European Commission

FOOD 2030 PATHWAYS FOR ACTION

Research and innovation policy as a driver for sustainable, healthy and inclusive food systems

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Research and Innovation

Food 2030 pathways for action: Research and innovation policy as a driver for sustainable, healthy and inclusive food systems

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Food 2030 pathways for action

Research and innovation policy as a driver for sustainable, healthy and inclusive food systems

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FOREWORD

For European citizens, food is central to their way of life. Ensuring a sustainable food system is crucial in the European Green Deal. The Green Deal is a new and ambitious political initiative aiming to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where economic growth is decoupled from resource use. It also aims to put Europe firmly on a new path towards sustainability by accelerating the transition needed across all sectors. **Horizon Europe, the next EU's research and innovation programme (2021-2027)** will be an essential part of the **Green Deal toolkit** to tackle climate change, achieve the UN sustainable development goals, and boost the EU's competitiveness. It entails strategic research and innovation (R&I) investments in digital infrastructures, clean energy, circular economy and smart transport systems, which, coupled with the Farm to Fork strategy will help build a more inclusive, sustainable, and resilient Europe.

The **Farm to Fork strategy** gives the EU Member States a strong and integrated policy framework to redesign their food systems and to rethink the use of soils, the role of livestock, and to provide healthy and sustainable diets. Moreover, the strategy highlights R&I as a key enabler to accelerate the transition to sustainable, healthy and inclusive food systems from primary production to consumption; to develop and test solutions, and to overcome barriers and uncover new market opportunities. In this framework, the European Commission's Food 2030 initiative, has, since 2016, advocated the key role of R&I policy to future-proof our food systems and deliver co-benefits for nutrition, climate, circularity and communities. The Food 2030 publications and conferences have increased awareness and provided evidence that a well-governed food system approach is needed to tackle this important challenge.

I am therefore proud to present this timely publication on "**Food 2030-Pathways for action**", which frames the Food 2030 deployment and guides future policy reflections relevant to Horizon Europe, the Farm to Fork strategy and European Green Deal. The publication presents 10 Pathways, which can contribute to a multi-objective food systems transformation at local, regional, national, and international levels. It also underlines that an inter- and transdisciplinary approach to research and innovation is crucial for success. The COVID-19 crisis has shown that transformations are not only technical and academic; they also encompass social, legal, economic, financial, ethical, and philosophical dimensions, which need to be fully embedded in future R&I policy and programmes.

The future of our food and nutrition will be different, and business as usual is not an option. We are aware of the many opportunities. Strong leadership and a clear vision are needed to make sure that the actions under Horizon Europe and the European Research Area become a lever for sustainability, a contributor to jobs and wellbeing. I therefore consider this publication to be an important and apt contribution to the debate on how future R&I actions can help us address one of the most important and interconnected challenges of our time.

Mariya Gabriel
European Commissioner for
Innovation, Research, Culture,
Education and Youth

INTRODUCTION

1 FIXING OUR FOOD SYSTEMS

The global food system is facing a range of **challenges** from malnutrition, climate change, resource scarcity, biodiversity loss, soil degradation, a growing and ageing population, urbanisation, food waste and food poverty. COVID-19 has shown the pivotal importance of functioning food supply chains and the need to further increase their resilience to emergencies and crises like pandemics, climate change and geopolitical forces.

To address these challenges, a **food system transformation** is required which shifts towards more sustainable and healthy diets and aims to ensure food and nutrition security for all. This requires a better understanding of the interactions between the different components of the current food systems to maximise co-benefits, and to accelerate such a system-wide transformation.

The European Commission (EC) is now leading the way to future-proof our food systems for sustainability, health and inclusion. Through its **Farm to Fork strategy** and its broader **European Green Deal** policy it commits to ambitious food systems objectives that will be decisive in ensuring a just and fair **transition** that respects planetary boundaries. These important policy advances also align with the recommendations set out in the EC strategic advice mechanism opinion (SAM) ([1]) towards a *sustainable food system*, which highlights the need for food to be considered as a common good and not just as a trading commodity, and that 'business as usual' is not a viable option as it will eventually endanger our natural resources, our health, the climate and the economy.

