of demand-side water policies (e.g water pricing and quotas) aligned with agricultural policies (e.g CAP and the WFD) to address water scarcity in a sustainable technology-driven and policy-driven context. This integration ensures sustainable fresh water withdrawals across farms and landscapes, the adoption of IWRM and the protection of aquatic ecosystems (SDG6.5; SDG6.6)

SDG12. Diversified production systems contribute to the sustainable use and management of natural resources, such as land and water, the protection of ecosystems and the provision of ecosystem services (e.g. water regulation services)

SDG13. Diversification needs the integration and coherence of agriculture, environmental and climate change policies and therefore it will contribute, among other factors, to encourage the expansion of protein-rich crops and reduction of GHG emissions.

SDG15. Diversified agroforestry and livestock systems support the integration of agricultural systems and ecosystems (agro-ecosystems) and contribute to the maintenance of terrestrial and freshwater ecosystems, halt land and soil degradation and protect biodiversity

Contribution to EU Policies:

CAP towards 2020 (2010); CAP regulation (2013); CAP reform package (2017); CAP European Agricultural Fund for Rural Development (EAFRD) (2013); Water Framework Directive (2000); PRIMA (Partnership for research and innovation in the Mediterranean Area) (2016); Roadmap for a Resource efficient Europe (2011); EU strategy on

adaptation to Climate change (2013); Paris climate change agreements. Climate actions/COP 21.

Trade-offs with other Focus Areas

Undertaking this Focus Area there could some trade-offs with the Focus Areas related to nutrition and health as these might not involve necessarily an EU-wide and regionally-based diversified and sustainable production system:

- *(Focus Area 3) To reduce food insecurity and increase the consumption of healthy and sustainable diets by doubling the variety of energy and protein sources used on food production.* A variety of protein sources could come from food imports, thus to counterbalance both actions (SMs) there will be a need to support diversified local productions and processing plants and revise international protein-based food production standards.

- *(Focus Area 13) To increase consumer trust by 50% by improving the authenticity, transparency and guaranteeing safety along the Food system by 2030.* To reduce trade-offs and attain synergies of both SMs, it will be required to differentiate the safety standards of the local and short value chains retailers from the centralized large retailers.

What needs to be done

To achieve diversified farming systems progress can be made in the following areas:

- Support innovations along the entire supply chain to foster diversification with the aim to counterbalance the single crop trend (due to economies of scale, regional agro-climatic comparative advantages for a given crop, and lower crop prices).

- Develop strategies for reducing farm intensification for all farm inputs (fertilizers, pesticides, water), and diversify crop rotations to achieve diversification at the scale of farms, landscapes, production areas and regions.

- Support the cropping of more diversified N fixing and extensive leguminous protein crops across EU regions and local sites to build resilience to climate change and reduce demand for fertilizers. Develop certifications of production origin (e.g. organic farming). Support transition from animal protein sources to vegetal proteins.

- Support the integration of crop production with forestry and animal productions in single diversified farms. Use the potential of integrating and developing perennials in agro-forestry systems (permaculture). At the landscape level, support the combination and integration of specialized farmers in one single production that would result in diversified landscapes and the provision of ecosystem services.

- Support investment in R&I programs for assessing the benefits of diversification (climate change resilience and risk shelter, environmental sustainability, provision of ecosystem services, job creation and economic development).

- Develop investment in management practices and new forms of governance to permit a well-balanced and effective use of diversified agricultural production potential and the provision of ecosystem services and biodiversity.

- Development of education and training programs (tool kits) to understand the links between diversified farming practices, protection of natural resources, climate resilience and healthy diets involving a wide range of actors along the entire supply chain, facilitating collaborative schemes (regulations, codes).

- Overall, direct R&I to better understand the scientific base of the 'food systems approach' for explaining the interlinkages between the natural system and human activities, under an integrated multi-disciplinary, multi-actor, economy-wide value chain, social-inclusiveness and policy coherence.

Actors who should be mobilised

Diversification for attaining climate proof and sustainable food production systems needs the involvement of multi-level actors along the entire food production and consumption chain.

Farming sector: It requires the involvement of food producers, such as individual **farmers and farm cooperatives**. Access to new varieties to address diversification will require the involvement of **plant breeders** and the adoption of new technologies (e.g. irrigation, tillage, precision farming, satellite, low-energy) will require the participation of **machinery companies, ICT industry, renewable energy companies, data and information companies. Farm insurance companies** are also important to reduce climate and market risks of new varieties.

Processing and consumption sector: SMEs related to food transformation, processing and distribution. **Retailers** that develop new labelling systems that reflect differences in the product to reach consumer preferences (e.g palatability and taste). **Consumer organizations** are important actors to valorize the performance of different types of crop varieties and food products that increase consumer acceptance and maintain competitive prices.

Government Authorities: Municipal authorities are key players for local-scale farmers and producers, dissemination of new technologies and advisory services. **Regional** (as well as **state-level**) authorities are key for ensuring the application of agricultural and environmental policy programs, such as the CAP , the WFD, the regional climate change measures (e.g. new climate-resilient crops), **River basin authorities** are important stakeholders for delivering sustainable water services at farm and basin levels and for assuring the preservation of aquatic ecosystems.

Civil society organizations and NGOs, are important actors in the co-production of innovative farming and organizational systems in cooperation with farmers and researchers. They play also a major role in consumer protection rights. Given the key role of diversification in the protection of the environment, landscapes and biodiversity, Environmental NGOs are important actors for assuring a sustainable transition to diversified production systems

Indicators

- Number of crops and their shares in the total amount of arable land in a farm holding (crop diversification measures: EC- JRC (EC, 2015)
- Proportion of agricultural area under productive and sustainable agriculture
- Number of farms adopting precision agriculture techniques and linked % reduction of external inputs use (fertiliser, pesticides)
- Water use efficiency, agricultural water productivity, freshwater withdrawal as a proportion of available freshwater resources, , area under IWRM
- Public expenditure on conservation and sustainable use of biodiversity and ecosystems

8. Redesign, re-integrate and encourage low impact animal production systems.

Vision

Animal production systems have been thoroughly re-designed to be able to adapt to rapid changes in demand for animal products in the EU and globally, as well as to changes in climate, and in environmental and animal welfare requirements. They have developed strategies for higher added value, lower environmental impact and higher resilience to changes in climatic and socio-economic conditions. Animal production levels have also been decreased, which has posed a challenge to regions specialised in intensive animal production (sharp reduction in stocking densities and in use the of feed inputs), for which reconversion strategies have been developed towards low impact systems (that are not necessarily low input) and higher added value per unit of animal product. In low input production systems and regions, extensive and grazing systems have been the object of innovation to increase the value produced while ensuring a reduction in environmental impact as well as the preservation of positive externalities.

They have radically reduced their contribution to GHG emissions and are re-integrated in their agricultural and ecological landscape, closing the cycles of nutrients as closely as possible from the local scale. This implies, valorising manure as a by-product for fertilization, to avoid emissions into the atmosphere and to waters, as well as reducing their dependency on external feed inputs, that make the production very dependent on always more intense international markets (like soybeans for feed), and thus constitute not only an economic risk in terms of variability but also a political risk given the concentration of large consumers and producers globally. The reduction in feed inputs also constitutes a contribution to global food security by reducing the pressure of these production systems on land that can be used to produce food for humans. To respect the food first priority and the cascading principles, as well as to reduce GHG emissions from feed, they are mainly fed on permanent grasslands, the grass of which is not edible by humans, and on waste streams from arable production, the food industry and the retail sector (Schader et al., 2015, Mueller et al., 2016). The role of grassland in carbon storage and in water pollution reduction is rewarded in payment for ecosystem services schemes. Grazing landscapes, for which the role of these animal production systems is crucial, are valorised in public policies and also on markets, as a quality label encapsulating environmental and landscape positive externalities, as well as nutritional and food quality value.

Animal production systems have also been redesigned to reduce their vulnerability and increase their resilience and resistance to zoonosis, while reducing the use of antibiotics and antimicrobials, as well as improving animal welfare conditions. They are thus also better connected to changes in the demand for animal products, and have built trust between producers and consumers, thanks to high standards in transparency, traceability and food safety, enabling them to take a prominent position on international markets.

Bottlenecks

A first bottleneck is that, to improve jointly the impacts of animal production systems on all these dimensions, and to minimize trade offs between them, **system scale innovations** (in the design of the production system, of its integration in the local landscape and ecosystem, as well as in the organisation of the value chain and the food system and connection to consumers) is needed, complementary to innovations in breeding, feed processing, buildings or machinery, as well as innovations to **improve working conditions and attractiveness of jobs** in the livestock sector. This scale of innovation necessitates an innovation system embedded in regional and local territories, and with public support. Depending if current systems are extensive, intensive, ruminants or monogastrics, specialised animal production or mixed crop/livestock systems, the innovations can consist either of developing a policy framework and marketing strategy to maintain the current low impact systems, or on the opposite to redesign completely the system.

A second bottleneck in realising this vision is that repeated crises in the animal production sector (avian flu, BSE, milk safety standards, fipronil) tend to particularly impact the smaller and more vulnerable production systems from the sector and favour consolidation of larger animal production systems, with an incentive to increase the size of herds and to favour strategies of mass production, rather than **differentiation and added value strategies**. This trend is reinforced by current policy incentives, that support investment strategies in line with economies of scale rather than differentiation, and that have also long favoured other productions over grasslands (for instance through biofuel incorporation mandates and despite specific support dedicated to permanent grasslands). To limit the impact of effluents on local and landscapes and ecosystems, the size of production (and the size of herds) needs to be adapted to the absorption capacity of the local ecosystem, as well as to seek for a differentiation through added value. This necessitates both **innovative marketing and communication strategies** to ensure the differentiation strategy and the added value (environmental and landscape externalities, traceability, safety) are recognised by consumers, and **innovative transition policies** to accompany farmers and compensate for their losses in the transition period. Policies to limit density of animal per hectare of land might have become necessary, and thus particularly imply a support for reconversion. Policies need also to be set right: for instance, support programs within the CAP of autochthonous less productive livestock breeds is not sufficient to prevent producers from shifting to modern breeds with a higher productivity per animal, which can be detrimental to diversification, resilience and economic differentiation strategies.

A third bottleneck is that **investments in machinery and buildings** have been very important in the last decades, leading to high levels of debt in animal production farms : this is both a bottleneck and an incentive for change, in order to reduce fixed costs, decrease dependency and increase autonomy. Investments that are currently made or will soon be made in housing or machinery for livestock production: ensuring that they are made consistently with a longer term vision of the transformation towards resilient and sustainable low impact animal production systems is critical, to ensure these investments do not become stranded assets.

Synergies with other Focus Areas

This Focus Area would be helped by a territorial scale approach to food system redesign (Focus Area 6). It will free up the crop sector from producing feed (which accounts for a very important part of the use of crops in Europe in 2018), thus enabling a shift to diversification in crop production systems (Focus Area 7). Better manure management and using waste as feed ensure better circular economy (reduce waste and losses).

Even if the result of this redesign and reconversion strategy for the livestock sector will need to be accompanied, it will in particular enable renewed added value and differentiation strategies for the livestock sectors in remote rural areas and coastal areas, as well as propose a viable and resilient future for intensive livestock producing regions.

Contribution to SDG and other (EU) policies

This Focus Area would contribute to SDG2 by decreasing the pressure on cropping systems (reducing the need to produce feed), thus contributing to sustainable food production systems, both animal and vegetal (SDG 2.4), it will also provide opportunities for animal producers and pastoralists (SDG 2.3), promote decent work (SDG 8.3) in the meat and milk industry (by providing better animal welfare as well as improving working conditions on farms and in slaughterhouses) and reducing inequalities (SDG10).

One critical challenge concerning sustainability of animal production systems is their impact on climate change (SDG13): this Focus Area is a direct consequence of the Paris Agreement and the EU climate policy that requires a reduction in GHG emission of 30% by non ETS sectors in 2030, with a longer term perspective of net zero emissions from agriculture after 2050. The radicalism of this challenge explains why the sub mission is about system redesign and not only marginal adjustments. In this perspective,

identifying which are the investments compatible with the vision proposed here above will be key to ensure that the animal production systems are not locked into an unsustainable pathway. Sustainability of animal production systems also entails water quality protection (SDG 6.3 and SDG 14.1) that is at the heart of a reintegration of animal production systems in their environment, biodiversity protection particularly through permanent grasslands in Europe (SDG 15.1), and the diversity of animal breeds (SDG 2.5) that should be an important feature for robustness to zoonosis as well as for added value strategies. This Focus Area contributes also to health through the prevention of NCDs (SDG 3.4). It also contributes to life cycle management of waste (SDG 12.4) and reduction of food losses (SDG 12.3).

What needs to be done

This Focus Area relies on the complementarity and combination of innovations at different levels:

- At the scale of organisms: new breeding techniques, re-oriented breeding goals to low input and roughage based feeding of ruminants, enabling multiple objectives (productivity, robustness, reduction in GHG emissions, for instance), reintroducing diversity in breeds and exploring the performance of older breeds.

- At the scale of the production system: new alternatives to feed, better management of grassland as feed, integration of animal production system in their environment, reintegration of crops and animal production in the same farm, robotisation to increase attractiveness of the working conditions while not increasing the level of debt of farmers, innovations in health management (precision livestock farming can be oriented in these directions).

- At the scale of groups of farmers in the framework of territorial approaches of innovation: innovative solutions to reintegrate crops and animal production, to use manure as a resources for fertilisation, to develop collaborations on labour sharing.

- At the scale of the organization of the food system, particularly concerning waste reduction and reutilization as feed, as well as the use of by products as feed, and also for traceability and trust between producers and consumers.

- Innovations in monitoring and exchanges of data on the environmental (and particularly GHG emissions by animals and the whole system, and carbon storage in grassland), nutritional and economic performance of different types of animal production systems (including animal welfare).

- Innovations also concern the strategies at the level of supply chains or territories, to increase resilience and adaptability of the sector, develop added value strategies and differentiation rather than mass production orientation, and seek for economies of scope between animal and vegetal production. These strategies will also benefit from a better trust and better transparency between producers and consumers.

- Policy research is also particularly important to align the incentives towards the vision presented here above, and correct the incentives that are currently rather aligned on a mass production strategy that will be incompatible with economic viability and environmental and social sustainability of the sector.

Actors who should be mobilised

Farming Stakeholders: Groups of farmers have been very active in innovation for more sustainable animal production, and they will continue to be very important to identify innovative pathways of transformation for their production systems, at individual or collective level. They are supported in this perspective by **researchers and**

extension services that play a key role in the production of locally relevant knowledge and also to knowledge transfers from one specific local situation to another. **Feed producers** will need to undergo a radical change in their sourcing and in their recommendations to farmers. **Breeders** also are critical actors, as the reorientation of the breeding objectives towards multiple objectives will be necessary, while it remains a challenge. It is also the case of **innovators on data, information and machinery** adapted to the challenged presented above (attractiveness of working conditions while keeping upfront costs low). The **processors** in the dairy industry, as well as in the meat industry, need also to play a critical role in identifying innovative strategy for their whole industry, towards higher added value and higher margins.

Territorial Scale Stakeholders (local authorities, local NGOs, drinking water companies and cities): will play an important role to reconnect animal production systems to the landscape and territory, and to valorise these externalities once they become positive (biodiversity, landscape and carbon value of grasslands, for instance) need to be on board.

Regional Authorities: will also have to play a key role in planning and supporting new pathways for animal production sectors, particularly in specialized regions depending on the livestock sector.

Indicators

- Greenhouse gases emissions of the EU livestock sector (target value: -30% 2030 / 2015),
- Maintained permanent grassland areas,
- Use of antibiotics in animal production sector is halved,
- Decent jobs in the animal husbandry industry are maintained,
- Reduction of stocking densities in sensitive livestock areas and watersheds,
- High % of roughage in feeding of ruminants (e.g. over 90 %).

9. Arrive at a sustainable and smart use of natural resources: zero land degradation by 2030, healthy soils, reduction of the yearly input of virgin minerals (such as phosphate) by 50%

Vision

The overall vision is a truly sustainable and smart use of natural resources of carbon and nutrients in the food and farming system with zero land degradation by 2030, healthy soils, and reduction of the yearly input of virgin minerals (such as phosphate) by 50 %.

Two pathways are outlined that are both linked to how we cultivate our soils:

1) **Increasing soil carbon stocks by optimized management practices: Capturing C as mitigation and adaption strategy in agriculture**

The vision here is that soil organic carbon management is optimised, to support future food production, as well as capturing C. One aspect is the significant reduction of soil degradation, another aspect is to enhance soil biodiversity, which is important to maintain a good soil structure and water and nutrient holding capacity. A strong reduction of the use of herbicides in Europe is achieved.

The soil organic carbon content, which is low in about half of arable soils in Europe, will be significantly raised. This has many positive implications on all soil based ecosystem services (Bünemann et al., 2018): reduction of soil loss due to water and wind erosion,

less soil compaction, soil activity and biodiversity loss, better nutrient recycling and pest and disease control, humus formation, etc.

2) Harnessing soil microbiome for sustainable use of phosphorus and nitrogen

The vision here is that minerals in the agro-food systems are being used more effectively, with a lower use of fossil fuel (for nitrogen fertilizer production) and a lower use of virgin minerals for the production of phosphate and other minerals fertilizers. An important route is better profiting from the soil microbiome for use and recycling of phosphorus and nitrogen (Schütz et al., 2018; Möller et al., 2018). Biofertilizers (P solubilizing bacteria and fungi and N fixing rhizobia) are easy available and affordable for major staple food crops in Europe.

Nitrogen fixation by bacteria (mainly in symbiosis with leguminous crops) is at least doubled in 2030, while the use of synthetic N fertilizers is reduced by 20% in 2030. This has also climate benefits (lower use of fossil fuel, and lower nitrous oxide emissions), as well as environmental benefits (air and water pollution).

The use of virgin P is reduced by 50%, by a combination of increasing the availability for plant roots of soil P stocks, as well as by an improved recycling of P (and other minerals) from waste streams, such as waste water, food processing waste and slaughterhouse waste.

Bottlenecks

a. Carbon management

A major bottleneck in many regions is the current farm structure, where a stronger segregation of livestock and arable farms continues. The EU agriculture policy (CAP) has little financial incentives to run mixed farms, use organic fertilizers, use recycled fertilizers and make proper organic residue management. The infrastructure for storage and spreading manures on farms is often poor.

A bottleneck is the missing knowledge how to apply reduced tillage, together with mechanical weed control, and to recycle biogenic waste from urban areas properly.