It is recommended to:

- Drive a step-wise, learning-focused policy transformation on global, EU, national, regional and local levels;
- Address power and information asymmetries and make the easiest choice for citizens to drive sustainability;
- Use an iterative, responsive and adaptive policy mix, with binding measures as the main drivers.

([1]) https://ec.europa.eu/info/research-and-innovation/strategy/support-policy-making/scientific-support-eu-policies/group-chief-scientific-advisors/towards-sustainable-food-system_en

The Farm to Fork strategy highlights **research and innovation** (R&I) as key drivers in accelerating the transition to sustainable, healthy and inclusive food systems, from primary production to consumption. It recognises that R&I can help develop and test solutions, overcome barriers, and uncover new market opportunities. It mentions Horizon Europe (HE) and some key areas of research such as the microbiome, food from the oceans, urban food systems, alternative proteins, agro-ecological approaches and Living Labs, and the HE *Soil Health and Food* mission. It further refers to the HE **'Partnership for safe and sustainable food systems for people, planet and climate'** that will put in place an R&I governance mechanism engaging Member States and food systems' actors from farm to fork, to deliver innovative solutions providing co-benefits for nutrition, quality of food, climate, circularity and communities. These R&I ambitions build on the **Food 2030** initiative which, since 2016, has convened and fostered a systems approach to R&I policy that connects land and sea, producers to consumers, from 'farm to fork to gut and back'.

2 FOOD 2030 – AN R&I VISION AND POLICY FRAMING

Food 2030 provides a **vision** and **policy narrative** that through a well-governed and more systemic R&I policy, we can develop impactful solutions to the urgent, complex and interconnected challenges inherent to food systems that need to be transformed to respect planetary boundaries, to provide healthy safe and nutritious food and diets for all, and to sustain a diverse fair and inclusive thriving food economy.

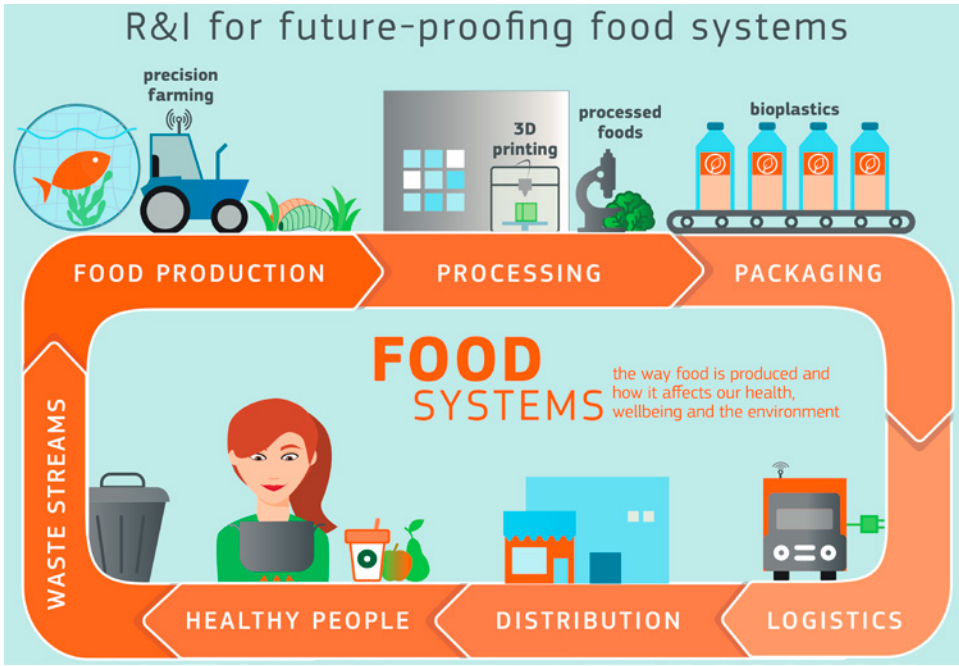


Figure 1: R&I for future-proofing food systems

Food 2030 consists of a framing and **multi-actor engagement process** within which R&I, and R&I policy, can flourish, European competiveness can grow, citizens and a wide diversity of stakeholders can engage, multiple global challenges can be addressed, and innovative solutions – from new products, tools, approaches and technologies to social, governance and institutional innovation, and new business models can be developed, tested and demonstrated.

Finally, Food 2030 applies a **systemic approach** to connect, scale-up and boost EU R&I and investments to provide solutions to **four overarching priorities**.