Other bottlenecks are missing standards for proper quality checks of manure and waste based fertilizers (compost, digestate) and missing of useful models, which forecast adequately the development of soil organic matter for farmers and advisors.

b. Microbiome for phosphorus and nitrogen use

The first bottleneck to realise this vision is the limited use of recycled P and N fertilizers due to constraints in quality. In particular common-agreed quality standards (formulations, shelf life) for bio effectors and inoculants with potential to increase the use efficiency of P and N fertilizers, adapted to pedo-climatic zones and crops, are missing. As long quality standards are not well developed, it is still difficult to legalize multiple strain inocula. A second bottleneck is short time thinking of farmers, which prefer to use cheap nitrogen and phosphorous fertilizers instead of investing in infrastructure for better nutrient recovering and use of biofertilizers. Another bottleneck are knowledge gaps with regard to microbiome as related to different soil functions and how the soil metagenome is affected by different management practices. Therefore, the predictability for efficacy of the use of inoculated microbial strains (i.e. P solubilizing bacteria and fungi) is still difficult. There is also insufficient knowledge of farmers how to optimize crop rotations including N fixing leguminous plants to improve nitrogen-efficiency in different pedo-climatic conditions. And there are not enough stringent financial incentives in the CAP to make crop-rotations more resilient.

Synergies with other Focus Areas

The sustainable management of carbon, phosphorus and nitrogen nutrients has synergies with several other Focus Areas:

- Develop sustainable and climate-resilient food systems on a territorial scale.
- Diversify fields, farms and landscapes to achieve climate-proof and sustainable resource use, for healthy people, healthy environment and a healthy planet.
- Redesign, re-integrate and encourage low impact animal production systems.

Furthermore, it will contribute to the Focus Area to *reduce food insecurity and increase the consumption of healthy and sustainable diets by doubling the variety of energy and protein sources used on food production* as well as to the Focus Area *upgrade innovation capabilities of actors in food systems.*

Contribution to SDGs and other (EU) Policies

This Focus Area contributes to:

- *SDG2 (End hunger, achieve food security and improved nutrition and promote sustainable agriculture)* by ensuring soil fertility and sufficient energy and protein rich plants on European and Global scale;
- *SDG 6 (clean water)* by improving the buffering of soils through better carbon and humus management;
- *SDG 12 (Sustainable consumption and production)* by reducing the dependency of non-renewable energy for fertilizer production and improving the soil fertility;
- *SDG 13 (combat climate change)* by achieving better soil structure and humus content, better adapted to strong weather implications (drought, flooding).

Furthermore, this Focus Area will contribute to the implementation of the EU Action Plan on Circular Economy (COM 215/0595 final) as well as for the implementation of the EU Soil Strategy and the EU Nitrate directive. (Council Directive 91/676/EEC) as well as the CAP.

Trade-offs with other Focus Areas

Redesign, re-integrate and encourage low impact animal production systems: there can be trade-offs with redesigned animal systems with much less animal manure and slurry and less clover-grass in the rotations. A certain share of leys (grass-clover, alfa-alfa-grass) with leguminous plants in the rotations in combination with arable crops maintains soil fertility (important for carbon sequestration and nutrient cycling).

What needs to be done

a. Carbon management

- Fully exploit the potential of nutrients (N, P, and Potassium) recovery from solid bio-waste and waste water (compost, biochar, struvite, etc.) to reduce the use of mineral fertilisers.
- Drone and satellite based monitoring systems using spectroscopy and image analyses for soil organic matter and erodibility of soils.
- Further development of minimum tillage without herbicide use (robotics for efficient weed control).

- Elaborate proper guidelines to use recycled fertilizers with respect to carbon build-up.
- Calibration of models for proper carbon balances under European pedo-climatic zones. To our knowledge, none of the models available so far has the capacity to predict the carbon development accurately under a defined management in a specific pedo-climatic zone (a bit astonishing after decades of research, hundreds of publications).
- Development of subsidy systems, which allow for investments in specific equipment for minimum tillage and storage capacities for manure.
- Develop policies that favour mixed farming at the farm and regional scale, including proper residue management and permanent soil cover by crops and cover crops.
- On-line training courses for farmers and advisors.

b. Microbiome for phosphorus and nitrogen use

- Elucidating soil microbiome in various pedo-climatic zones with respect to soil P solubilization and N fixation.
- Research on predictability of efficacy of inoculants dependent on indigenous soil microbiome, soil chemical and physical soil properties.
- Development of multi-strain inoculants for P solubilisation and N fixation (rhizobia, bradyrhizobia) for target crops.
- Development of formulations to extend shelf life and of quality standards and test protocols for bio-fertilizers in Europe.
- Assessment of effects on non-target soil organisms.
- Use the potential of mixed cropping (leguminous plants with cereals or oil crops) for natural N-fixation.
- Improve nutrient recycling on farm, between farms (crop-livestock) and along the food chain through new ways of cooperation or arrangements between multiple actors.
- Farmers have to be involved in testing management options for favouring soil metabiome with respect to specific soil functions (collaborative learning process between farmers, advisors and researchers).
- Improve nutrient recovery and purification/concentration from waste streams (e.g. food processing, slaughtering, wastewater) also made feasible for SMEs.
- Assess food safety risk of re-using slaughterhouse by-products (waste) for fertilization and further develop sanitation techniques for smaller-scale operations.

Actors who should be mobilised

The most important actors are for both areas (Carbon management and microbiome for phosphorus and nitrogen use):

Farmers: need better knowledge on potentials better carbon management, nutrient recycling from waste streams, bio-fertilizers supported by smart monitoring systems and ICT support tools.

Machine Industry: Further development of soil conserving tillage machinery without the use of herbicides.

Extension Services: Better knowledge, models and tools for site-specific advice for carbon and nutrient management on farms.

Biofertilizer Companies: Market opportunities for development of bio-fertilizers for specific crops and soils.

Food Industry (Processors): support to better valorise biogenic waste from food processing transformed to suitable (pelleted) forms or biochar.

Biogenic Waste Processors: better knowledge to produce high quality recycled fertilizers.

Policy Makers and Regulators: Models and incentives for mixed and climate-smart farming. Relevant data for approving of biofertilizers and biochar (safety, environmental impact, efficiency under specific conditions).

Indicators

a. Carbon management

- Percentage point increase of soil organic matter.
- Share of arable land under minimum tillage without increasing herbicides (transparent statistics in Europe).
- Share of urban waste recycled in agriculture.
- Area monitored by remote sensing for soil organic carbon and erosion.

b. Microbiome for phosphorus and nitrogen use

- Statistics of biofertilizer (including bio-inoculants) sales in Europe.
- Strong reduction of import of phosphorous in Europe.
- Much higher proportion of phosphorous in wastewater reused and documented (today only 25 %).
- Indicators, which show the increase in farm independency from inputs.

10. Reduce the environmental impact of food packaging by 2030 by 75%

Vision

In 2030, the environmental impact (in terms of greenhouse gas emissions, use of primary raw materials (such as aluminium and plastic from fossil fuels), waste and litter) caused by food packaging used in the EU will be reduced by 75 %. This will imply the partial elimination of food packaging, a reduction in material use, the use of innovative, sustainable and environment-friendly alternative packaging materials as well as a better recycling and less littering of food packaging. As a result, the input of virgin materials and energy use related to food packaging will be largely reduced.

Currently, around 25.8 million tonnes of plastic is being used annually in the European Union for packaging[24] (total, not only food), of which only 6% is being recycled. Of total packaging, less than 30% of the post-consumer amount is being recycled[25]. It was estimated that plastics production and the incineration of plastic waste give rise globally to approximately 400 million tonnes of CO^2 a year. Globally, 5 to 13 million tonnes of plastics — 1.5 to 4 % of global plastics production — end up in the oceans every year.[26] The implementation of the vision will reduce the environmental impact of food packaging by 2030 by 75 %.

Bottlenecks

- Business models of packaging industry, retailers, food service and food companies: Packaging is often used to provide product information and for marketing purposes.
- Fast-food restaurants and coffeehouse and other 'on the go' retailers often depend on single use packaging and the problem is therefore expected to grow.
- Increased use of processed and packaged food.
- EU and national food safety regulations/standards (or concerns) and shelf-life standards (including impact on food waste) limit in some cases the application of certain alternative packaging materials.
- Lack (in some cases) of practical alternatives. For example, biodegradable packaging solutions have been developed, but these are not applicable for all product groups yet.
- Consumer behaviour and lack of awareness.
- Waste management systems (collection, sorting, disposal) at the local level.

Synergies with other Focus Areas

The reduction of the use of plastics and its environmental impact will have several synergies with other Focus Areas.

- Reduced import dependency of fossil fuels for plastic production with less CO2 emission will help to *develop more sustainable and climate-resilient food systems on a territorial scale.*
- Increase of the use of reusable materials in restaurants, catering, etc. will also involve social innovation. It will *strengthen the distinct roles of citizens in healthy, diverse and sustainable food system.*
- Opportunities for EU companies, when having developed breakthrough technologies for packaging and labelling, which could be a potential for SMEs. This will contribute to the *Upgrade innovation capabilities of actors in food systems.*

---

[24] http://ec.europa.eu/environment/waste/plastic_waste.htm

[25] European Commission. 2018. COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS. A European Strategy for Plastics in a Circular Economy. {SWD(2018) 16 final}.

[26] Jambeck et al., Plastic waste inputs from land into the ocean, Science, February 2015.

Contribution to SDGs and EU Regulations and Communications

Reducing packaging and improving recycling of packaging will help to reduce litter (including marine litter) and will reduce greenhouse gas emissions and the dependence on (mostly) imported fossil fuels and packaging materials. This contributes to the *Circular Economy Action Plan2015*, as well as to the *European Strategy for Plastics* in a *Circular Economy* and to the *2030 Climate and energy framework*. It also will contribute to national policies, as well as to SDG 8 and 12.

Trade-offs with other Focus Areas

- *Reduction of food waste:* packaging helps to prolong shelf life of food and in this way reduce potential food waste.

- *Increased consumer trust by 50% by improving the authenticity, transparency and guaranteeing safety along the Food system by 2030:* food packaging helps to maintain and guarantee food safety. In some cases however, food packaging itself impacts food safety, for example in case of migration risks of toxics from packaging materials.

What needs to be done

- First, it should be stressed that reducing the environmental impact is not only a matter of technical innovation, also social innovation is crucial. Therefore, it is essential to have a better understanding of the systemic causes of current practices, and to identify leverage points for change. This includes for example incentives for changing the practices and behaviour of actors (including consumers), both in terms of reducing the use of single-use plastic (more multiple use packaging, use of reusable and recycled materials in, for example, restaurants, no-packaging sales stores) and other packaging materials and in terms of improving recycling rates. It also includes the design of new logistical models, which could reduce packaging.

- Also on the technical side, there are important areas of progress, such as the development of bio-degradable packaging material, with an emphasis on organic material (bioeconomy). This material needs to be clearly labelled. Novel packaging materials with lower environmental impact could be developed, with for example lower material use, of which are easier to recycle. Further technical progress is possible in waste collection, waste separation and use of recycled materials (plastic, metals, etc.), which improves the economics and quality of plastics recycling. Better and more dynamic LCA tools are needed: for example, if energy for dishwashing is generated by renewable sources, the balance might sooner tip to reusable dishes. The use of multiple use packaging material (such as bottles) can be improved, by providing better ways of collecting and cleaning. In case of the development of novel materials (for example, the use of Nano-technology), a full risk-assessment needs to be made.

- In general, good tools need to be available for decision makers in the supply chain to make evidence-based decisions between various choices (plastic, bio-degradable, reusable, recycled etc.).

- R&I can also play a role in the supporting development of evidence-based legislation, both at the EU as well at the Member State level.

- Another area of action is to develop alternatives for labelling to provide consumers with product information (e.g., smartphone supported applications for consumers, etc.).

Actors who should be mobilised

For the implementation of reduction of food packaging a number of different actors need to be involved:

Catering, Restaurants, Fast Food and Drinks Vendors: Out-of-home consumption is one of the main sources of food related use of packaging (including the use of single use cups, plates and cutlery). These actors need to be involved in reducing the environmental footprint of packaging, for example by using less packaging (use of washable materials, less material) and by better recycling and reducing litter. This not only involves technical R&I, but also social innovation, aiming at changing current practises (changing norms, expectations and values).

Food Companies, Food Retailers and Online Food Delivery Services: Reduction of single use packaging, or the use of lighter products, which are also better recyclable. Important aspect is the use of single materials, which are better recyclable than layered materials. Consumers could be stimulated to use their own bags and containers.

Food Packaging Manufacturers: Development of bio-degradable materials, which can also enhance the collection and valorisation of food waste. Special attention is needed for environmental impacts of biodegradable plastics (residues, effect of environment (water versus soil) etc.). Development of multiple use food packaging, lighter food packaging, and better recyclable food packaging. Use of recycled products for manufacturing. Transparency about composition is necessary. Development of clear labels on food packaging, for more effective recycling by consumers.

IT industry: The Internet of Things (IoT) will help to promote recycling.

Consumers: Higher awareness of environmental consequences of food packaging, as well as of alternatives. Providing feedback to food companies and retailers. Higher awareness of what materials can and should be recycled (what materials cannot and should not) according to the city rules in line with waste management systems.

Waste Collectors: Develop techniques to separate and recycle food packaging.

Policy Makers: Research will provide accurate and timely information for better informed decisions. Will provide clear and 'smart' regulation, which can respond properly to changing conditions and new techniques.

Local and Regional Authorities: Implement efficient and appropriate collection systems at the city level.

Indicators

- Energy use for production and recycling of food packaging.
- Input of primary raw materials (such as aluminium) for packaging.
- Amount of littering.
- Amount of recycled food packaging.

11. *Halve food waste and food losses from the EU food and farming system by 2030*

Vision

The overall vision is to halve the food waste and food losses in the EU by 2030. This will lead to a more resource-efficient food system, with lower environmental impacts. Food waste and losses will be prevented significantly, and where waste still occur, this waste is re-used as feed, feedstock, or used for energy generation. Food waste in EU amounted to 88 million tonnes in 2012, estimated in the EU funded EU Project FUSION (FUSIONS, 2016). [27] In this study, the major origin of food wastes in Europe was estimated as 53 % from household, 19 % from processing, 17 % from wholesale and 11 % from production.

Halving food waste and losses will generate new business opportunities at farm and company level, with positive returns on investment and additional income. New biorefinery technologies for by-products are implemented, which have interesting benefits for consumers (e.g., health promoting functional ingredients). New ICT support tools for storage optimization in food companies and in households help to reduce food losses and food waste significantly.

At the regional level, an optimal allocation of food and feed streams is achieved, with significant lower environmental impact (greenhouse gases, energy use). In some regions, additional labour and income will be generated, boosting zero-waste circular economy at local level. With consumer research, social innovation and targeted communication tools the consumer, processors and cooks are much more aware of their responsibility in reducing food waste and take action.

Bottlenecks

There are three main bottlenecks:

- The first one is that for most people food is very cheap, so there is no economic incentive to reduce food waste. Historically, there used to be a cultural barrier which prevented food waste, but in many countries, this is less the case. The second bottleneck is the current food system 'logic', which is often based on oversupply. Shops, restaurant, hotels and caterers have an aversion to empty shelves or tables. The result are high losses and waste, both at the farm level (especially in horticulture), as well as in the whole supply chain. The third bottleneck are the food quality standards, which prevents fruits and vegetables, which do not have the right colour, shape or size to be sold, while these are perfectly edible.

- A lot is already known about the causes and sources of food waste and losses. There is basic knowledge available on technologies for further processing of food waste, for feed or for to use as energy source through anaerobic fermentation. But there is a demonstration gap due to lack of funding.

- At institutional level a bottleneck is that effective and coherent policies in the EU are missing. A report of the European Court of Auditors, (2016), who focussed on actions of prevention and donation to reduce food waste, concluded that a better alignment of existing policies is needed with improved coordination, and clearly identifying the reduction of food waste as a policy objective. In terms of donation of food, a number of the barriers that currently exist, such as different interpretations of legal provisions, could be addressed to facilitate the donation of food that would otherwise be wasted. Food waste is seen as a problem along the entire food supply chain and therefore action should be targeted to all along

[27] FUSIONS, Estimates of European food waste levels. Project Report. 2016

the chain with potential benefits for all those involved. Emphasis should be put on prevention, as the benefits of avoiding waste outweigh those of dealing with it later.

- A number of food waste material that in the past was used as animal feed (bone meal, swill from restaurants) has been forbidden in a reaction to unprofessional use leading to food safety scandals. With new Internet of Things technologies and improved options for control systems, this issue could be revisited.

- Another bottleneck is the lack of awareness of consumers regarding food waste and the current food safety and shelf life standards, incl. their implementation on national level.

Synergies with other Focus Areas

Research and innovation for reducing food waste and losses, in particular with a broad involvement of partners on regional scale, will create important synergies with other Focus Areas.

- It would overlap positively with Focus Area Food processing with *better outcomes for nutritional and sensory food quality as well as environment* (many synergies).

- It contributes significantly to global food security policies and climate policies to reduce greenhouse gas emissions (mitigation) and the use of non-renewable supporting the Focus Area *Develop sustainable and climate-resilient food systems on a territorial scale.*

- There are synergies with the Focus Area to *reduce food insecurity and increase the consumption of healthy and sustainable diets by doubling the variety of energy and protein sources produced.*

- It will have synergies with the Focus Area *Upgrade innovation capabilities of actors in food systems* and the Focus Area *Strengthen the different roles of citizens in healthy, diverse and sustainable food systems.*

Contribution to SDGs and other (EU-) policies

Food waste is considered today as one of the main challenges of society. Several institutions and organisations take action against food losses and waste, e.g. FAO in Rome launched a Food Loss and Waste website (www.fao.org/platform-food-losswaste). FAO supports a Global Initiative on Food Loss and Waste reduction, with public and private partners. However, there is not 'one size fits all' solution because studies on food waste have shown that the causes of food waste and losses vary greatly by region, country and continent (FAO, 2017)[28].

The EU Commission emphasizes the food waste challenge in their Action Plan on Circular Economy (COM 215/0595 final) as well as in Horizon 2020 calls, taking into account that solutions and supportive research and innovation must be adapted to the region and context.

The reduction of food losses and waste is directly linked with SDG 12.2 (Sustainable consumption and production patterns) and in particular with SDG 12.3 aiming to halve by 2030 global food waste at the retail and consumer level and reduce food losses along

[28] FAO. 2017a. The Future of Food and Agriculture – challenges and trends. Rome p. 111-117.

production and supply chains, including post-harvest losses. The reduction of food loss and waste will contribute to a number of other SDGs that target either more efficient resource use, reduction of hunger by increasing the availability of food or reduction of greenhouse gas emissions as well as use of non-renewable energy.

Trade-offs with other Focus Areas

- Often mentioned is the trade-off between food waste utilization and food safety legal requirements, which relates to the Focus Area *Increased consumer trust by 50% by improving the authenticity, transparency and guaranteeing safety along the Food system by 2030.*

- There can be trade-offs between the zero-waste goal and the goal to make a profitable businesses based on food waste. Some food waste used for non-food utilisation might contradict with the cascading approach, where the use as food has the highest priority.

- Reducing waste might result in higher energy input, especially for preservation of food, which contradicts with the goal for a resource-smart food system with 50% less greenhouse gas emissions by 2030. This relates to the Focus Area *Develop sustainable and climate-resilient food systems on a territorial scale.*

What needs to be done

The strong reduction of food waste and losses, primarily through prevention and reduction, needs a broad approach with different policy instruments and actor involvement. We need a broadly accepted mind-set for change, the reinforcement of the connection of all actors at different scales (also links with municipalities), from decision makers to consumers, with a combined top-down and bottom-up approach. Research and innovation alone cannot achieve "zero food waste" or at least halving it, but it can make important contributions for food waste prevention, reduction and revalorisation:

Three pathways for action, in order of priority, are proposed:

1) Prevention of food waste (design issue);

2) Reduction of food waste (innovation and supply chain issue);

3) Revalorisation of waste streams (innovation and re-design issue).

Social research & innovation and cross learning will play a key role and can be even more important than technical solutions. It will be important for redesigning food systems, monitoring waste and losses in a transparent way and the development of 'smart' policies (changing the rules of the game: legislation, multi-stakeholder processes).

a. R&I supporting the supply chain actors:

- Prioritize opportunities and mechanisms for saving food from being wasted through social innovations in the public domain (special curricula for schools, children's gardens).

- Develop and test innovative and cost-effective technologies for reducing waste for different product groups along the food chain in the pre-commercial phase (in particular fruit and vegetables, potatoes, etc.).

- More technologically oriented research and innovation is needed for the revalorisation of food waste, e.g. for high value by-products for food, feed or other uses in cosmetics, pharmacy, chemical industry, etc.

- One cost factor is to guarantee that the by-products are safe for human and animal health; supportive research with regard to food safety would be helpful. Research is also needed about upscaling successful food waste revalorisation, which is often still done by small start-up companies.

- Development of ICT tools, including the Internet of Things, to better identify early problems of shelf life and decrease of food quality leading to food waste, helping operators (wholesalers, retailers, storehouses) to take corrective action. Until now, these instruments are not enough known yet and need to be better adapted to different product groups and actors to use them more effective.

- Develop economically viable and sustainable business models for food waste avoidance or re-use for a territorially adapted circular economy, according to a biorefinery cascading approach.

- Develop further logistics models for multiple food waste collection and redistribution for production of multiple by-products from food waste.

- Integrate food waste biorefinery systems into existing local waste management schemes, while calculating the private and societal benefits.

b. R&I for improving legislation and regulatory frameworks as well as policy incentives:

- Food safety concerns with evidence based experiments (e.g. use of insect protein from insects based on food waste for human nutrition and animal feeding (incl. fish) as basis for adaption of legislation.

- Develop effective incentive systems for reduction of food waste and/or multi-use of by-products both for consumers and market actors and test its implementation with suitable indicators for different product groups (e.g. price incentives or new labelling systems for products falling out of the norm).

- Further development of full cost accounting of the hidden (environmental and social) costs of food waste of a methodology developed by FAO 2014[29] to inform mitigation policies. Further research should focus on specific contexts, at national or supply chain level. To assess the optimum level of food waste reduction for societies, it will be important to incorporate economic equilibrium analysis to simulate the interactions between food supply, prices, income and welfare in a dynamic economy. A further priority is to improve aspects of the social cost estimates (Müller et al., 2014).

- Research on upscaling best practices (investment needs for private and public sector) and shifting food waste management upwards to prevention, reuse and recycling, in particular on a territorial scale.

- Develop and promote ethical value-based decision systems for food waste policies in circular economies, in particular for municipalities.

Actors who should be mobilised

For the implementation of this Focus Area, different actors need to be involved:

[29] Mueller et al. 2014. Food wastage footprint – Full-cost accounting. FAO Report. www.fao.org/nr/sustainability/food-loss-and-waste

Farmers and Fishermen: improved harvesting and on-farm storage techniques leading to less food losses, supported by additional marketing possibilities of non-normed products.

Food Processing Companies: innovative technologies, labelling concepts and business models to use and sell better new by-products of food processing for different uses.

Machine Industry: development of new multi-crop harvesting equipment, resource-smart and quality conserving, cooling and storage technologies.

ICT-Developers: Use of Internet of Things for quality control.

Civil Society Groups: Improving capacities for awareness rising regarding food waste (e.g. with special apps on smartphone).

Retailers (in particular, the large retail chains and food services): Packaging sizes and logistic systems leading to less food waste. Development of special labelling and communication systems for non-normed products.

Consumers: Understanding better their important role in reducing food waste. Better knowledge about consumer behaviour with regard to food waste reduction. Testing of effective incentives.

Policy Makers and Public Administrators: evidence based studies on food safety for new by-products to better adapt regulations (e.g. insect protein from food waste). Research can test policy incentives to reduce food waste and losses. In addition, it can contribute to innovative organisational models how to better optimize food streams from the field to the household on a local/region/territory scale with SMEs, municipalities and farmers.

Indicators / Metrics

- Amount of post-harvest losses by 50 % until 2030.
- Measurement with the Indicator 12.3.1 Global Food Loss Index on Country level, which was developed by FAO.
- Calculation of potential CO2-emssions due to food waste and losses.
- % of effective yield used for human consumption (e.g. potatoes or meat from nose to tail)

12. Double the sustainable production of high quality food from EU aquatic systems by 2030

Vision

In 2030, the EU will have doubled the production of high quality food from fresh water and the seas in a way that maximizes the benefits for future generations. This will be mainly in the form of a higher production of seafood and fish and their products. Newer products, such as wild fish species, which are not exploited today, algae and seaweed will also make a substantial share of the aquatic production. In addition, the production of feed and feed additives from aquatic sources will increase, to be used either for livestock or in aquaculture, and the land dependency of aquaculture production will decrease. The aquatic food production is of high quality, contributing to healthier diets, by supplying proteins, micronutrients and n−3 fatty acids amongst other. The production structure is such that jobs will be created and they will contribute to vital coastal communities, boosting offshore innovation and blue economy.

Bottlenecks

Currently, food and feed from the oceans is still relatively cheap, partially because externalities, such as depletion of fish stock, are not priced. Although much progress over the last decades towards a more sustainable management of fisheries has been made through the implementation of the Common Fisheries Policy (CFP), a significant share of the global fish stocks is currently overfished or fully fished. Relieving the pressure on wild stocks has led to a significant decline in the EU domestic production over the last 15-20 years. In response to that, the consumption has shifted to more imported fish both wild-caught and farmed. In 2016, the trade flow grew to EUR 54.3 billion and 14.1 million tonnes (EUMOFA, The EU fish market, 2017). EU self-sufficiency (ratio between EU production and apparent consumption of the EU market) is approximately 46.0%.

Thus, wild fisheries cannot support a significant increase in aquatic production and aquaculture is foreseen as the activity to secure sufficient quantities of aquatic food and feed. Major bottlenecks in increasing aquaculture production are a) the production of high quality progeny, b) the production of feeds based on sustainable raw materials with low ecological footprint, c) the fight against parasites and diseases, d) the space management of the activities to minimize environmental impact and fish health and welfare, e) cultural preferences for certain types of fish (especially carnivorous fish such as salmon and tuna).

The challenge of obtaining more food from the sea also raises several contested issues. Researchers are in almost universal agreement that there are major benefits by improving marine management, both at the European and global scales. There is also widespread agreement around the bioeconomic benefits of a right-based management system and a change of consumer preference towards food from lower trophic levels. However, the social and cultural issues connected with such a reorientation of the marine sector are many and conflicted. More holistic approach including social science and humanities. The societal acceptability of the aquaculture industry and its products is also a barrier to overcome, which makes a Responsible Research and Innovation approach with involvement of social sciences desirable.

Synergies with other Focus Areas

- More seafood can help in *halting obesity, reducing the incidence of Non-Communicable Diseases* in Europe by 50% and adding healthy years to the ageing population.
- Aquatic production can contribute to *reducing food insecurity and increasing the consumption of healthy and sustainable diets by doubling the variety of energy and protein sources used on food production.*
- *Developing sustainable and climate-resilient food systems on a territorial scale*, since aquatic production is dictated by local aquatic ecosystems that appear to be more resilient to climate changes compared with terrestrial ecosystems.
- *Reducing food losses and waste* (discard issue).
- *Food processing with better outcomes for nutritional and sensory food quality as well as environment.* Also in processing of fish and other aquatic products progress can be made.
- *Developing a resource-smart food system with 50% less greenhouse gas emissions by 2030.* Increased aquatic production will take pressure of land-based systems. In general, seafood is less greenhouse gas intensive then land-based products.

- *Supporting remote rural and coastal areas to perform innovatively in food systems*.

Contribution to SDGs and other (EU-) policies

The mission primarily contributes to SDG2 (End hunger, achieve food security and improved nutrition and promote sustainable agriculture), and to SDG14 (Conserve and sustainably use the oceans, seas and marine resources for sustainable development).

It also contributes to other SDGs, notably SDG8 (Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all), and SDG17 (Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development).

The Focus Area will support the implementation of:

- the **Common Fisheries Policy** and the **Marine Strategic Framework Directive**, that govern the exploitation of aquatic resources and the environmental status of the European Seas,

- the **Bioeconomy** and the **Blue Growth Strategies** that support innovation and sustainable growth of the economy based on renewable biological resources and the marine and maritime sectors,

- the **Biodiversity Strategy** that fights the loss of biodiversity and ecosystem services and the 7th **Environment Action Programme** that guides the environmental policy in the EU,

- the **EU Cohesion Policy** that supports job creation, business competitiveness, economic growth, sustainable development, and improvement of citizens' quality of life in all regions in the EU.

Trade-offs with other Focus Areas

- *Sustainable and climate-resilient food systems, as well as with sustainable and smart use of natural resources:* should aquaculture remain dependent on land-based feed crops, it will lead to competition for arable land and water with other uses. In addition, a significant increase in the production of aquaculture systems could lead to environmental pollution, for example in the form of nutrient enrichment, which causes eutrophication of coastal areas. Other risks are the use of pesticides (to control sea lice), and the escape of non-native species.

- *Personalised nutrition, healthy aging, and increase safety and transparency*: Although food from aquatic systems is generally safe and nutritious, some new issues might occur. Some examples are food contamination (heavy metals, persistent organic pollution), and the lack of nutritional studies on the use of novel aquatic products, such as products based on seaweed.

- *Increase safety and transparency:* Finally, new ways of production, and even more complex food systems lead to new challenges regarding authenticity, transparency and guarantying food safety.

What needs to be done

The ways to increase the food production in the oceans have also been the focus of the recently published SAPEA report, which identifies four lines of action:

1. Improvements in management and increased utilisation of wastes in the traditional capture fisheries;

2. fishing on new wild species that are not, or only marginally, exploited today;

3. mariculture of organisms that extract their nutrients directly from the water; and

4. mariculture of organisms that require feed.

More concrete:

- Explore aquatic resources that can sustainably provide the raw materials for aquaculture feeds, and active compounds for pathogen and parasite elimination.
- Enrich vaccine toolkit for effective protection against pathogens and elimination of chemical use in aquaculture.
- Develop new techniques, tools and methods in aquaculture breeding to support sustainable disease control and feeding.
- Improve the availability of feed for aquaculture from alternative, sustainable sources, such as algae, insects, fish residues, while considering food safety concerns and cultural aspects.
- Improve the animal welfare, both in wild catch as well as in aquaculture systems.
- Prevent or reduce the use of drugs and pesticides in aquaculture systems.
- Develop systems towards 'zero-waste, circular economy' in aquatic production.
- Advance technologically to make offshore farming operations that combine several activities in the same marine space, including integrated multi-trophic aquaculture (IMTA), viable and cost-efficient.
- Improve management of the fisheries on wild species stocks, which can potentially increase the global annual catch of seafood.
    - Redirect part of the landings from reduction fisheries into human consumption.
    - Harvest wild animal species at lower trophic levels, which today are either not exploited at all, or only marginally.
- Tackle the problem of discards and other wastes: a) Reduce discards, by developing selected harvesting, or by landing and using them; b) Utilise discards and other post-harvest wastes, by processing them.
- Improve the culture of micro- and macro-algae, design and validate innovative processing methods to increase yield and diversify uses in the food system.
- Develop new approaches to social responsibility in the aquatic production, which focus on open innovation, co-production of knowledge and social responsibility on multiple levels.
- Promote ocean literacy and increase citizen awareness to secure their engagement and role in implementing a socially and environmentally responsible code of conduct in aquatic production.
- Provide social and technological support for vivid coastal and inland fisheries communities.

- Support Regional Seas policies and Blue initiatives through a governance system that connects people, areas, cultures and facilitates open innovation.

Actors who should be mobilised

Aquatic Bio-scientists: to generate knowledge on aquatic species and processes, enhance aquatic bio-resourcing and advance blue production and biotechnology.

Fishermen: Fishermen, both EU based as well as from abroad, play a major role in the development and implementation in improved fishing methods, including aspects as reduction of waste and discards, as well as in the exploration of new wild species.

Food processing industry: development of 'zero-waste, circular economy', for example by the utilisation of discards and other post-harvest wastes, by processing them.

Retail and food service: Increase transparency, increased availability of more sustainable products, new recipes and methods of preparation, to encourage consumers to adapt to novel products.

Equipment manufacturers: development of new machinery and technology to support novel forms of aquatic production and novel processing.

IT-industry: Further development of tools to improve food safety control, traceability and marketing.

Consumers: Higher ocean literacy and increased citizen awareness, more transparent systems, better understanding of issues at stake and acceptability of novel products (new fish species, invertebrates, plant-based marine food).

Civil society: Provide check and balances, especially needed as innovative techniques and methods.

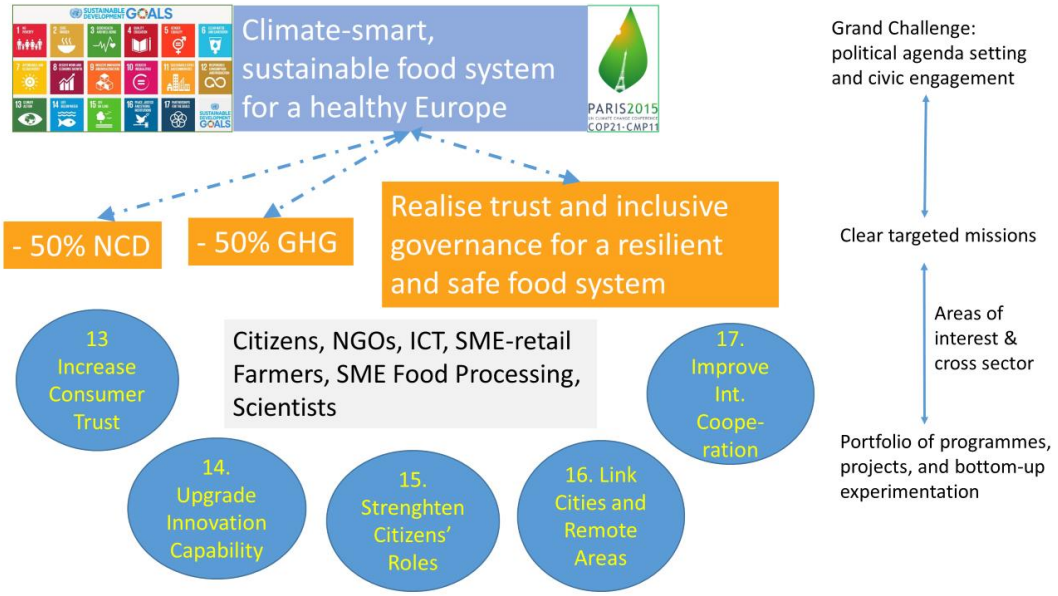
Regulators and policy makers: Design and implementation of responsible and just regulations, which safeguards public values, while at the same time being flexible enough to respond to new developments. Appropriate data systems. Food safety studies that help to adapt the food safety and feed regulations with regard to new sources for fish feeding (e.g. insect proteins from food waste, etc.).

Indicators

Progress can be measured with the following indicators:

- Number of new aquatic species in production
- Volume of reduction fisheries discards
- Volume of aquaculture production
- Volume of imported aquatic food in the EU
- Consumption of seafood per capita in the EU
- Carbon footprint of aquatic products
- Forage Fish Dependency Ratio (FFDR) and Feed Conversion Ratio (FCR) of farmed species.

C. Realise trust and inclusive governance for a resilient and safe food system



Bold, inspirational with wide societal relevance: A resilient food system that copes with new challenges applying responsible innovation, benefits from fast feedback loops. Challenges should quickly lead to action. Current food systems fail in that respect. Unsustainable practices at farm or consumer level do not lead to enough action in the food system. Actors need to be empowered to take action. From time to time there are major food crises, sometimes resulting from mistakes but often from fraud. A resilient food system maintains a high level of consumer trust in products and (new) production processes, and in which consumers pay the true cost for their food. In a resilient food system vulnerable actors like farmers, fishermen, consumers and (small) innovators benefit from open data and open innovation processes. Transparency in open innovation stimulates societal debate and acceptance of new technologies.

A focus on social innovations, changing the role of actors, empowering vulnerable groups and with organizational and governance changes is key. There are a number of elements contributing to shape citizens actions in the food system including migration and religious practices, education and employment, economic possibilities, demography and geographical location. Understanding the dynamics that these elements generate and how they impact on the food system in different contexts is necessary to develop effective ways to approach, educate and raise awareness over the food system. Cities should be supported to develop urban food policies and participatory governance models and practices to enable participation of stakeholders and new forms of citizenship. Remote rural and coastal areas need to be linked to the metropoles and the centers of innovation in the major food regions of Europe; otherwise they lose out if innovation speeds up in the next decade.

A clear direction: targeted, measurable and time bound: Transparency should not only be organised downstream but also upstream and inform farmers about the consumers that buy their products to improve the (direct) marketing of producer organisations and farmers or fishermen. Multifunctional farms in and around cities and eco-tourism farms provide services and transparency in different ways. Big data analysis will speed up innovation and support farmers, fishermen and others to take better decisions. Principles of open data and open innovation will also help, and ICT can be instrumental in diffusion of innovations from the centre to the periphery.

Ambitious but realistic research and innovation actions: To manage and equalise the food system, we need to look at certain pressing issues. These include stimulating social innovation, including and empowering small food businesses, combining the modern and

old, and creating new business and governance models. We also need to look at ways to engender a sense of community that keeps isolated locations feeling "liveable" in emptying rural/coastal areas with an ageing population.

Connecting communities of small businesses to innovation hubs (with ICT tools or otherwise) can improve the knowledge flow. Engaging citizens through educational and social programmes can strengthen their role in the system, as can short supply chains. Urban food policy networks help. New technologies and organisational arrangements (like e-platforms) make it possible to share data along the food chain; this promotes transparency and trust in food data and food. Methods to assess sustainability, like true cost accounting, can improve the governance of the international food system. We must also pay special attention to institutional development frameworks to upgrade local food systems in an urbanising Africa and the Middle East.