- **Nutrition** for sustainable and healthy diets: the first Food 2030 priority focuses on fostering R&I on nutrition for sustainable and healthy diets. Key issues under this priority include tackling malnutrition and obesity; improving nutrition for healthy ageing; sourcing protein alternatives to reduce meat and dairy consumption; developing new food authenticity and food safety systems; encouraging diet diversity by, for example, reviving forgotten crops for nutrition and resilience; and supporting healthy diets that are environmentally sustainable. In addition to supporting the new Farm to Fork strategy, this priority also aims to contribute to further development and implementation of EU food regulation and food safety policies ([2]), the Steering Group on Health Promotion, Disease Prevention and Management of Non-Communicable Diseases ([3]), and the relevant targets of Sustainable Development Goals 2, 3, 8 and 10.

- **Climate**-smart and environmentally sustainable food systems: it is vital that natural resources – water, soil, land and sea – are managed responsibly within the Earth's capacity to ensure they are available to future generations. The second Food 2030 priority fosters R&I to make climate-smart food systems that are adaptive to climate change, preserve natural resources and ecosystem functions, limit environmental degradation and contribute to climate change mitigation. For example, the Commission supports R&I projects that demonstrate sustainable aquaculture approaches, makes precision farming techniques available for small farmers, boosts photosynthesis for food & energy, and encourages the sustainable use of land to keep soils healthy. In addition to supporting the new Farm to Fork and Biodiversity strategies, this priority also aims to contribute solutions relevant to the common agricultural policy, the common fisheries policy, the EU Strategy on Adaptation to Climate Change, EU environmental policies, the Paris Climate Agreement (COP21) and the relevant targets of Sustainable Development Goals 2, 7, 14 and 15.

([2]) https://ec.europa.eu/food/overview_en

([3]) https://ec.europa.eu/health/non_communicable_diseases/steeringgroup_promotionprevention_en and https://ec.europa.eu/jrc/en/health-knowledge-gateway

- **Circular** and resource-efficient food systems: the third Food 2030 priority aims to achieve circularity and resource efficiency in food systems. Circularity implies sustainable, resource-efficient food systems that address the 1.3 billion tonnes of food lost and wasted per year on a global level. Challenges in this area include: achieving zero food waste throughout the food system; tackling waste streams from primary production; more efficient recycling of food waste; rethinking food packaging for better biodegradable options that limit micro plastics; and responding to an increasing demand for more tailored and local food. In addition to supporting the new Farm to Fork strategy, this priority also aims to contribute solutions to the modernisation of the Common Agricultural Policy, the Common Fisheries Policy, the EU Bioeconomy Strategy, the EU Circular Economy Package including the Waste Directive and Climate Action policies, and the relevant targets of Sustainable Development Goals 2, 8 and 12.

- Food systems **innovation** and empowerment of **communities**: the fourth Food 2030 priority focuses on developing a healthy innovation ecosystem that supports new business models and the delivery of solutions for the social good and/or having market potential that benefits society. The priority will help to create new jobs across the EU and foster thriving urban, rural and coastal economies and place-based communities. Through closer partnerships with industry and society, markets can function in a responsible manner, foster fair trade and pricing, inclusiveness and sustainability. Challenges in this area to be addressed by R&I include: fostering governance innovation with a strong evidence base, fostering citizens' empowerment through social innovation for SFP, achieving sustainable and accessible food in cities and regions, engaging citizens in food science and policy, developing a sharing economy for food production and consumption, and implementing data-driven food and nutrition systems. In addition to supporting the new Farm to Fork strategy, this priority also aims to contribute to the European Commission's Digital Single Market strategy, the EU Urban Agenda, and Europe for Citizens programme, among other policy priorities, as well as relevant targets of Sustainable Development Goals 2, 9, 11 and 16.

As mentioned in the Reflection Paper *Towards a Sustainable Europe by 2030* ([4]), Food 2030 is closely aligned with the EU commitment to the UN Sustainable Development Goals (SDGs). In this respect, Food 2030 endorses 'the wedding cake' approach to viewing the economic, social and ecological aspects of SDGs.

([4]) https://ec.europa.eu/commission/sites/beta-political/files/rp_sustainable_europe_30-01_en_web.pdf

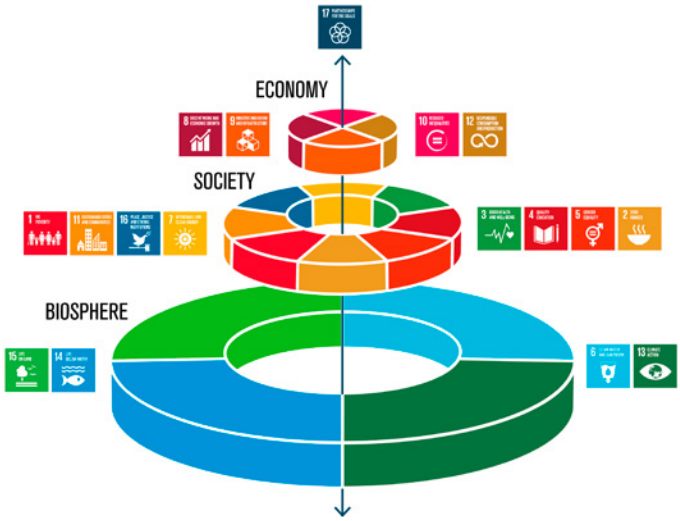


Figure 2: *Source* – Azote for Stockholm Resilience Centre, 'New way of viewing the Sustainable Development Goals and how they are all linked to food'

This implies that economies and societies are seen as embedded parts of the biosphere. This moves development away from the current sectorial approach where social, economic, and ecological development are seen as separate parts towards an economy serving society within the safe operating space of the planet. Using this model, one can argue that all the sustainable development goals are directly or indirectly connected to sustainable and healthy food systems.

This publication outlines the Food 2030 philosophy towards a coherent and focused food system approach. One where R&I and R&I policy can flourish, European competiveness can grow, citizens and a wide diversity of stakeholders can engage, multiple global challenges can be addressed, and innovative solutions – from new products, tools, approaches and technologies to social, governance and institutional innovation, and new business models – can be developed, tested and demonstrated.

3 FOOD 2030 PATHWAYS FOR ACTION

This publication describes a deployment stage for Food 2030 that targets 10 *pathways for action.* These pathways aim to provide a structured basis for **R&I policy** and **R&I areas** relevant to building up Horizon Europe and future R&I programmes in Europe and beyond. The pathways represent **key levers of change** where R&I can have a deep and multiple impact in realising the food system vision. The relevance of each pathways co-benefits to the four different Food 2030 priorities is scored in Table 1, while the individual chapters for each pathway sets out the systemic challenges, the expected **co-benefits,** barriers and enablers of change, and highlights potential R&I areas meriting further consideration and investment.

Table 1: Food 2030 pathways, priorities and diversity of expected co-benefits

FOOD 2030 PATHWAYS	NUTRITION	CLIMATE	CIRCULARITY	INNOVATION
Governance and systems change	+++	+++	+++	+++
Urban food systems transformation	++	+++	+	+++
Food from oceans and freshwater resources	++	+++	++	++
Alternative proteins and dietary shift	+++	+++	++	+++
Food waste and resource efficiency	+	+++	++	++
The Microbiome world	+++	+++	+++	+
Healthy, sustainable and personalised nutrition	+++	++	+	++
Food safety systems of the future	++	+++	++	++
Food systems Africa	++	++	++	+++
Food systems and data	+++	+++	+++	+++

These pathways, have been built up in consultation with European Commission services, as well as via an ongoing process of stakeholder engagement, which began in 2016. The pathways and their orientations were largely created as a result of the 2018 Food 2030 High-Level Event held in Plovdiv under the auspices of the Bulgarian Presidency, and a follow-up Austrian Presidency event in Vienna. They were subsequently confirmed and strengthened during a European Commission Food 2030 pathways survey and workshop held on 4 March 2020 in Brussels.

The pathways do not cover all of the areas requiring food system intervention. However, they respect the Food 2030 philosophy in that they integrate land and sea, production to consumption, and deliver co-benefits to the Food 2030 priorities. Additional key areas of work relating to sustainable primary production, biodiversity, water management and rural development aspects are dealt with in other parts of Horizon Europe, which include R&I on healthy soils, agroecology, alternative pesticides, rural growth, precision farming, and SME interactions along the food chain.