Cross-disciplinary, cross-sectoral and cross-actor innovation: 100% transparency linked with open data, open innovation processes and citizen science creates cross-sectoral innovation that could support the highly valued diversity in European farming, fishing and food culture. It could counterbalance the big network effects ('the winner takes all') that characterises the platform economy. New technologies (e.g., block chain) and organisational arrangements (like e-platforms) make the sharing of data along the food chain possible. New governance arrangements for the food system will develop that threaten the position of some actors and will bring new players. In the governance of data a consent-driven system of data exchange seems attractive. In computer science machine learning and other big data techniques will contribute to new services. The data revolution could support new links between producers and consumers in short supply chains. Research and innovation are needed to empower and protect smaller actors like farmers, fishermen and consumers.

Research and innovation include all actors in the food system, but especially ICT companies, retailers, consumers, NGOs, standard organisations and managers and auditors of sustainability schemes. Food safety agencies are also be an important player. Urban food policy networks are important, especially also for innovative urban and peri-urban farm systems. To re-vitalize remote rural areas that become depopulated in the next decades, links with forestry, local services, tourism, energy production are important and new arrangements should be developed that guarantee a basic societal life.

Cross-disciplinary research is needed here between areas like computer science, law, economics, auditing and innovation science. Plant and animal science, food science as well as environmental science need to be involved in the analysis of real time big data.

Multiple bottom-up solutions: Given the different organisational and technical solutions that contribute to the mission, multiple bottom-up solutions exist and are needed for a resilient food system.

A portfolio of 5 R &I programmes can support this mission:

13. **Increase food safety and consumer trust:** increase consumer trust by 50% by improving the authenticity, transparency and safety along the food system by 2030.

14. **Upgrade innovation capability**: Upgrade innovation capabilities of small actors in food systems.

15. **Strengthen citizens' roles:** Strengthen the different roles of citizens in a healthy, diverse and sustainable food system.

16. **Link cities and remote areas:** Linking cities, remote rural and coastal areas to perform innovatively in food systems.

17. **Improve international cooperation:** Improve international cooperation in trade and development, especially with Africa and the Middle East

We discuss these Focus Areas below:

13. Increase food safety and consumer trust in food and food data by 50% by improving the authenticity, transparency and safety guarantees along the food system by 2030

Vision

Consumers trust the safety, transparency and authenticity of the food system. Food contamination and authenticity incidents are controlled and prevented using efficient strategies, technologies and predictive modelling tools. Food fraud has been eliminated. Integration of ICT and other emerging technologies (blockchain, genomics, sensors) together with advanced data analysis assure a food system that food safety and food quality are integrated providing trust and transparency to consumers. EFSA has state of the art databases and information on emerging issues for an early reaction to potential food crises and new channels for appropriate risk communication are available. Trust in data and in science, including big data techniques for risk profiling and food advice is high.

The lack of transparency in food production, incidents of food counterfeiting and fraud (horsemeat scandal, melamine contamination in milk powders, inter-species fish substitution), and the global burden of foodborne disease have resulted in a loss of consumer trust. Food safety is a global concern that needs continuous efforts to support the development of transformations occurring in the food system, such as use of new raw materials and ingredients, technologies, business models, shorter food chains or distribution channels. Microbiological and chemical safety, as well new and more efficient communication tools are available to guarantee consumer trust. New tools assuring traceability, fraud free and authenticity of foods are developed to meet consumer expectations. Safety aspects of recycling of nutrients/materials, implementation of new processing technologies or development of new supply chains are assured.

Bottlenecks

Collaboration between food and other sectors (e.g. ICT) is necessary to develop, validate and test innovative solutions that make the food system safer, authentic and more transparent to the consumer. The complexity and diversity of the food system is a challenge and the integration of actors along the food chain is needed to implement the solutions developed. The lack of predictive tools for control and risk analysis compromises preventive actions. Better methods are needed to communicate between consumers and the industry, e.g. on the worries of consumers regarding new production technologies (crispr-cas etc.). Issues of data ownership, data governance and data ethics have to be solved. Focus in science communication on results of individual projects that contradict earlier findings, make consumers suspicious on food advice. Big data techniques like machine learning to generate risk profiles and food consumption advice without exact knowledge of causal effects have the potential to strengthen this trend. The governance of the current food system has for a large part been based on the price of products as the main form of information between actors. As the external effects of the food system on the environment are not priced in, this has led to alternative information flows like food safety and sustainability schemes of retailers and food processors and labelling of their products. Governments have started to regulate so that part of the externalities have been prized in. This leads to unclear signals and has not solved the unsustainable situation. A 100% transparency, now within reach due to developments in ICT, would make it possible for consumers and NGOs to judge the sustainability and the nutritional value of products. It would help consumers to make

better choices, probably with personalised nutrition tools from the ICT-industry and education in schools.

Synergies with other Focus Areas

Trust aspects are inherent to almost all Focus Areas, but more specifically:

- *To increase the consumption of healthy and sustainable diets* – This mission will provide tools for the assessment of the safety aspects of new raw materials, ingredients, foods as well as production processes and consumption.

- *Redesign, re-integrate and encourage low impact animal production systems* – This mission will provide tools for the assessment of safety, traceability and authenticity of low impact animal production systems need.

- *Double the availability of high quality food production from EU aquatic systems* - This mission will provide tools for the assessment of the safety, traceability and authenticity of the aquatic systems.

- *Halve food waste and food losses from the EU food system by 2030* – This mission will strength the impact of reducing food waste by improving the safety and traceability of "recycled" nutrients and including toxicity and pesticides.

- *Food processing with better outcome for nutritional and quality* – Development and evaluation of processing technologies requires safety aspects to be considered. The tools that will be developed in this Focus Area will speed up the implementation of safe processes.

- *Strengthen the different roles of citizens in healthy, diverse and sustainable food systems* – Understanding consumer concerns regarding food safety aspects is necessary to increase consumer trust.

Contribution to SDG and other (EU) policies

- **SDG2**: Adopt measures to ensure the safety of foods.

- **SDG3:** Strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks.

- Regulation (EU) 2015/2283 on novel foods

- REGULATION (EC) No 178/2002 of the European Parliament and of the Council of 28 January2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety.

- COMMISSION REGULATION (EU) No 16/2011 of 10 January 2011 laying down implementing measures for the Rapid alert system for food and feed.

- COMMISSION REGULATION (EC) No 450/2009 of 29 May 2009 on active and intelligent materials and articles intended to come into contact with food.

- Regulation (EU) No 1151/2012 of the European Parliament and of the Council of 21 November 2012 on quality schemes for agricultural products and foodstuffs.

- Commission regulation (EC) No 607/2009 of 14 July 2009 laying down certain detailed rules for the implementation of Council Regulation (EC) No 479/2008 as regards protected designations of origin and geographical indications, traditional terms, labelling and presentation of certain wine sector products.

- Commission Regulation (EC) No 401/2006 of 23 February 2006 laying down the methods of sampling and analysis for the official control of the levels of mycotoxins in foodstuffs.

What Needs to be done

- Provide consumers real time visibility into the supply chain to understand what they are buying, where food was produced and when food is spoiled
- Development of food consumption databases that are standardised across Europe representing data about toxic substances and biological agents from all countries to allow suitable food risk analyses to be performed.
- Development of sensors, such as near-infrared spectrometers and hyperspectral imaging to tackle food fraud and conduct non-destructive analysis of food
- Fast technologies/ analytical tools to identify pathogens preventing expensive product recalls
- Explore the role of labelling and packaging in assuring traceability and authenticity
- Improving cybersecurity to avoid food security crises
- Traceability of food ingredients
- Evaluate how the changes in climate factors affects pathogen distribution and drive food contamination
- Assure quality of data with transparent validation and certification.
- Better utilisation and federation of existing and future data and information streams
- Regular assessment of new methodologies, technologies, production processes and their implementation in the food chain to support EFSAs assessment
- Use ICT technologies including blockchain protocol(s) to secure the ledger of global trade and manufacturers that can be trusted by all of its users and be effectively un-hackable. For example, blockchain can be applied to the supply chain:
    - Use of a standardised an independent database shared by the global community, costumers included, that provides information on authenticity and production practices and increases trust
    - Track back and have instant quality assurance of products.
    - Use of smart contracts to automatically execute payments support short food chains
    - The information flow can be widely shared to enhance decisions at all levels of the supply chain
- Further developments in predictive risk analysis as tool to enhance identification of risks.
- Safe food for all, food intolerance and allergies are growing and suitable and safe foods should be available for these groups

Actors to be Mobilised

For the implementation of a safe, authentic and transparent food system a food system approach on food safety involving the following actors is needed:

Policy Makers: development and implementation of specific policies to improve safety, authenticity and transparency.

Food Authorities: to collaborate regarding data generation and analysis, risk assessment and management in order to prevent future food safety crises. Better communication tools with consumers. Data and methodologies to support assessment of new foods, technologies, and production processes.

Food Industry: to support the production of safer processes and foods. Together with the other actors of the food supply chain, to carry out the validation and implementation of tools, technologies or strategies to improve safety, authenticity and transparency.

Equipment/ Sensors Suppliers, ICT Companies: development of hardware and software for control, and prevention of microbiological and chemical hazards, spoilage, fraud, etc.

Packaging Suppliers: packaging solutions to assuring traceability and authenticity.

Supply Chain, Retailers, Distributors: together with food industry to validate and implement tools, technologies or strategies to improve safety, authenticity and transparency of the food system.

Consumer Organisations: dialogue partner about concerns on food safety and measures implemented.

Researchers: to generate evidence and independent data regarding issues that compromise food safety, authenticity and transparency.

Metrics / Indicators

Progress can be measured with the following indicators:

- Consumer trust index (KIC Food)
- Number of food crises and how fast they are tackled (data from EFSA)
- Reported cases of food fraud (Europol)
- Data about number of deaths due to food poisoning (WHO)
- Data of food contamination

14. Upgrade innovation capabilities of small actors in food systems

Vision

The innovation environment of the food system has changed significantly in the recent years, with concepts such as Open Innovation, citizen science, user-driven innovations and social innovation gaining increasing relevance. The food production landscape in the EU is dominated by small actors, either primary producers or SMEs in food processing, retailing or food services. Many small actors in the food systems have limited access to resources and know-how for R&I activities so that they require new or adapted capabilities to successfully benefit of this new innovation environment. Empowering these small actors is crucial to unlocking their potential to innovatively participate in sustainable food systems.

Considering that the EU agriculture sector consists primarily of very small or small holdings, their substantial impacts on rural development, job creation, crisis resilience and maintenance of landscape is disproportionally large, farms provide a flourishing environment for innovation, in which new models of farming and living are experimented, combining different types of activities, integrating the production with downstream stages of supply chains (processing and trade) and waste management.

Equally, fisheries have been a traditional employment in coastal areas and the link to aquatic food resources. Fishing communities retain a strong cultural character and they have been acting as managers of aquatic natural resources since a long period of time. Sustainable management of natural resources is a prerequisite to robust and future-proof food systems. Building awareness to farmers and fishermen of their function as natural resources managers is pivotal in safeguarding biodiversity, enhancing ecosystem services, alleviate environmental impact, and decreasing ecological footprint. Acting in their local environment as natural resources managers, primary producers will revolutionize food systems and positively influence other actors along the value chains towards sustainability.

Increased innovation capabilities of the food processing and retailing SMEs and of the catering services becomes crucial for future competitiveness of the food system of the EU. Thereby, traditional food SMEs will combine their knowledge in traditional recipes, food processing technologies, (regional) niche markets and citizens' needs with new technologies or innovation approaches. Additionally, the financing and entrepreneurial environment for high-tech food or retailing start-ups, which often focus on science- or knowledge driven innovations or technologies, will be improved in the EU. Increased R&I co-operations between in particular traditional food SMEs and research institutions will benefit both sides in knowledge creation and implementing innovations. New co-operation and business models between food multinationals and SMEs will allow the creation of a fruitful business environment for both groups, thereby taking into account the needs of citizens. Out-of-home and public food catering services will embrace new concepts and business models for delivering healthy and sustainable meals, with public institutions taking the leadership using the opportunities of public procurement.

Connecting communities of small actors to innovation hubs using ICT systems and tools will boost participation to activities designed centrally, allow better knowledge flow between them, facilitate new co-operation models between small actors and other stakeholders, and place any remote region in the centre of global developments and close to distant markets. Practicing more open forms of innovation can transform many areas of primary production (precision farming), food processing and retailing, and bring wider acceptance and application of new technical solutions. Digital tools can make remote areas attractive to young people that would like to be active professionals in food systems. The wide use of ICT tools in innovation and in commercial activities of the food systems will be governed by the appropriate legal framework that will go beyond the Protection of Personal Data (POPD) and will safeguard commercial interests of business actors, data protection and safety, ownership of data and access to them, who can generate knowledge out of them, their uses for commercial or scientific purposes. Such issues will have the international attention and consider the interests of the different stakeholder groups of the food system.

Bottlenecks

Several bottlenecks exist in realising this vision. A good number of primary producers still practice traditional production and harvest methods and lack the background to appreciate environmental dynamics and ecosystem services. Besides, there is a scarcity of incentives for farmers and fishermen to act as managers of natural resources and optimise their use contributing to the sustainability of the food systems. The fairly low degree of IT literacy among primary producers and other small actors of the food system hinders the digitalization of the food systems. Underwater internet is under development, and the Internet of Things is under-exploited in primary production as well as in

traditional food processing and retailing. High distances have to be covered to connect remote rural areas to internet services.

Knowledge transfer methodologies overlook the particularities of the small actors and as a result knowledge transfer is not efficient. The limited human resources, the lack of specialised staff and the distance from research activities limit the access to novel knowledge and know-how and deprive small actors from the benefits generated by R&I activities. The strong traditional views of many small actors of the food system that resist to openness and to social innovations is another bottleneck to implementing transforming, systemic innovation in food systems.

Synergies with other Focus Areas

This vision has positive effects on:

- *Personalised nutrition and diversified diets:* In particular, high-tech food start-up companies can contribute to the target of personalized nutrition. Small farmers and fishermen as well as food processing SMEs are mainly acting on local or regional markets (what increases trust in these actors) and produce a rich variety of different food products.

- *Sustainable resource use in food systems:* Small farmers have a key role in preserving biodiversity and soil health, and they implement a diversity of farming practices that are beneficial for the environment (e.g. agroecology, organic agriculture, and in general solution developed and experimented on a local scale). Small-scale producers provide food for local markets with very little transport needs and low ecological footprint. Primary producers are predestined managing sustainably natural resources on land and sea.

- *High quality food production from aquatic systems*: Improving the innovation capabilities of fishermen and other small-scale actors on coastal areas will increase effectiveness of related activities.

- *Food processing with better outcomes for nutritional and sensory food quality*: Small actors produce food adapted to the nutritional requirements and sensory needs of their customers in regional markets.

- *Linking cities and remote areas*: Small-scale actors play a key role in integrating rural or coastal areas innovatively in food systems.

Contribution to SDG and other (EU-) Policies

- SDG 2: Small actors hold crucial roles in food systems that ensure food availability and sustainable management of food resources.

- SDG 8: Small actors form the foundations of food systems in the EU and provide employment even in remote areas. They are inclusive and productive and vital to the EU economy.

- SDG 9: The empowerment of small actors will foster innovation and resilience at sustainable scale.

- SDG 12: Small actors producing locally and acting as managers of natural resources will promote sustainable production and low ecological footprint.

- SDG14: Fishermen and aquaculturists will be empowered to increase the aquatic production through unlocking the potential of the aquatic ecosystems and safeguarding their biodiversity and function.

- SDG15: The farmers and forest managers will manage terrestrial ecosystems to produce sustainably.

Trade-offs with other Focus Areas

No trade-offs with the other Focus Areas are foreseen.

What Needs to be done

Progress can be achieved in the following areas:

- Identifying the innovation needs and potential barriers of small actors as basis for developing participatory R&I models that are inclusive of small actors and other stakeholders of local food systems.

- Developing R&I models that combine traditional knowledge and modern scientific knowledge/methods adapted to sustainable small-scale food production systems.

- Developing adapted co-operation and innovation models (including financing schemes for food SMEs) between large food multinationals, international food retailing companies and small actors of the food system.

- Develop knowledge transfer tools tailored to support innovation by small actors, in specific locations, remote rural and coastal areas.

- Developing strategies and educational approaches to raise primary producers' awareness as managers of natural resources and empower them in this role.

- Developing co-operation and participation models for small actors to actively use digitalisation tools for more sustainable and healthy food systems.

- Elaborating rules and regulations on international level how to use electronically collected data taking into account POPD as well as the interests of all actors involved.

Actors who should be mobilised

In addition to **scientists/researchers** (economists, agronomists, ecologists, innovation scientists, social scientists, ICT engineers) a number of other actors need to be involved in order to upgrade the innovation capabilities of small actors in food systems:

Smallholder Farmers/Family Farmers, Pastoralists, Forest Keepers, Fishers and their Associations: they will offer valuable empirical knowledge to enrich innovation strategies and they will be empowered to take on new roles in food systems to support sustainability and circularity.

Small Food Processing, Food Retailing and Service Companies: they will embrace innovation to support the development of food products that meet the demands of the different groups of consumers and bears low ecological footprint through efficient knowledge transfer of research results and technological upgrade.

ICT Industry, Hardware Manufacturing, and ICT Services develop networks and hardware necessary for the new applications in primary production and connectivity between actors. They also organise exchange of information with attention to issues like privacy of data and network effects of platforms.

Policy Makers, Governmental Agencies, Regional Planners: they will shape the appropriate regulation framework to facilitate open innovation and incentivise small actors in new roles in the food systems.

Environmental Organisations, Social Scientists, Educators, Media Developers: they will support the building of awareness of the role of primary producers as managers of natural resources.

Indicators

Progress can be measured with the following indicators:

- Number (or relative proportion) of small farmers, fishermen, food processing SMEs, small retailers or food service providers who are active in Open Innovation activities or other forms of innovation.
- Internet coverage in remote, rural and coastal areas.
- Number (or relative proportion) of farmers and fishermen acting as natural resource managers.

15. Strengthen the different roles of citizens in a healthy, diverse and sustainable food system

Vision

In responsible societies, the food system is shaped to serve eaters' needs, make sustainable use of resources and generate minimal environmental impact. Moving towards more responsible societies implies a major cultural shift and in parallel it requires greater awareness of the diverse roles citizens play in society and more specifically in the food system. Each citizen plays at least one role in the food system. Becoming aware of the impact that every day choices have on the food system is crucial to nourish a responsible society and actively contribute to shape an inclusive, healthy, diverse and sustainable food system.