Many of the pathways have strong interconnections which are illustrated in Figure 3, and it is exactly here that co-creation across the different parts of the food system can lead to the expected co-benefits, and a greater farm-to-fork coherence working under a food system R&I policy framework. In addition, the pathways will deliver on issues linked to the renewed **European Research Area** (ERA) policy priorities and the EU circular and sustainable **Bioeconomy Strategy** and Action Plan. Investments in food systems R&I also provide promising avenues for the **Next Generation EU Recovery Package** to deploy a reinforced EU budget to help repair the immediate economic and social damage brought by the coronavirus pandemic, kick-start the recovery, and to prepare for a better future.

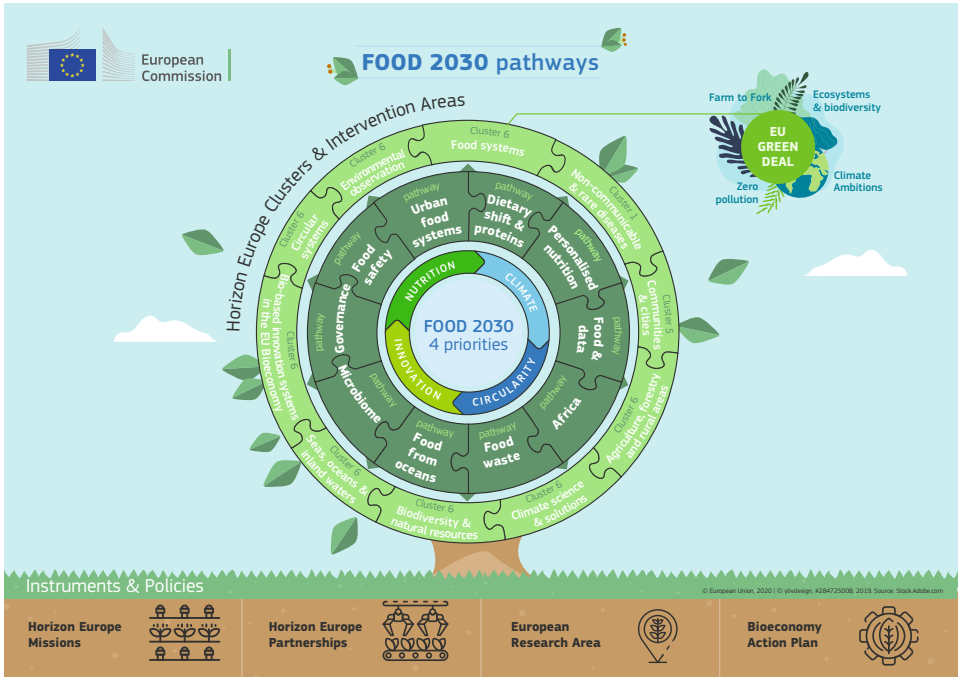


Figure 3: Illustration of Food 2030 pathways – linkages and interactions.

Food 2030 will strongly engage with Horizon Europe to help deliver on these pathways; but far more can be achieved if we **work together**. Collaborating closely with other food systems **R&I funders and performers** will provide more focus, joined-up actions, impact and leveraging of R&I investments. As such, Food 2030 will continue to convene around these issues and foster better R&I governance.

Horizon Europe has the chance to provide responsible research and innovation working examples of these pathways. They will employ a **multi-actor approach** to R&I that involves a wide diversity of **sectors** including primary production, food processing, logistics, retailing, food services (e.g. restaurants, canteens) and public health, etc. It will also engage a wide range of **stakeholders** including researchers and academia, policymakers, SME and industry, NGOs, educators, knowledge brokers, consumers and civil society; upstream and throughout the R&I process.

Under HE these Food 2030 pathways can help drive policy reform, new social norms, innovation and development of disruptive technologies that will provide fully transformed, sustainable, resilient, healthy, and inclusive food systems in Europe and beyond.

PATHWAY 1 – GOVERNANCE AND SYSTEM CHANGE

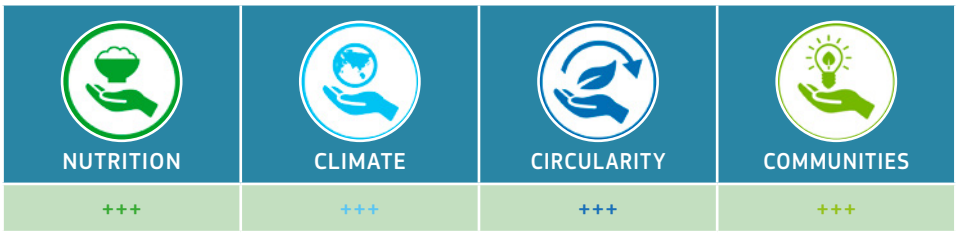
1 SYSTEMIC CHALLENGES

Resilience against global challenges and shocks such as climate change or COVID-19 depends upon the successful implementation of policies, actions and development strategies, which all need to be facilitated by high quality and efficient governance. Well-run institutions operating under good governance are thus key determinants of long-term stability and sustainable growth, making relevant policy, addressing present-day challenges, and providing quality welfare and services. The many challenges related to Food Systems (FS), as well as their key impact on climate, sustainability, health, and livelihoods, have made clear that we urgently need to improve our FS governance beyond today's fragmented, siloed approach. In this respect, there are a number of major ongoing policy developments where the issue of improved research and innovation (R&I) governance will play a key role. These include:

- The major political goals of the EU Green Deal, The Farm to Fork strategy, the EU Biodiversity Strategy and the Food 2030 R&I strategy.
- The Sustainable Development 2030 Goals and the COP21 objectives and commitments.

- The challenges of rising populations and the need to feed 9 billion people by 2050, which will require a 60 % increase in food production.
- The increasingly unsustainable global demand for meat and animal products.
- The reduction of food waste which is now 33 % of our total food, production while 800 million people go hungry and are underweight or malnourished
- The challenge of improving the diets of the 2 billion people who remain overweight or obese.
- The 25-30 % greenhouse gas contribution from farm to fork food production, with half of this coming from meat production alone.
- The challenge of natural resources scarcity where 70 % of global fresh water, and 30 % use of global energy production are consumed in making our food.
- The weak resilience and insecurity of our food system to respond to global shocks such as the COVID-19

2 CO-BENEFITS



NUTRITION AND HEALTH

Co-benefits include:

- Improving well-being. Diet is the key lever for transition to a sustainable food system and planetary health.
- Reducing obesity-related non-communicable disease. A healthy diet and a sustainable food production system can prevent 11 million premature adult deaths per year (EAT-Lancet report), and substantially reduce the health costs of diet-related diseases (SDGs 2, 3, 11, 12, 13, 14 and 15).

- Fighting hunger and malnutrition.
- Ensuring food safety and maintaining the high EU safety standards which is a key objective in maintaining a healthy population.

CLIMATE AND ENVIRONMENTAL SUSTAINABILITY

Co-benefits include:

- Lower GHG emissions: Moderate changes in food consumption, such as reduced meat diets, could significantly decrease agriculture-based GHG emissions. By 2070, emissions could reduce by 13 % to 44 % in connection with different types of diets (EC Communication 'A Clean Planet for All') (SDGs 13, 14, and 15).
- Biodiversity: Reducing pressure on land use generates huge co-benefits for biodiversity and ecosystems services, and creates potential for afforestation and feedstock for use beyond food and feed (European Decarbonisation Pathway Initiative) (SDGs 13, 14 and 15). Biodiversity can be improved through better management of land and ecosystem services, and reduced application of harmful pesticides and fertilisers.
- Soil: An increasingly degraded and eroded non-renewable carbon sink resource (FAO). Soil regeneration and its organic content can be improved in a circular manner, through the controlled return of organic matter to agricultural land (SDGs 2, 13 and 15). Improved soil health and restored degraded soils make land more fertile, reduce soil erosion and capture greenhouse gas emissions.

CIRCULARITY AND RESOURCE EFFICIENCY

Co-benefits include:

- Reducing food loss and waste across all parts of the food systems – from farm to fork.
- Upgrading unavoidable waste into new value-added products and their use within a circular and sustainable bioeconomy.
- Improving circularity and resource efficiency in food production and manufacturing, supply-chain logistics and food services.