Food is a multifaceted issue. It embeds cultural, social, religious, as well political and economic components. There are a number of elements contributing to shape citizens actions in the food system including migration and religious practices, education and employment, economic possibilities, demography and geographical location. Understanding the dynamics that these elements generate and how they impact on the food system in different contexts is necessary to develop effective ways to approach, educate and raise awareness over the food system. Traditionally citizens' engagement is positioned at the end of the food production process and tends to be experienced as an activity of pure diligence. On the contrary, we need to open the way to citizens' right at the beginning and welcome their contributions, knowledge, understandings, visions and desires. Ultimately, they are the food buyers and eaters and as such their needs and behaviour matter.

Becoming a responsible actor in the food system requires certain sensitivity towards all these issues. It also requires active participation in the construction and definition of food system futures. It is important to listen others' views, accept differences, and be reflexive and sensitive to changes. If managed appropriately differences (views/knowledge etc.) are likely to enrich our futures. Create dialogue amongst all implicated actors is important when the aim is to let differences emerge and nourish the food system. Citizens' participation to the food system requires they become aware of their roles and importance in shaping the food system and our societies in general. This is a cultural shift that turns on the role of citizens in food systems. On the one hand, citizens must grow in credibility, and develop certain familiarity with nutrition, healthy diet and full food cycle. It is necessary they become conscious of their position and impact on the food system in shaping the present as well as the future[s]. They should be aware of the impact of food production on the environment, on their bodies and the rest of society. On the other hand, it is crucial that all the actors implicated in the food system strength their openness, inclusiveness and sensitivity towards each other,

heterogeneous needs and views. Ideally this frame paves the way to a future where citizens' needs and wishes are the main leverages colouring the food system.

We are all citizens and we are all eaters. Nonetheless, not all citizens are food producers or food buyers. We can indeed identify specific categories which are playing major roles in terms of food buyers, i.e. parents, health personnel, dieticians, catering and housing services. We can argue these groups are among those contributing more significantly to define the panorama of food consumption. Identify these crucial players and act on them is especially urgent. Ideally, they should be aware of the impact of food consumption on nutrition and health for themselves and those they care for as well as for the environment and the system. Supporting food producers and food buyers, caregivers, caters and eaters in adopting and promoting a healthy diet are major priorities.

Bottlenecks

There are a number of bottlenecks that need to be considered and do not allow the immediate realization of this vision. Citizens are largely uneducated about food, nutrition and the food system. Food consumption depends significantly over citizens' behaviours with regards to food, their education, cultural habits as well as accessibility and individual experiences. Citizens fail to recognize the importance of healthy nutrition, and education over these issues requires a long-term strategy, effective communication and diversified information. Convenience, low prices and habits often prevail over quality in food choices. In addition, misleading labels and speculative market strategies contribute to create confusion. Contexts, availability and bureaucratic constrains tend to further add complication.

Synergies with other Focus Areas

As citizens perform differing functions in the food system, this Focus Area is expected to act in synergy and contribute fundamentally to the following Focus areas:

- Focus Area 1: knowledgeable citizens will make responsible food consumption choices for themselves and those that they cater for thus fighting obesity.
- Focus Area 2: informed food eaters and consumers as well as nutrition professionals will be open to personalized nutrition choices and will implement them responsibly and effectively.
- Focus Area 3: nutrition is vital to sustain healthy and independent elderly citizens. Aging citizens and their care-holders knowledgeable of the role of food will contribute to consumption patterns with a positive impact.
- Focus Area 4: Knowledgeable citizens will drive the production of diverse, healthy food and exercise responsible food consumption with low ecological footprint minimizing food waste.
- Focus Area 6: citizens will support with their informed choice the local food production.
- Focus Area 11: citizens will drive with their choices the application of environmentally friendly food packaging.
- Focus Area 12: citizens aware of the actions that contribute to high production of food waste will opt for practices against it and will be engaged in community activities that target reducing food waste.
- Focus Area 14: informed citizen will support the innovation by small actors towards sustainability. Those who are entrepreneurs will seek and support innovations that ensure sustainability.

- Focus Area 16: citizens will have the background to deploy their roles responsibly in the food systems of their geographical area.

Contribution to SDG and other (EU-) policies

- **SDG 3**. Ensure healthy lives and promote well-being for all at all ages.
- **SDG 4**. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. Thereby all learners should acquire the knowledge and skills needed to promote sustainable development, including e.g. through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development.
- **SDG 11**. Make cities and human settlements inclusive, safe, resilient and sustainable.
- **SDG 12**. Ensure sustainable consumption and production patterns.
- **SDG 16**. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.

Trade-offs with other Focus Areas

There are no direct negative trade-offs to other Focus Areas but points of attention are the following:

- Citizens education
- Cultural shift of all included actors towards the idea of coproduction and shared responsibility
- Diversification and legitimation of roles opinions, views and needs of the other actors
- Participative food system governance
- Media role in influencing food system and consumption habits

What Needs to be done

Progress can be achieved in the following areas:

- Understanding the psychological, religious, social and financial obstacles to healthy, diverse and sustainable food consumption.
- Develop the educational and social innovations required to bring full attention of the citizens into the food functions. Religion, ethnicity, culture and age should be carefully considered.
- Identify trigger points for increasing engagement of each citizen in the food system.
- Develop policies and practices that facilitate the inclusion and engagement of citizens in the food system.
- Develop tailored educational approaches to target citizens and professionals according to their function in the food system.

- Educate citizens about the basic science as well as production, distribution, consumption, marketing and food waste related to the food system providing the full geographical dimension.

- Enhance knowledge exchange amongst actors/stakeholder.

- Developing strategies to open food production to society as a mean to increase citizen education with regard to science and in parallel facilitate stakeholders understanding of society's desiderata with regard to the future of food and food production.

- Develop policies that legitimate the role of citizens in the definition of the direction of science and the food system.

- Promote food co-creation to increase citizens and food producers awareness.

- Create a community of food ambassadors that are well-recognised and widely accepted to help spread of the principles of responsible and sustainable consumption.

- Design and develop social media and digital innovations for the cause.

- Develop methods to monitor the impact of citizen participation in different points within the food system.

- Elaborate new certification schemes to measure sustainability of food systems and implement clear labels in this area.

- Elaborate new business strategies and (public) intervention schemes that consider the interest of citizens to a higher extent than in the past.

- Clarify the effects of price incentives or other interventions on food markets or eating situations to support consumption of healthy and/or sustainable food products on citizens, other actors of the food system as well as public health effects and macro-economic effects in different regions.

Actors who should be Mobilised

Scientists (Nutrition Scientists, Food Scientists, Social and Policy Scientists, Consumer Scientists, Environmental Scientists): Analysing and developing strategies to healthy, diverse and sustainable food consumption. Clarifying the effects of price incentives or other interventions on food markets or eating situations as well as impact on all actors in the food system.

Policy Makers and Public Authorities: Development of new policies and interaction schemes that allow open participation of citizens and other actors in the food system. Implementing policies and practices that facilitate the inclusion and engagement of citizens in the food system.

Food Producers, Food Processing Companies, Food Retailers and Distributors: Elaborating new certification schemes to measure sustainability of food systems and implement clear labels in this field. Develop new business strategies which consider the interest of citizens to a higher extent than in the past.

Educators and Media Developers: Develop tailored educational approaches to target citizens and professionals according to their function in the food system and educate them in this respect.

Citizens, Consumer Organisations, Civil Society Actors: Including these groups in all activities is crucial for realising this vision.

Indicators

Progress can be measured with the following indicators:

- Number of educational programmes of different levels on food and nutrition.
- Levels of meat consumption; fresh vs processed food consumption; local vs non-local food consumption.
- Percentage of informed choice of food with low ecological footprint.
- Indications over changes in terms of access and availability to healthy food.

16. Linking cities, remote rural and coastal areas to perform innovatively in food systems

Vision

Cities are centres of economic, political and cultural innovation, and manage vast public resources, infrastructure, investments and expertise. As urban population is increasing (by 2050, an estimated 70% of world's total population will be urban), cities exert considerable pressure on both local and global resources, facing fundamental challenges including food and nutrition security. As a consequence, cities will play a key role in promoting more sustainable food systems, are well suited to grasp the complex nature of food systems, and consequently can adopt cross-sectorial policies. Due to their "territorial" approach, cities can include divergent motivations and views of various actors (like e.g. citizens, economic actors, public entities), enhance trust between stakeholders, develop projects that fulfil different objectives (integrating local economic development with environment preservation, health, quality of life, poverty alleviation, building of social capital). Furthermore, cities will increasingly become places of local food production both in high-tech environments as well as more socially-oriented forms of collaboration among citizens.

Cities should be supported to develop urban food policies and participatory governance models and practices to enable participation of stakeholders and new forms of citizenship. In this context, cities and the research community should cooperate in order to enable researchers to develop innovative solutions grounded on local needs. Furthermore, the collaboration between academic researchers and urban food policy networks could ensure that what is learned in urban food policy can be analysed independently and in turn widely shared outside the scientific community. This ultimately is going to stimulate the development of sustainable innovations in the food systems that are adapted to local environments and citizens' needs.

"Territorial" aspects play a key role when considering the contribution of remote coastal and rural areas in the food systems. There is a concentration process in agriculture food processing that makes that many of the value added processes and innovation are carried out in and around the metropolises. Headquarters, research labs and universities are traditionally located in those areas, and developments in ICT have the potential to govern the food system from those central hubs. Mechanisms should be in place that help remote areas to keep up with the innovations in the metropoles.

Moving towards more sustainable food systems requires the maintenance of vivid communities in remote, rural and coastal areas and the involvement of young people with adequate background and potential to innovate. Creating links between remote areas and cities will strengthen awareness among local actors of the food system to actively participate in innovation activities. Novel approaches to re-localize jobs and

revitalize local economies, manage locally available land more sustainably and in a resource-friendly manner, reduce malnutrition and improve health, test alternative governance mechanisms, increase the participation of stakeholders in policy and planning at a local level are important cornerstones to implementing an efficient shift towards sustainable, open and diverse food systems.

In addition, safeguarding economic activities in farming and outside farming (e.g. handicrafts, local services, forestry, tourism, ecosystem services) are important measures to re-vitalize remote rural areas. This is also relevant to ensure the supply of (the often) aging population with daily-life services as well as age-adapted nutrition that is affordable by elderly people with limited income. Therefore, support of "basic" societal life and community activities are required in order to keep the young population in such remote areas as well to increase interests of citizens of urban regions to engage in such areas. Furthermore, the supply of ecologically-friendly and sustainably produced raw materials in farming or the fishing sector could attract processing industries to invest in such remote areas.

Bottlenecks

Bottlenecks concerning the role of cities in food systems relate to the lack of knowledge on small-scale food production in cities as well as to the highly restricted area available to produce food in urban areas. Furthermore, city dwellers appear disconnected from and unaware of the processes and techniques of food production and food processing. Competences related to food are scattered in different departments and organisations in public authorities. The alternative ways of organising food production, based on new ways of social interaction, are not always accepted by the entire population. Limited collaborations between urban authorities and R&I specialists hamper social and other forms of innovations in many cities. The governance of the food system is often complicated because the competences may be included not only in different levels of government, but also within one level in different departments (e.g. agriculture, economics, health, environment etc.).

Concerning remote rural and coastal areas, the population structure, with mostly an aging population and only few young people residing in remote rural or coastal areas, is a major bottleneck. The traditional social support systems (like multi-generation families, neighbours, local clubs or churches) are often weakened in local societies of such areas, and old farmers or fishermen that are working in these areas hardly make a living from their activities. Additional industrial employment possibilities or other alternative income (e.g. tourism, eco-services) are limited in many remote rural or coastal areas. Finally, there is a lack of entrepreneurs, innovative ideas and innovation-supporting "infrastructure" in many rural or coastal areas that hinder impactful innovations of all forms.

Synergies with other Focus Areas

Realising this vision has positive effect on:

- *Personalised nutrition and diversified diets:* The stronger involvement of cities, rural and coastal areas in food systems will contribute to more regionally-organised value chains that retain the regional food diversity and establish a direct interaction between the producers and the citizens based on trust and transparency. Ensuring the daily-life services and an affordable age-adapted nutrition of elderly people in cities and linked rural or coastal areas will positively contribute to their life expectancy and quality.

- *Sustainable resource use in food systems:* Aiming at food production at a local scale, this Focus Area directly contributes to developing sustainable and climate-resilient food systems on a territorial scale as well as to diversifying fields, farms and landscapes to achieve climate-proof and sustainable resource use, for healthy people, healthy environment and a healthy planet.

- *High quality food production from aquatic systems*: Due to the support of remote coastal areas, this action directly contributes to doubling the availability of high quality food production from EU aquatic systems (fresh water, coastal areas, seas and oceans) by a truly sustainable use of these systems.

- *Reducing food packaging:* The mostly local and regional value chains of this vision allow reducing packaging materials in the food system.

- *Inclusion of all stakeholders in an open food system:* The inclusion of small-scale actors is a direct target of this vision and thus will contribute to upgrade innovation capabilities of small actors in food systems. The same relates to strengthening the roles of citizens in healthy, diverse and sustainable food systems.

Contribution to SDG and other (EU-) Policies

- **SDG 1** (End poverty in all its forms everywhere) Support to remote, rural and coastal areas will increase the employment and quality of life as well as reinforce the interaction with the cities, with a positive impact on the income of producers.

- **SDG 2** (End hunger, achieve food security and improved nutrition and promote sustainable agriculture). The organization of local communities to act appropriately in the food systems will optimise resource use and adequate food production.

- **SDG 8** (Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all). All citizens participate in the food systems in the EU and benefit from the employment opportunities even in remote areas. They are inclusive and productive and vital to the EU economy.

- **SDG 11** (Make cities and human settlements inclusive, safe, resilient and sustainable). Cities and human settlements in general, are re-organised to perform efficiently at a territorial level towards sustainable and circular food production and consumption.

- **SDG 12** (Ensure sustainable consumption and production patterns). Citizens knowledgeable of the geographical dimension of the food systems will participate in the processes of the food systems in their area.

- The current Focus Area will also create the wide foundation for the implementation of all EU policies relevant to food production (**CAP, CFP, Bioeconomy Strategy, Circular Economy Package**); the **EU Cohesion Policy** that supports job creation, business competitiveness, economic growth, sustainable development, and improvement of citizens' quality of life in all regions in the EU; the **UN-FAO food for the city** programme that promotes the organization of *City Region Food Systems* (CRFS) through wider participatory approaches.

Trade-offs with other Focus Areas

No trade-offs with the other Focus Areas are foreseen.

What needs to be done

Progress can be achieved in the following areas:

- Identifying cities' triggering point in order to act towards more sustainable food systems as basis for developing related strategies.

- Developing and supporting innovative, open and participatory forms of governance for urban and rural food systems.

- Establishing platforms for collaboration between academic researchers, cities and involved actors of urban food systems.

- Supporting cities in the evaluation of the local food system as well as cooperation among them as a way to disseminate best practices and stimulate innovation.

- Identifying the needs and actual behaviour of elderly people in remote rural and coastal areas and the extent and kind of technical and social infrastructure that is needed to safeguard supply of the aging population.

- Elaborating and implementing social innovations/alternative organisational structures to ensure basic societal life in small rural communities.

- Developing alternative ways of farming (including viable business models) as well as more sustainable forms of the use of aquatic resources in restricted spaces.

- Connecting engaged (retired) people in cities with elderly people in rural/coastal areas via IT services in order to motivate them to start common activities or to identify the potential of remote rural areas to be attractive living places for retired people.

Actors who should be mobilised

Scientists (Sociologists, Environmental scientists, Economists, Food and Nutrition scientists, Agronomists, Urban planners, Innovation specialists, RRI experts): Identifying triggering points in cities to act towards more sustainable food systems and developing innovative, open and participatory strategies based on this. Analysing and developing alternative ways of farming and for aquatic activities in remote areas.

Policy Makers and Public Authorities (Urban, Rural and Coastal Authorities, Regional and National Authorities, Policy Makers on different levels, Governmental Agencies): Development of new policies and interaction schemes that allow open participation of citizens and other actors in the food system. Implementing policies and practices which facilitate linking cities with remote rural and coastal areas in innovation activities and societal life.

Farmers, Fishermen, Food Producers, Food Processing Companies, Food Retailers and Distributors, Forestry Authorities, Tourism Companies, Companies which are active in Processing of Biomass for Non-Food Purposes: Developing and realizing innovative, open and participatory forms of governance for urban and rural food systems. Analyse alternative ways of farming, viable business models and income possibilities outside farming in remote rural areas as well as sustainable forms of the use of aquatic resources in restricted spaces. Elaborating and implementing social innovations/alternative organisational structures to ensure basic societal life in small rural communities.

Citizens, Consumer Organisations, Civil Society Actors, Farmers Associations, Fishermen Association, Trade Organisations, and Environmental Groups: Including these groups in all activities is crucial for realising this Focus Area.

Indicators

Progress can be measured with the following indicators:

- Number of initiatives in cities, remote rural or coastal areas which actively contribute to more open and sustainable food systems.

- Number of actors involved in *City Region Food Systems.*
- Quantity and quality of IT-links that are required in *City Region Food Systems.*

17. Improve international cooperation in trade and development, especially with Africa and the Middle East

Vision

The SDGs define a global framework where each country and region invents its own pathway towards reaching sustainable development, specifically adapted to its national circumstances, whereby not preventing other countries and regions to reach sustainable development. Europe is both a large exporter and importer of agricultural and food products, and the transformation of its food system to sustainability needs to be assessed with regard to its capacity to contribute rather than prevent sustainable development in other regions and countries.

Nutritional imbalances in both Europe and Africa are increasing, characterised by growing diet-related, non-communicable diseases and persistent under-nutrition. The UN projects that the global population will increase from 7 billion to more than 9 billion by 2050[30], of which the majority is expected to occur in Africa. To anticipate such population growth and challenges associated with enhanced climate change, agricultural systems need to become more sustainable and better linked to nutrition performance by strengthening the agro-biodiversity of resilient cropping systems, thereby increasing the range of food products for a balanced, healthy diet. Furthermore, resource-efficient, resilient food value chains need to be developed to deliver sufficient, safe, affordable and nutritious food to local consumers and for high value global markets. Africa has a wealth of local varieties, food intelligence and healthy African diets including plant based proteins, which are currently largely untapped and not reaching the market, neither in African cities nor in Europe.

The healthy Mediterranean diet is shared across the Mediterranean Sea in many regional variations. Many countries of Europe have adopted parts of it and more food innovations could be exchanged.

Europe has the world a lot to offer, also in the domain of food. With its rich soils, attractive climate, water resources as well as innovative farmers and renowned companies in the food chain, it is a major exporter of high quality foods. In addition there is also an important export of machines and services, from milking robots to feed ingredients and auditing services for sustainability schemes. At the same time Europe is a main importer for e.g. basic commodities in feed, aquaculture and tropical products. Parts of farming in the EU depend on migrant labour from outside the Union. This international cooperation in the form of trade brings benefits to the European Union as well as its trade partners and has to be promoted and improved in those cases where negative effects occur.

Especially a harmonious relation of the European Union with its neighbours is of importance. The challenges to the local food and agriculture systems due to rapid demographic growth and urbanisation, to social dynamics, governance challenges in Africa as well the effects of climate change, especially in the Middle East and Northern Africa are to be solved by more intense collaboration, more coherence within the programs and more commitment to build resilient food systems. Assessing the impacts of changes in EU policies (and not only trade policies) and of the EU food systems on third countries capacity to reach sustainable development are essential to ensure EU's

---

30 http://www.un.org/en/development/desa/news/population/2015-report.html

contribution to global achievement of SDGs. In particular, negotiations on free trade (with Mediterranean countries, or in the framework of the Post Cotonou conversations with ACP countries) need to be informed trough a reflexion on innovative pathways towards sustainable development both for the European food system and for developing countries.

Europe's public support to agriculture innovation in Europe and in third countries can also be considered as a contribution to a global commons, in particular when development aid is targeting support to innovation systems in agriculture in developing countries themselves, but also through knowledge and innovations developed in Europe that can find relevance in other contexts.

Bottlenecks

International trade and cooperation are under stress due to geo-political tensions. Decades of globalisation after the end of the cold war, supported by technological developments like the internet and cheaper air travel and mulit-lateral agreements in the GATT / WTO (World Trade Organisation), seems to be taken for granted and give way to an orientation that is more nationally focussed. Inequality and a feeling of insecurity, as a result of the welfare generated by increased globalisation and fast technological development, play an important role in this change of political views. As a result the WTO is not able to make progress, while bilateral trade agreements are developing.

The Paris Agreement on Climate Change forces countries to make agriculture and food production more sustainable, but with levels of ambition and speed of transformation that are differing depending on each country's circumstances. Partly because some developing countries have lower emission-reduction targets, partly because agriculture has a different share of the national emissions and varying political power in the different countries that will lead to specific targets in the national allocations of the effort sharing. This could lead to relocations of food production that not necessarily contribute to sustainability ("carbon leakage"), while the capacity to assess the mitigation potential in each country also needs to take into account not only GHG reductions but other environmental performance dimensions, impacts on food security and on capacity to reduce poverty and inequalities.

This is just one example of interactions between national sustainability pathways and changes in trade patterns. More general: over the last decades the price mechanism in the food system has been complemented by sustainability, food safety and fair trade certification systems as prices do not reflect externality effects on the environment and inequalities. And at the same time governments have started to regulate production to reduce environmental effects. These norms, standards and certification systems are sometimes presented as non-tariff barriers in the trade negotiations, or precisely as collective preferences that need to be preserved. Reaching SDGs globally necessitates that ambition in sustainability is increased, while this would not be used as a barrier to access to markets, for instance from least developed countries to the EU market. There is also a big risk that the more sustainable food that the European food systems will market in the next years face competition on price from less sustainable products from outside the EU that under current WTO rules cannot be blocked from entering the market. An additional issue for developing countries is that they need to increase food production and want to protect the infant food industry by copying a type of agricultural policy that Europe ran so successfully in the 1950s and 1960s to modernise its agriculture. A global scientific forum, comparable to e.g. the IPCC in climate change, to support the governance of the international food systems would be necessary, to assess the global sustainability and food security impacts of national policies to make the food system more sustainable, as well as of bilateral or multilateral trade negotiations. The existing High Level Panel of Experts attached to the UN Committee on World Food Security (CFS) plays a key role to organise a structured negotiation within the CFS on many crucial issues and should be supported, but its current mandate and resources are probably not sufficient to answer the critical questions asked at the interface between SDGs and trade in the global food system. Supporting existing science policy interface institutions and

identifying the best institutional option to complement them to address these key global questions is very consistent with the EU's past intervention in this field[31].

Trade in food can bring progress to rural areas. In the 19th century several regions in Europe, from Denmark and the Netherlands to Bretagne, kick started regional development by exporting food to the cities of the industrial revolution in England or the German Ruhr area. The urbanisation in Africa can have a similar effect for the poor African country side. However this asks for a leap forward in building institutions in those countries (land cadastre, food safety inspection, education and extension, credit and insurance systems etc.) as well as infrastructure (irrigation, transport) and research in local farm systems and breeding of its typical plants and animals. Such research is especially needed given the effects of climate change. Smallholder farmers and fishermen need access to financing instruments in their rural environments. An approach like in the European Innovation Partnerships that link local innovation systems and bottom-up processes to European research and innovation systems might be considered in Africa as well.

Supporting the development and implementation of technical/social/organisational innovations based on the resources of the African countries and the ideas which are emerging there is needed. Agriculture and nutrition are of particular importance for their development. This requires technical innovations (better varieties for plants and animals, production techniques, irrigation, animal hygiene, storage and post-harvest technologies etc.), organisational innovations (e.g. strengthening the role of farmers associations, cooperatives), systemic innovations (e.g. development of business models for African countries, marketing and distribution within the country and internationally), and social innovations (strengthening the role of women and girls etc.).

In terms of nutrition, according to The Africa Nutrition Report recently released by WHO (2017), undernutrition is still persistent in the WHO African Region, with major implications for health, particularly among poor and vulnerable population groups. Analysis of data shows that, instead of falling, the rates of stunting are increasing. Furthermore, the prevalence of overweight among children under 5 years of age (as well as the overall number of children affected) is also rising. A lot needs to be done to drive progress on the global targets for 2025 and Sustainable Development Goal No. 2. Malnutrition (both under-nutrition and obesity) is associated with poor availability of nutrient balanced foods and micronutrient deficiency (food intake low in minerals and vitamins).

Another important aspect (which fits in the food system approach) is safeguarding the (rich) natural resources of Africa. There are a lot of challenges (much more drastic impacts of climate change, over fishing, strong increase in population will increase pressure on natural habitats, subsidies e.g. for fossil energies prevent solutions based on renewable energies etc.). On the other hand, in a lot of countries the use of natural resources contributes to more than 50 % of the gross domestic product of many African countries. Therefore sustainable innovations are needed which could be much supported by co-operation projects between EU and Africa.

The European Union has in this respect a special responsibility to use its research and innovation capacity also for the benefit for production in the neighbouring countries. Not only as a good neighbour policy or given historical ties, but also out of some well-understood self-interest: a collapse of food systems in Africa and the Middle East under the stress of climate change can easily lead to large migration flows, sometimes in connection to local civil wars. Moreover, research and innovation in Southern contexts

[31]https://www.iddri.org/en/publications-and-events/policy-brief/recent-trends-global-governance-food-and-nutrition-security

http://www3.lei.wur.nl/WECRGeneral/FoodSecurePublications/Treyer_Governance_R6.pdf

could also provide interesting solutions to inspire in return innovations in food systems in Europe.

The High Level Policy Dialogue (HLPD) on Science Technology and Innovation launched as a first priority the EU-Africa Research and Innovation Partnership on Food and Nutrition Security and Sustainable Agriculture (FNSSA) which links to the Comprehensive African Agriculture Development Programme (CAADP) and the Science, Technology and Innovations Strategies for Africa (STISA). All these initiatives are mainstreaming research and innovation in an approach of linking farmers, advisors, businesses and civil society organisations to researchers to contribute to African development, and facilitate concrete innovation stories, build capacities on the continent and mobilise resources for agri-food research and innovation.

The FNSSA roadmap, endorsed in April 2016 builds on 4 pillars:

- Sustainable intensification to reduce the environmental impact and waste of agriculture systems
- Agriculture and food systems that improve nutrition
- Expansion and improvement of agricultural markets and trade, amongst others with a focus on food safety issues
- Cross-cutting issue such as innovation processes, capacity-building in terms of human development and research infrastructures and the science to policy interface.

Among the concrete first outcomes are research and innovation partnerships such as LEAP-AGRI with a total budget of 33 million euros. Further projects include SEACRIFOG, investing 2 million euros in EU Africa collaboration in research infrastructures for food security and greenhouse gas assessments. or the 4.8 million euro project INNOVAFRICA improving knowledge linkages between farmers and research which are all funded by Horizon 2020.

Part of the HLPD-FNSSA is also the African Union Research Grants. This programme, funded by the Pan-African Programme of the European Commission for 17 million euros assists the African Union Commission in building its own research and innovation funding programme.

So far the FNSSA priority has attracted more than 150 million euros in funding from Horizon 2020, the Panafrican Programme and contributions of EU and African Union Member states.

Synergies with other Focus areas

Aspects of international cooperation and trade are inherent to almost all Focus areas, but more specifically:

- *To increase the consumption of healthy and sustainable diets* – This Focus area will provide insights and tools that are also very relevant for the population in developing countries, where phenomena like 'double stunting' are prevalent.
- *Sustainable resource use in food systems:* Aiming at food production at a local scale, this Focus area directly contributes to developing sustainable and climate-resilient food systems on a territorial scale. Its insights and tools will be directly relevant for production systems in developing countries. Synergies with conservation (biodiversity) and water programs should be strengthened, but not excluding links with education and support of legal systems.

- *Increase consumer trust in food and food data by 50% by improving the authenticity, transparency and guaranteeing integrity along the food system by 2030:* The use of certified sustainability schemes in international trade that is coherent with the price mechanism, will increase trust with the actors in the food chain.

Contribution to SDG and other (EU) policies

- **SDG1:** End poverty in all its forms everywhere
- **SDG2**: Adopt measures to ensure the safety of foods.
- **SDG3:** Strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks.
- **SDG17:** Partnership based cooperation
- **HLPD Roadmap**

What Needs to be done

- Organise authorative (IPCC-like) assessments of sustainable food and agriculture systems transformation pathways and roadmaps to sustainability (public and private strategies and incentives) and their transboundary impacts in terms of sustainability, food security and sustainable development opportunities of other countries
- Support the UN_ CFS (Committee on World Food Security) and its science policy interface. Include sustainability dimensions in it.
- Work on a framework for addressing the lack of attractiveness for small-scale farmers and boosting regenerative agriculture as an engine for growth and sustainable development.
- Further develop the Food and Nutrition Security and Sustainable Agriculture priority of the EU-African Union High Level Policy Dialogue on Research and Innovation by including more Member States (EU and AU) in co-funding mechanisms.
- Develop internationally recognised frameworks for True Cost accounting of food and other bio-based products.
- Develop and deploy frameworks for institutional development to upgrade food systems in developing countries, especially in relation to urbanisation in Africa and the Middle East.
- Use ICT technologies including blockchain protocol(s) to secure the ledger of global trade and manufacturers that can be trusted by all of its users and be effectively un-hackable.
- Strengthen the strategic links and collaboration frameworks with the core regions (like Africa) in the domains of agriculture research (FARA, NEPAD), policy coherence and SDG target monitoring
- Support agriculture and food knowledge and innovation systems in Southern countries, in particular in Africa.

Actors to be mobilised

Policy Makers: development of framework and research programmes

Farmers groups and farmers federations as well as Extension systems: to work on innovation.

Researchers: at regional, sub-regional and national level, from both natural and social sciences.

Processing companies: helping to reduce food and post-harvest losses and create employment (and so indirectly make farming more attractive)

Metrics / Indicators

Progress can be measured with the following indicators:

- Level of self-sufficiency in food in Africa and the Middle East
- Number and % of undernourished children
- % public investment in agriculture, % public investment in agricultural research
- Average age of farmers
- Development of international trade in food
- Number of trade disputes in international food trade.

CONCLUSIONS AND RECOMMENDATIONS

Like a Michelin-starred menu, the food system has a lot of ingredients – individual farmers, multinational vendors, international governments and of course consumers, who may not equate what is healthy with what is tasty. There is no one switch for a sustainable system.

Interventions at the point where the problem occurs do not solve it: the taxpayer will continue to subsidize farmers and pay for the increasing costs of the health system. Meanwhile, small food companies, farmers and fishermen continue to lack incentives to provide sustainable and healthy food. So, we need a multi-objective and multi-actor drive for responsible innovation across the food system, with new partners like cities and health insurers. New technologies in genetics and preventive health (e.g., the microbiome, neuroscience) and ICT (artificial intelligence, precision farming, personalised nutrition) could also help to bring change, if applied in the right way. Social innovation and organizational changes are required to realize a climate-smart, sustainable food system for a healthy Europe.

In the age of the bioeconomy, Europe is well positioned to take the lead and guide the world towards a food system that is future proof. We have a sense of urgency plus state-of-the-art food production systems, high levels of food safety and environmental quality standards and a first-class knowledge infrastructure. Europe has the capacity to lead the world in creating a sustainable food system and benefit from the business it will generate. In this way the European industry (food, health, ict) will improve its competitive position vis-à-vis other continents.

Tackling this grand challenge by completing the three missions will need major investment, way above the currently allocated framework funding. We, as experts, therefore call for substantial investment within the framework of the next EU budget in partnership with Members States, industry, civil society, and others. This investment should be deployed via a dedicated Research, Innovation and Investment Strategy (RI&IS) which engages all possible instruments and partnerships necessary to get the job done. Past investments in agricultural research have resulted in a large societal return: US data suggest that $1 invested was worth ten times as much, over time. Even greater results have been shown with non-communicable diseases: reducing salt intake by 30% in the high-burden population of sick people reportedly gave US society $19 of benefit for every $1 spent. In Europe, greenhouse gas emissions from the food system are currently around 1180 Mtonnes CO2-equivalents. Reducing that by 50% would save the equivalent of €20 billion a year.

Recommendations

European Union (Commission, Parliament, Council): Adopt the main conclusion of this advice to develop a unified, health-centric, climate-smart, sustainable and resilient food system for Europe based on a system approach to R&I and of a substantial investment way above the current allocation from the EU budget and beyond.

Directorate General RTD Lead by example and convene and organise the necessary critical mass within the European Commission as a first step to working together towards these common goals. Work closely with DG Agri and others to deliver a food system that improves the social contract between agriculture and society on providing healthy, sustainable food at prices that are fair for farmers and consumers.

Member States (and regions in federated member states) Support the approach in the EU by making your own research and innovation programmes mission-driven, with

the same grand challenge and three missions advocated here. You could choose from the 17 focus areas to represent your national priorities and specialisms. Work jointly in ministries and authorities across departments to implement a systems approach to R&I policy and governance on these missions.

Companies (in food processing, retail, input industries, ICT, health, and finance) Reconsider your business strategy, given the challenges for the food system, scale up your innovation activities and link them to the research and innovation programmes of the EU and the member states.

Farmers, SMEs in the food chain and start-ups in the food system Realise that there are chances to improve your position in the food chain by pursuing innovation, stronger collaboration with different food chain actors and participation in multi-party innovation programmes.

Citizens and consumers: eat in a healthy and sustainable way; contribute ideas to innovative projects to support the transition of the food system.

Cities and other local (water) authorities Introduce a proactive food policy that creates healthy, sustainable urban environments to make healthy and sustainable choices appealing for consumers. Make sure that city neighbourhoods are connected with the surrounding green countryside and seaside for a healthy lifestyle. Multi-party innovation should be an important part of urban food policies.

Civil society and non-governmental organisations Your objectives can partly be realised by advocating for the proposed missions and by taking part in innovation programmes with the people you represent.

REFERENCES CITED

- AiCARE [Italian Agency for Responsible and Ethic Countryside and Agriculture], (2015). *Revolutionary solutions for local food systems*. Online resource. Available at: http://www.agricultureinanurbanizingsociety.com/content/uploads/2015/09/Finalists-Award-Aicare-2015.pdf.

- Allen, B. and Maréchal, A., (2017). *Agriculture GHG Emissions: Determining the Potential Contribution to the Effort Sharing Regulation*. Report prepared for Transport and Environment. Institute for European Environmental Policy, London.

- Baptista, A., et al, (2014). *AKIS and advisory services in Portugal. Report for the AKIS inventory (WP3) of the PROAKIS project*. Online resource. Available at: www.proakis.eu/publicationsandevents/pubs.

- Bowman, M.S., and Zilberman, D., (2013). 'Economic factors affecting diversified farming systems'. *Ecology and Society*, vol. 18. doi:10.5751/ES-05574-180133.

- Bünemann, E. K., Bongiorno, G., Bai, Z., Creamer, R. E., De Deyn, G., de Goede, R., Fleskens, L., Geissen, V., Kuyper, T. W., Mäder, P., Pulleman, M., Sukkel, W., van Groenigen, J. W. and Brussaard, L., 2018: Soil quality – A critical review. Soil Biology and Biochemistry 120: 105-125.

- Detang-Dessendre, C., F. Geerling-Eiff, H. Guyomard and K. Poppe: *EU agriculture and innovation: What role for the CAP?,* INRA, Paris, 2018.

- DeFries, R., et al, (2015). Metrics for land-scarce agriculture. Science 349, 238–240.

- Dithmer, J. and Abdulai A., (2017). 'Does trade openness contribute to food security? A dynamic panel analysis'. *Food Policy*, vol. 69, pp. 218–230. http://dx.doi.org/ 10.1016/j.foodpol.2017.04.008 0306-9192/

- European Commission, (2014a). *An ex-post evaluation of the rationale, implementation and impacts of EU Seventh Framework Programme (2007-2013)*. Cooperation Theme 2: Food, agriculture and fisheries, and biotechnology. Report to the European Commission.

- European Commission, (2014b). *Performance of SMEs within FP7: An interim evaluation of FP7 components*. Brussels.

- European Commission, (2015a). *Sustainable Agriculture, Forestry and Fisheries in the Bioeconomy - A Challenge for Europe*. 4th SCAR Foresight Exercise. Directorate-General for Research and Innovation. HORIZON 2020, Societal Challenge 2. ISBN 978-92-79-47538-2 doi:10.2777/179843 KI-01-15-295-EN-N.

- European Commission, (2015b). HORIZON2020 WORK PROGRAMME 2014 – 2015 'Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy'. (European Commission Decision C (2015)2453 of 17 April 2015).

- European Commission, (2015c). European Innovation Partnership for Agriculture: EIP-AGRI Network 2015.

- European Commission, (2016). *European Research and Innovation for Food and Nutrition Security*. Directorate-General for Research and Innovation. Directorate

F-Bieoconomy-Unit F3- Agri-Food Chain. ISBN 978-92-79-63516-8 doi:10.2777/549154 KI-07-16-013-EN-C.

- European Commission, (2017a). *Europe's future: Open innovation, open science, open to the world*. Reflections of the RISE Group. Brussels.

- European Commission, (2017b). *Commission Staff Working Document Interim Evaluation of Horizon 2020*. Directorate-General for Research and Innovation Directorate A — Policy Development and Coordination Unit A.5 — Better Regulation. ISBN 978-92-79-69545-2 doi: 10.2777/220768 KI-01-17-599-EN-N.

- European Commission, (2017c). *Interim evaluation of Horizon 2020*. Brussels.