INNOVATION AND EMPOWERING COMMUNITIES

Co-benefits include:

- Citizen engagement: The large inequities and imbalances in our food system can be corrected, and citizens can be empowered to make healthy sustainable choices. (SDGs 3, 4, 11 and 12).
- Inclusion and equity: Measures to ensure a balanced, just and fair food system transition – economically, socially and environmentally – and coherently address demand and trade-offs, and take care of potential losers (SDGs 3, 4, 8, 11, 12 and 16).
- Innovation via multi-actor and citizen engagement processes and structures that empower place-based communities to co-create food systems solutions that deliver co-benefits and mitigate trade-offs.
- Fostering inclusion and equity: Measures to ensure a balanced, just and fair food system transition – economically, socially and environmentally – and coherently address demand and trade-offs, and take care of potential losers.
- Tackle food poverty and ensure all have access to healthy sustainable food and diets.

3 BARRIERS AND LOCK-INS

- Food systems are broad and complex, involving many different actors from diet and health to environmental to economic industry, business and trade sectors.
- There are substantial policy, regulatory, financial, technological and behavioural barriers to overcome.
- Current food systems are too fragmented and slow to change.
- The true cost of addressing the 'perfect storm' would be billions in R&I, or sums much greater than currently available for R&I.
- Difficulties in finding the right focus and ways to organise and mobilise available resources.
- Difficulties in keeping the urgency of the problem high on the political agenda and dealing with related fake news.

4 ENABLERS OF CHANGE

- High recognition of a need for governance and a food system transition role within the current philosophy of the Farm to Fork strategy, and within the EU Green Deal.

- Food system transition is strongly supported by international bodies such as the FAO, the IPCC, the IPES-FOOD, the EAT-Lancet report, the EU Scientific Advisory Mechanism (SAM) food systems report and the SAM Food from the oceans report.

- Recognition is growing that food is not only a commodity/consumer good, but an actual common good (SAM Food systems report), whose sustainability is indispensable for both human and planet health.

- The potential of public procurement is a powerful and underused tool to connect health, environment and economy. Better alignment of EU procurement policy with food systems could focus on the nutritional component and on wider social considerations, including reskilling and improved working conditions, as well as better links between smaller producers and buyers.

- The development of short supply chains to ensure that greater value from farms goes to producers supplying nutritious food from sustainable production methods. These can be designed to reach target groups such as schools and low-income groups. There is potential for further policy support and better governance to make short supply chains a more established feature in food environments, providing healthy food and a better deal for farmers. Better investment in skills can provide a skilled workforce, address food system recruitment, and provide improved economic performance. To advance improvements, incorporating nutrition and sustainability skills into food system decisions, practices, and outcomes will be required. Generational renewal is a growing EU concern and EU food systems need to attract new entrants and to ensure they have the skills to meet them. Improved skills and training must focus on the current and future needs of food systems.

- The COVID-19 emergency has demonstrated that the reorganisation of working arrangements is possible: shorter and/or flexible working hours could benefit both workers health and their productivity. In addition more free time would indirectly foster home-cooking and food growing, allowing more sustainable behaviour and increasing the possibilities for gender equality in caring activities such as cooking.

5 RESEARCH AND INNOVATION NEEDS

Food system resilience to global challenges such as climate change depends upon successful development, integration and implementation of policies, strategies, actions that can deliver co-benefits and mitigate trade-offs. The Green Deal Farm to Fork strategy sets out R&I policy as a key enabler for food systems transformation. The focus of this food governance pathway is on the development of R&I governance as a means to better organise and shape how we do science, research and innovation and on which issues, for which purposes, with whom, and for whom. This pathway also provides opportunities to expand our knowledge by pushing the boundaries of systems science to better understand and map complex food systems interactions, drivers and impacts to support decision-making, and provide science-policy advice for food systems transition.

Well-governed and impact-focused institutions, networks and initiatives able to work across silos, sectors, and scales are key determinants to achieving long-term sustainability and the ambitious goals of the European Green Deal. The many challenges related to food systems, as well as their key effects on climate, sustainability, health and livelihoods, have made clear that we urgently need to improve our FS governance beyond today's predominantly fragmented approach. In this respect, there are a number of major ongoing policy developments where improving the R&I governance landscape will contribute to the following relevant policy objectives.

- Green Deal: to deliver the European Green Deal, there is a need to rethink policies for production and consumption of food. To achieve these aims, it is essential to increase the value given to protecting and restoring natural ecosystems, to the sustainable use of resources, and to improving human health. This is where transformational change is most needed and potentially most beneficial for the EU economy, society and natural environment.