- European Commission, (2017d). HORIZON 2020 WORK PROGRAMME 2015 – 2016 'Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy'. (European Commission Decision C (2017)2468 of 24 April 2017).

- European Commission, (2017e). Fabbri, K. (ed). *FOOD 2030: Future Proofing our Food systems through Research and Innovation*. Directorate-General for Research and Innovation. Directorate F-Bieoconomy-Unit F3- Agri-Food Chain. ISBN 978-92-79-69841-5 doi:10.2777/249082.

- European Commission, (2017f). *Summary statistics FOOD 2030 Priorities for H2020 Projects*. CORDA_ iSearch_20170427.

- European Commission, (2017g). SC2 - Curated portfolio data and figures. CORDA Database.

- European Commission, (2017h). Expert Group Report Review of the EU Bioeconomy Strategy and its Action Plan Directorate-General for Research and Innovation Directorate F — Bioeconomy. ISBN 978-92-79-74015-2 doi: 10.2777/149467 KI-05-17-075-EN-N.

- European Commission (2017i). Meeting Societal Challenge 2: Approaches to examining how Framework Programmes address Societal Challenge 2: Food Security. Sustainable Agriculture and Forestry. Marine. Maritime and Inland Water Research and the Bioeconomy.

- European Court of Auditors, (2016), Combating Food Waste: an opportunity for the EU to improve the resource-efficiency of the food supply chain. Special report. No. 34 . https://www.eca.europa.eu/Lists/ECADocuments/SR16_34/SR_FOOD_WASTE_EN.pdfEuropean Social Innovation Research (2017). Online. Available at: http://siresearch.eu/social-innovation.

- European Environment Agency (2017): *Food in a green light*, Copenhagen.

- European Union (2011). *Sustainable food consumption and production in a resource-constrained world*. 3rd SCAR Foresight Exercise. Luxembourg: Publications Office of the European Union.

- FoodDrink Europe (2017). *Data and Trends of the European Food and Drink Industry 2017*. October 2017. Brussels: FoodDrink Europe.

- FAO (2014a). *Final Report for the International Symposium on Agroecology for Food Security and Nutrition*. 18 & 19 September 2014, Rome, Italy. Online resource. Available at: http://www.fao.org/3/a-i4327e.pdf.

- FAO (2014b). Food Wastage Footprint: Full-Cost Accounting, Final Report. http://www.fao.org/3/a-i3991e.pdf
- FAO (2017a). The Future of Food and Agriculture – challenges and trends. Rome p. 111-117.
- FAO, IFAD, UNICEF, WFP and WHO, (2017). *The State of Food Security and Nutrition in the World 2017: Building resilience for peace and food security*. Rome: FAO.
- Fresco, L.O. and K.J. Poppe (2016): *Towards a Common Agricultural and Food Policy*, Wageningen University and Research, Wageningen.
- Fuglie, K.O. and P. W. Heisey (2007): Economic Returns to Public Agricultural Research USDA-ERS, Washington.
- FUSIONS (2016) *Estimates of European food waste levels*. Project Report.
- Guillou, M., (2013). 'Vers des agricultures doublement performantes pour conciliar compétitivité et respect de l'environnement', INRA Agreenium, p. 163.
- Godfray H. et al., (2010). 'Food Security: The Challenge of Feeding 9 Billion People'. *Science*, Vol. 327, Issue 5967, pp. 812-818.
- Hekkert M.P., Suurs R.A.A., Negro S.O., Kuhlmann S., Smits R.E.H.M., 2007. Functions of innovation systems: A new approach for analysing technological change. *Technological Forecasting & Social Change,* 74(2007): 413-432.
- Herren, H.R., Bassi, A.M., Tan, Z., Binns, W.P., (2012). *Green jobs for a revitalized food and agriculture sector*. Nature Resources Management and Environment Department, Food and Agriculture Organisation of the United Nations. Rome: FAO.
- HLPE, (2015). Water for food security and nutrition. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome 2015.
- IAASTD, I.A. of A.K., Science, and Technology for Development, (2009). Synthesis report: a synthesis of the global and sub-global IAASTD reports, Agriculture at a crossroads. Island Press, Washington, DC
- IPES-FOOD (2016). *Thematic Report: 'From Uniformity to Diversity: A paradigm shift from industrial agriculture to diversified agroecological systems'*. June 2016. Online resource. Available at: www.ipes-food.org/images/Reports/UniformityToDiversity_FullReport.pdf.
- Kampers, F.W.H and L.O. Fresco (2017): *Food transitions 2030*. Wageningen University and Research, Wageningen.
- Krausmann, F., et al. (2009). Growth in global materials use, GDP and population during the 20th century'. *Ecological Economics*, vol. 68, pp. 2696–2705.
- Kurtz, Cynthia F.; Snowden, David J. (2003). "The new dynamics of strategy: Sense-making in a complex and complicated world". IBM Systems Journal. 42(3): 462–483.
- Lamy, P., Brudermüller, M., Ferguson, M. et al. (2017). LAB-FAB-APP. *Investing in the European future we want: Report of the independent High Level Group on maximising the impact of EU Research & Innovation Programmes*. Directorate-General for Research and Innovation, Brussels.

- Mazzucato, M. (2018) *Mission-oriented research & innovation in the European Union – a problem-solving approach to fuel innovation-led growth.* Directorate-General for Research and Innovation, Brussels.

- Meynard, J.M., Messéan, A., Charlier, A., Charrier, F., Le Bail, M., Magrini, M.B. and Savini, I., (2013). Freins et leviers à la diversification des cultures: étude au niveau des exploitations agricoles et des filières. OCL, 20(4), p.D403.

- Möller, K., Oberson, A., Bünemann, E. K., Cooper, J., Friedel, J. K., Glæsner, N., Hörtenhuber, S., Løes, A.-K., Mäder, P., Meyer, G., Müller, T., Symanczik, S., Weissengruber, L., Wollmann, I. and Magid, J., (2018). Chapter Four - Improved Phosphorus Recycling in Organic Farming: Navigating Between Constraints. In Advances in Agronomy, 147: 159-237.

- Mueller et al. (2014). Food wastage footprint – Full-cost accounting. FAO Report. www.fao.org/nr/sustainability/food-loss-and-waste

- Muller, A. et al. (2017). Strategies for feeding the world more sustainably with organic agriculture. NATURE COMMUNICATIONS | 8: 1290. DOI: 10.1038/s41467-017-01410-w

- Mouël, C. Le and A. Forslund (2017): How can we feed the world in 2050? A review of the responses from global scenario studies, in: *European Review of Agricultural Economics,* 44(4) p. 541-591.

- Nugent, R. (2017): *Benefits and costs of the NonCommunicable Disease Targets for the Post-2015 Development Agenda*. University of Washington

- OECD, FAO & UNCDF, (2016). *Adopting a Territorial Approach to Food Security and Nutrition Policy*, Paris: OECD Publishing. Online resource. Available at: http://dx.doi.org/10.1787/9789264257108-en.

- Pray, C.E. and Fuglie, K.O., (2015). 'Agricultural research by the private sector'. *Annual Review of Resource Economics*, vol. 7, no. 1, pp. 399-424.

- Ramanathan, V., Reyers, B., Sörlin, S., (2015). 'Planetary boundaries: guiding human development on a changing planet'. *Science* vol. 347, doi:10.1126/science.1259855.

- Rockstrom, J., et al., (2009). 'A safe operating space for humanity'. *Nature*, vol. 461, pp. 472–475. doi:10.1038/461472a.

- Schader C et al. (2015). Impacts of feeding less food-competing feedstuffs to livestock on global food system sustainability. J. R. Soc. Interface 12: 20150891. http://dx.doi.org/10.1098/rsif.2015.0891

- Schütz, L., Gattinger, A., Meier, M., Müller, A., Boller, T. and Mäder, P. and Mathimaran, N., (2018). Improving crop yield and nutrient use efficiency via biofertilization—A global Meta-analysis. Frontiers in Plant Science, 8(2204).

- Schutter, O. de (2017)The political economy of food systems reform, *European Review of Agricultural Economics,* vol. 44(4) p. 705-731.

- Sonnino, R. (2018, in press). The Cultural Dynamics of Urban Food Governance. *City, Culture and Society* (https://doi.org/10.1016/j.ccs.2017.11.001).

- Sonnino, R. (2016). The New Geography of Food Security: Exploring the Potential of Urban Food Strategies. *The Geographical Journal* 182 (2): 190-200.

- Steffen, W., et al, (2012). 'Increasing food production in Africa by boosting the productivity of under-studied crops'. *Agronomy*, vol. 2, pp. 240–283. doi:10.3390/ agronomy2040240

- Stilgoe J., Owen R., and Macnaghtencd P., (2013). 'Developing a framework for responsible innovation'. Research Policy Vol. 42. No. 9. pp. 1568-1580.

- TP Organics (2017). Research & Innovation for Sustainable Food and Farming. Position paper on the 9th EU Research & Innovation Framework Programme (FP9) http://tporganics.eu/wp-content/uploads/2017/11/TPOrganics_FP9_position_paper_final_Nov2017.pdf

- UNEP, (2016). *Food Systems and Natural Resources. A Report of the Working Group on Food Systems of the International Resource Panel*. Westhoek, H, Ingram J., Van Berkum, S., Özay, L., and Hajer M. ISBN: 978-92-807-3560-4. Online resource. Available at: http://www.unep. org/resourcepanel.

- USDA-ERS (undated): Economic Returns to Public Agricultural Research, Agricultural Research and Development / AER-735. Undated, downloaded from AgEconSearch 15.4.2018

- Vanloqueren, G. and Baret, P.V., (2009). 'How agricultural research systems shape a technological regime that develops genetic engineering but locks out agroecological innovations'. *Research Policy*, vol. 38, no. 6, pp.971-983.

- Veer, P. van't, L.O. Fresco and K.J.Poppe (2017): *Towards a European Food and Nutrition Policy,* Wageningen University and Research, Wageningen.

- Witzke, H. and, Noleppa, S., (2010). *EU agricultural production and trade: can more efficiency prevent increasing "land grabbing" outside of Europe?*. Berlin: University of Berlin Humboldt and Agripol.

ANNEX 1 MEMBERS AND MANDATE OF THE EXPERT GROUP

2 Members

Krijn Poppe, chair

Roberta Sonnino, vice-chair and rapporteur

Lilia Ahrné

Loraine Brennan

Nick Jacobs

Carlo Mango

Klaus Menrad

Katerina Moutou

Otto Schmid

Sébastien Treyer

Consuelo Varela Ortega

Henk Westhoek

Mandate

The group is expected to review the problems affecting the current European Research and Innovation (R&I) landscape relevant to food systems and food and nutrition security, assess the main drivers and barriers to high-impact R&I, explore how best to increase public and private R&I investments and impacts, and describe who is affected and how. Furthermore, the group will develop and assess the impacts of possible R&I missions and will provide policy recommendations to increase R&I investment and R&I impact towards future-proofing our food systems so that they become environmentally sustainable, resilient, responsible, diverse, inclusive, and competitive.

In addition, the experts will examine the current and future contribution of the European Commission FOOD 2030 initiative and how it can contribute to the EU's policy objectives (eg: President Junker's 10 priorities). The expert group should also consider how FOOD 2030 interacts with other relevant policy initiatives and targets such as the Sustainable Development Goals, modernisation of CAP, Circularity, COP21 climate commitments, etc.

The specific objectives of the group are to contribute to the preparation of a FOOD 2030 Research, Innovation and Investment Strategy (RI&IS) also exploring potential R&I missions, their impacts and targets, and R&I focused policy recommendations.

ANNEX 2 DATA ON PAST PERFORMANCE AS PRESENTED IN PART 2

2.1 Nutrition for sustainable and healthy diets

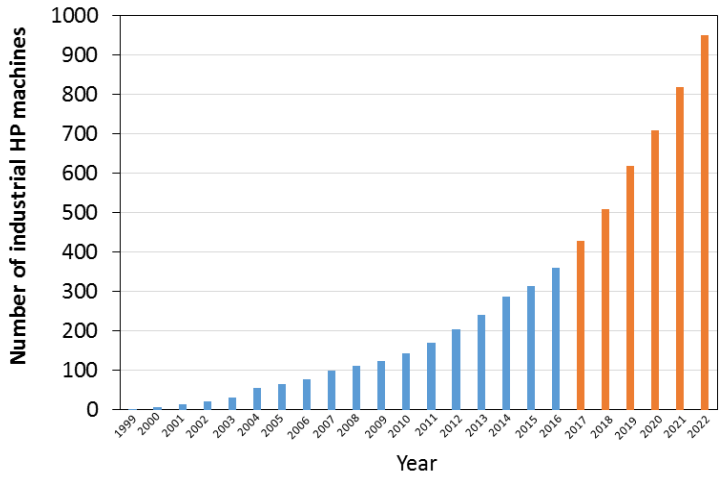


Figure 1: Number of High Pressure Processing (HPP) machines sold. First EU project on HPP was granted in 1992 (Source: Tonello 2016). For case studies in commercial products for HPP, see IFT 2016, Chicago, IL, USA.

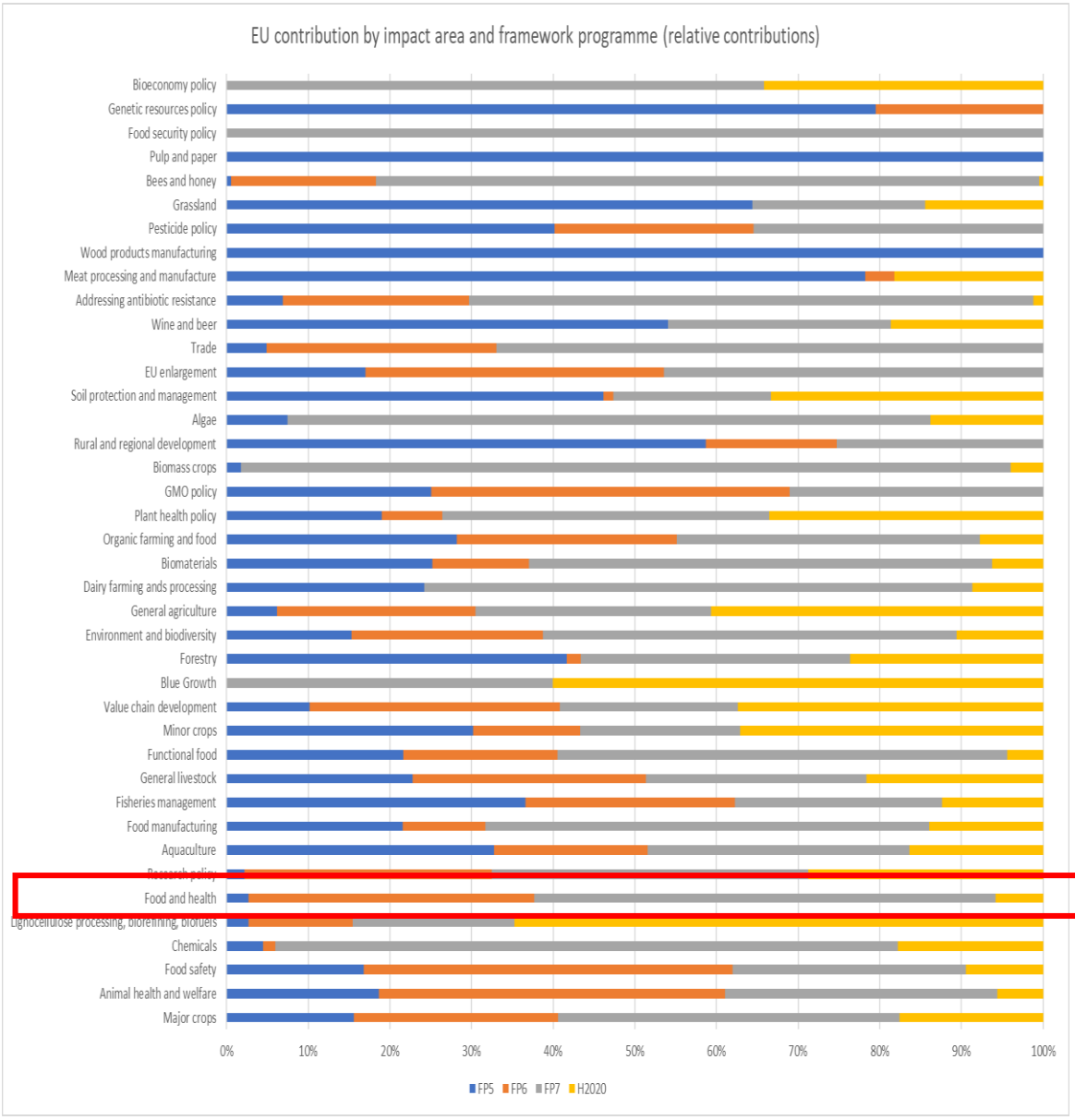


Figure 2: Overview of the framework contribution to the different areas. Note the reduction in contribution of H2020 to the area of Food and Health (highlighted in red box). (Source: Impact Assessment Report FP5-H2020).

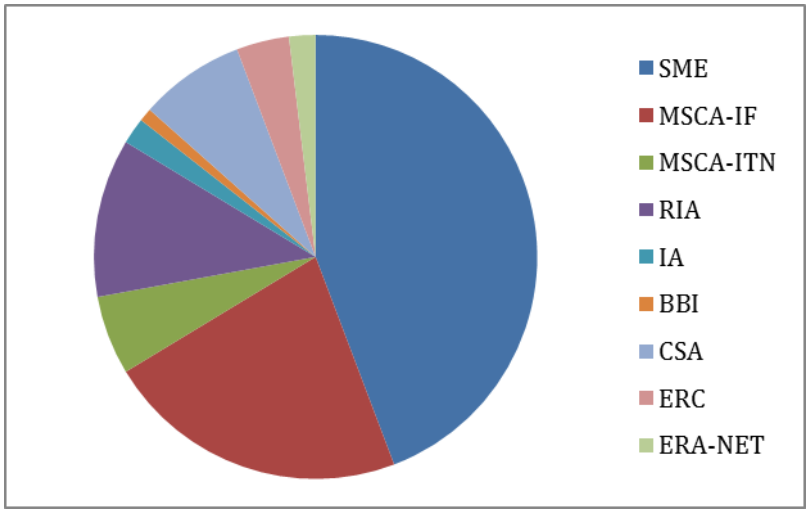


Figure 3: Number of H2020 projects in the area of Nutrition and Health. (Source: Summary Statistics provided by EU September 2017).

2.2 Climate-smart and environmentally sustainable food systems

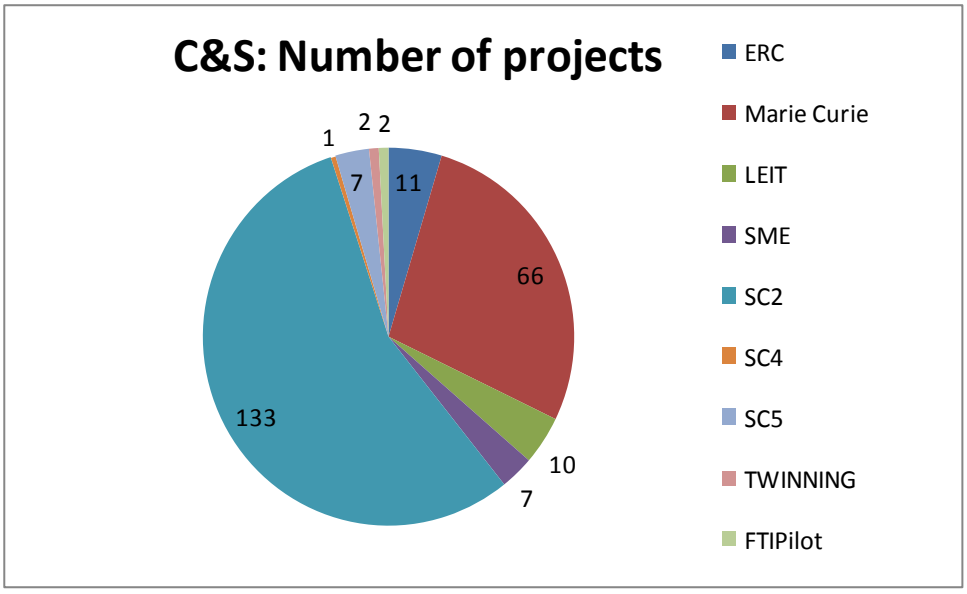
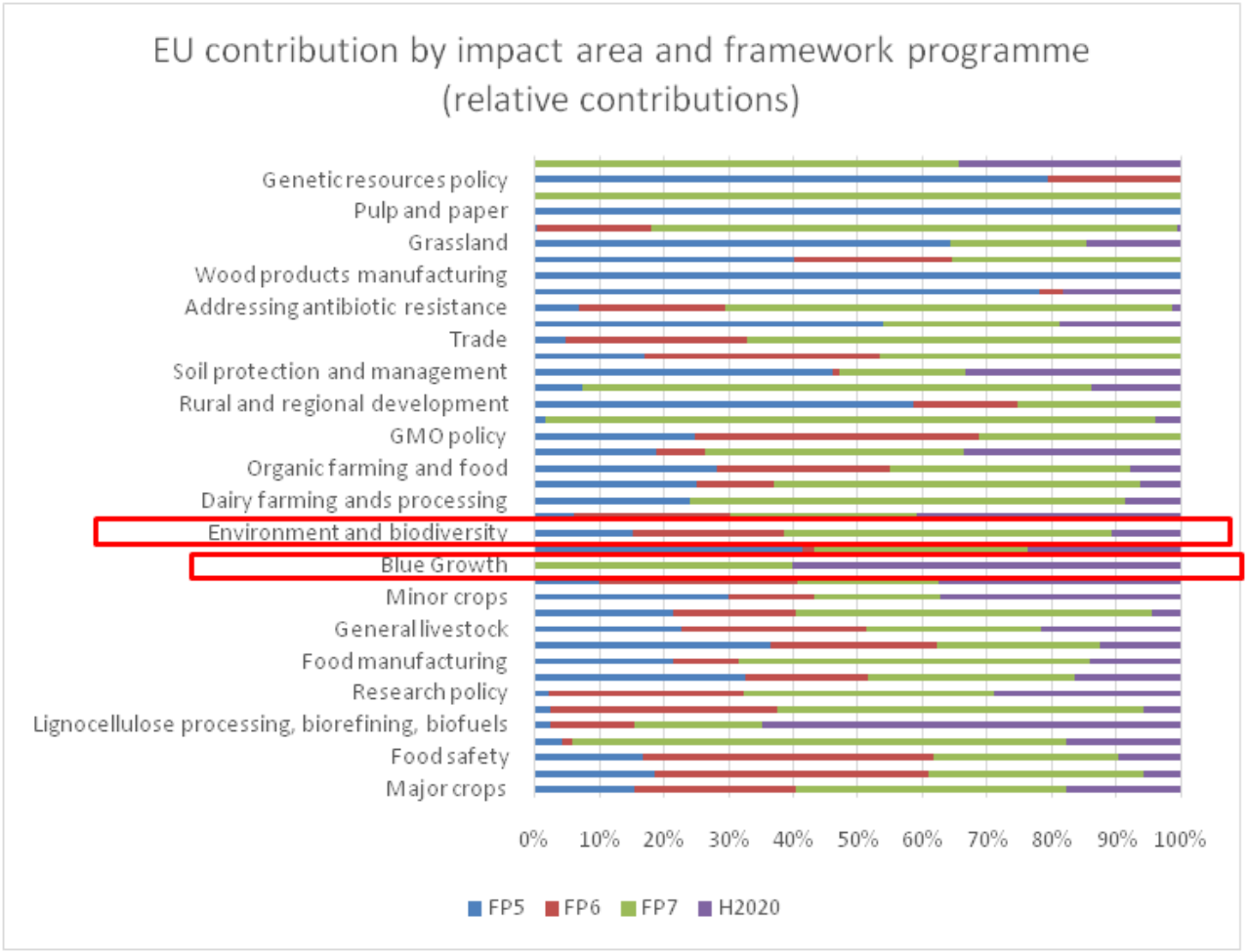


Figure 4: Number of H2020 projects in the area of Climate and Sustainability

(Source: Own elaboration based on: European Commission (2017) RTD. Summary



Statistics FOOD 2030 Priorities for H2020 Projects (CORDA database)).

Figure 5: EU percent contribution by impact area and Framework Programme.

Highlighted in red are the selected impact areas, where it can be observed the reduction of the relative budget to Environment and Biodiversity in H2020 with respect to FP7, whereas Blue Growth increases substantially in H2020 (see text above). (Source: European Commission (2017g) SC2 Curated portfolio data and figures (CORDA database)).

2.3 Circular and resource efficient food systems

Table 1: Additional analysis of the spending (in mln €) of FP7 and H2020 Programmes for agriculture, food, fish and bioeconomy - Curated portfolio data and figures (Source: Cordis database, 2007-2017).

	FP7	**H2020**	**Total**
Addressing antibiotic problems	9		9
Algae	17	4	22
Animal health and welfare	30	18	48
Aquaculture	9	14	23
Bioeconomy policy	1		1
Biomass crops	15		15
Biomaterials	23		23
Blue Growth	32	38	70
Chemicals	124	35	159
Dairy	14	2	17
Environment and biodiversity	27		27
Fisheries management	9		9
Food and health	69	12	81
Food manufacturing	22	14	36
Food safety	27	21	47
Forestry		11	11
Functional food	52	2	54
General agriculture		10	10
Lignocellulose processing, biorefining and biofuels	28	119	147
Livestock	15	19	34
Major crops	46	26	72
Meat		2	2
Minor crops	6	4	10
Organic farming and food	9	1	11
Plant health policy		7	7
Research policy	12	11	23
Soil protection and management		8	8
Trade	12		12
Value chain development		16	16
Wine and beer		1	1

Rounded figures. Some categories used in FP7 and H2020 are very general, therefore a more detailed analysis of the content of specific categories was made, in order to verify how strongly they can be linked to the agri-food sector.

Chemicals include:

- Industrial Crops producing added value Oils for Novel chemicals
- Effective redesign of oxidative enzymes for green chemistry
- Novel Polysaccharide Modifying Enzymes to Optimise the Potential of Hydrocolloids for Food and Medical Applications
- Rational design of plant systems for sustainable generation of value-added industrial products
- Wood Bark and Peat Based Bioactive Compounds, Speciality Chemicals, and Remediation Materials: from Innovations to Applications
- Biotechnological conversion of carbon containing wastes for eco-efficient production of high added value products
- Novel and more robust fungal peroxidases as industrial biocatalysts
- Systematic screening for novel hydrolases from hot environments
- Developing the Next Generation of Biocatalysts for Industrial Chemical Synthesis
- Marine Microbial Biodiversity, Bioinformatics and Biotechnology
- New-to-nature biosurfactants by metabolic engineering: production and application
- Mastering bioprocess Integration and intensification across scales
- Low-toxic cost-efficient environment-friendly antifouling materials
- Optimized oxidoreductases for medium and large scale industrial biotransformations
- A pipeline for the discovery, sustainable production and commercial utilisation of known and novel high-value triterpenes with new or superior biological activities.
- Programming synthetic networks for bio-based production of value chemicals
- Rewiring the Streptomyces cell factory for cost-effective production of biomolecules
- Synthetic Cellular Signalling Circuits
- Bringing innovative industrial biotechnology research to the market
- Quod Erat Demonstrandum: Large scale demonstration for the bio-based bulk chemicals BDO and IA aiming at cost reduction and improved sustainability
- Synthetic Biology for the production of functional peptides
- Camelina & crambe Oil crops as Sources for Medium-chain Oils for Specialty oleo-chemicals

- Flagship demonstration of an integrated biorefinery for dry crops sustainable exploitation towards bio-based materials production
- New enzymatic oxidation/oxyfunctionalization technologies for added value bio-based products
- Life Integrated Process for the Enzymatic Splitting of triglycerides

Bio-materials:

- EU-based Production and Exploitation of Alternative Rubber and Latex Sources
- Biopolymers from syngas fermentation
- Development of 2nd Generation Biorefineries – Production of Dicarboxylic Acids and Bio-based Polymers Derived Thereof
- Developing a validated technology platform for the application of oxygen dependent enzymes in synthesis and transformation of alcohols

Biomass crops

- The development and evaluation of multipurpose crops as new biorefining feedstocks for the production of industrial BioProducts and biomass
- NanoBioEngineering of BioInspired BioPolymers

Forestry

- Alternative models and robust decision-making for future forest management
- Optimising the management and sustainable use of forest genetic resources in Europe

Lignocellulose processing, biorefining, biofuels

- BIOSKOH's Innovation Stepping Stones for a novel European Second Generation Bio-Economy
- Flagship demonstration of an integrated plant towards large scale supply and market assessment of MFC
- Demonstration of solvent & resin production from lignocellulosic biomass via the platform chemical levulinic acid
- BIO-based products from FORestry via Economically Viable European Routes

Demonstrating more efficient enzyme production to increase biogas yields (4,629,586)*

- Optimised moulded pulp for renewable packaging solutions

Sustainable Algae Biorefinery for Agriculture and Aquaculture (1,499,500)*

- GENetic diversity exploitation for Innovative macro-ALGal biorefinery

* **In bold**: might be included in agri-food projects

Included are as well: Support to Policies - Set Up of a Bioeconomy Observatory (BISO project: Bioeconomy Information System and Observatory)

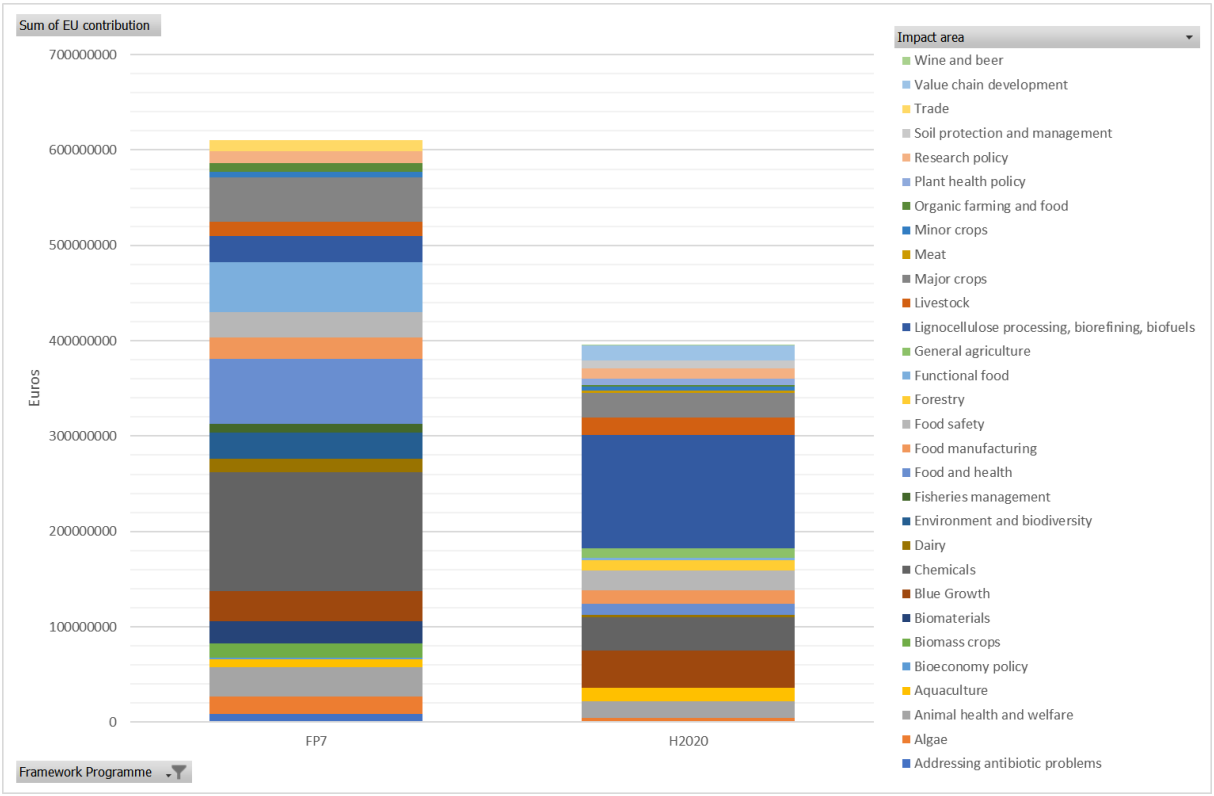


Figure 6: EU Research Framework Programme 7 and H2020 – Spending for agriculture related research compared with other research areas (food, non-food, fish, and biomass). (Source: European Commission 2014a and 2017, CORDIS Database).

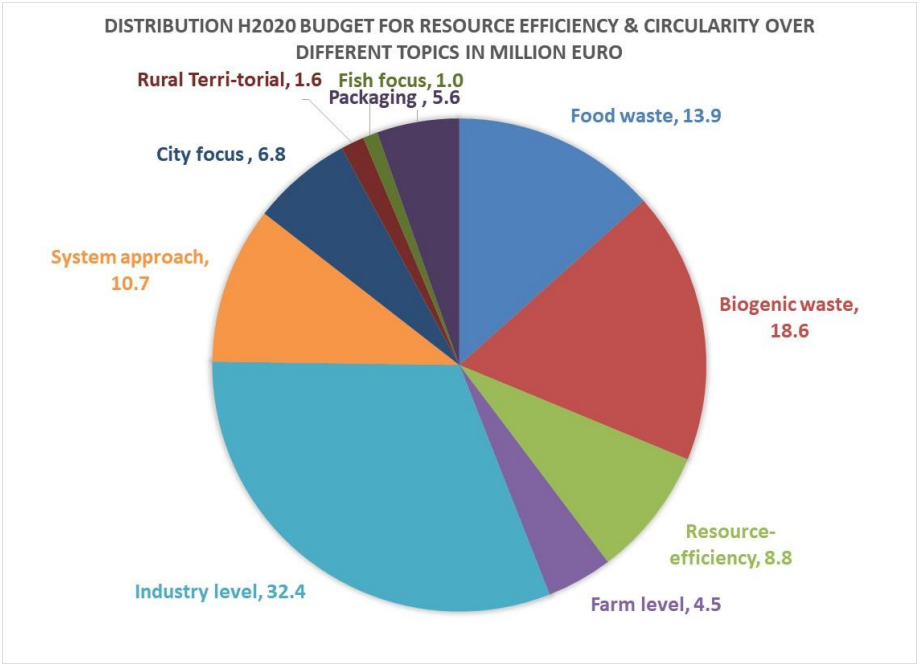


Figure 7: Percentage distribution of H2020 Budget for projects on Resource Efficiency and Circularity over different topics in Million euro (projects with significant spending more than 1 Million euro). (Source: European Commission 2017b, CORDIS Database)

2.4 Food systems innovation and empowering communities

Project instrument/Funding scheme	**Total funding in Euros**	**% of total funding**	**Number of projects**	**Average funding in Euros/project**
CSA	23,266,225.00	10.1%	11	2,115,111.36
ERA-NET-Cofund	20,906,370.90	9.1%	3	6,968,790.30
ERC	4,353,200.75	1.9%	3	1,451,066.92
IA	90,258,647.31	39.2%	13	6,942,972.87
JTI-BBI-IA-DEMO	9,937,997.02	4.3%	1	9,937,997.02
MSCA	6,258,052.16	2.7%	13	481,388.63
RIA	59,541,448.86	25.8%	13	4,580,111.45
SGA-CSA	928,446.00	0.4%	2	464,223.00
SME-1	1,850,000.00	0.8%	37	50,000.00
SME-2	13,092,840.33	5.7%	8	1,636,605.04
Total	**230,393,228.33**	**100.0%**	**104**	**2,215,319.50**

Getting in touch with the EU

IN PERSON

All over the European Union there are hundreds of Europe Direct Information Centres.
You can find the address of the centre nearest you at: **http://europa.eu/contact**

ON THE PHONE OR BY E-MAIL

Europe Direct is a service that answers your questions about the European Union.
You can contact this service

– by freephone: **00 800 6 7 8 9 10 11** (certain operators may charge for these calls),

– at the following standard number: **+32 22999696** or

– by electronic mail via: **http://europa.eu/contact**

Finding information about the EU

ONLINE

Information about the European Union in all the official languages of the EU is available on the Europa website at: **http://europa.eu**

EU PUBLICATIONS

You can download or order free and priced EU publications from EU Bookshop at: **http://bookshop.europa.eu.**
Multiple copies of free publications may be obtained by contacting Europe Direct or your local information centre (see http://europa.eu/contact)

EU LAW AND RELATED DOCUMENTS

For access to legal information from the EU, including all EU law since 1951 in all the official language versions, go to EUR-Lex at: **http://eur-lex.europa.eu**

OPEN DATA FROM THE EU

The EU Open Data Portal (**http://data.europa.eu/euodp/en/data**) provides access to datasets from the EU.
Data can be downloaded and reused for free, both for commercial and non-commercial purposes.

In this report, a group of European Commission (EC) appointed experts recommend orientations for food and nutrition security research and innovation in the years to come. The report calls for a Research, Innovation and Investment Strategy (RI&IS) in line with the EC FOOD2030 initiative to deliver on four priorities: nutrition for sustainable and healthy diets; climate smart and environmentally sustainable food systems; circularity and resource efficiency of food systems; innovation and empowerment of communities. Using food systems thinking, the experts have reworked and integrated these priorities to develop a mission-type approach.

Studies and reports

Publications Office