- Farm to Fork strategy: the Farm to Fork strategy will strive to stimulate sustainable food consumption and promote affordable healthy food for all.

- Climate change: by summer 2020, the Commission will present an impact assessment plan to increase the EU's greenhouse gas emission reductions target for 2030 to at least 50 % and towards 55 % compared with 1990 levels in a responsible way.

- The need to nurture, protect and strengthen our democracy.

- The need for an economy that works for people and for social fairness and prosperity.

Improved R&I governance will enshrine the need to foster co-benefits, while minimising trade-offs and rebound effects in areas such as:

- climate neutrality and adaptation to climate change
- halting biodiversity decline as well as preserving and restoring ecosystems
- sustainable and circular management and use of natural resources
- food and nutrition security for all within planetary boundaries and, farm to fork
- rural, coastal, peri-urban and urban areas are developed in a sustainable, balanced and inclusive manner thanks to a better understanding of the behavioural, socioeconomic and demographic drivers of change.
- zero pollution
- fair and just transition and a democracy that works for people

Research needs build upon the Food 2030 R&I policy framework to deliver co-benefits for nutrition, climate, circularity and communities. The overall R&I objective is to strengthen the enabling role of R&I to transform food systems for sustainability, health and inclusion. This will be achieved by fostering new scientific and technological advances in combination with different forms of innovation, including: institutional, governance, business model and social innovation. The pathway is of primary societal and policy relevance and will be crucial to oversee and achieve EU R&I policy and EU Green Deal priorities, including the Farm to Fork strategy. In this context, food systems include all those activities, sectors and actors taking part in primary production from land and sea, food processing and distribution, logistics and storage, retail, food services (canteens, restaurants), food preparation, consumption, and nutrition for health and wellness.

The R&I needs here are divided into four strands, which need to be aligned and mutually supportive, and which federate a wide diversity of food systems stakeholders and initiatives resulting from other pathways and intervention areas relevant to sustainable, healthy and inclusive food systems transformation.

The first strand, **Understand**, consists of creating an all-encompassing International Platform for Food Systems Science (IPFSS). This is a network of scientific experts from a wide diversity of relevant disciplines, which will gather and analyse the evidence to better understand the state of the art in food systems science. They will map existing food systems and typologies, establish relevant indicator sets, build and run new simulation models that advance the state of the art in, for example, multi-criteria analysis, integrated assessment and systems science; different

options and scenarios, foresight, dissemination and communication of scientific outcomes for multiple audiences: researchers, policymakers, science media and society; and provision of up-to-date science education curricula and learning opportunities for Higher Education institutes.

The second strand, **Engage**, consists of establishing a public-engagement mechanism to raise awareness and foster more citizen involvement in science, research and innovation to enable food systems transformation, and to build up scientific citizenship in this area.

The third strand, **Align**, relates to a more structured food systems research area (FSRA) which can align and leverage investments, in particular in mobilising possible partners in preparation for the Horizon Europe Partnership 'Safe and sustainable food systems for people, planet and climate', to be launched in 2023.

The fourth strand, **Deploy,** is about launching place-based demonstrators and pilot projects across the EU, and fostering a culture of entrepreneurship for food systems transformation.

Some key R&I work to be undertaken with respect to these four strands includes:

- **Understand**: build up a food systems *science-policy-society* interface, increase and measurement of food systems research impact, assessment, analysis, modelling and decision support, mapping and monitoring food systems performance, investing in evidence-based communication, dissemination, and knowledge exchange;

- **Engage**: raise food systems awareness, convene multi-actor and public engagement, involving youth, in support of evidence-based governance, institutional and social innovation, and monitor the social transition progress;

- **Align**: create a food system partnership, work with and align existing programmes and structures including the Standing Committee for Agricultural Research (SCAR) and its strategic and collaborative working groups, foster food systems education and training, build an academic/university network to foster food systems transition;

- **Deploy:** create a food systems technology and innovation observatory, and support food systems and bioeconomy demonstration, testing and deployment.

6 SHOWCASING SOLUTIONS

There are only two H2020 projects, which specifically address the issue of food systems R&I governance and food system change and transition. These are FIT4FOOD2030 and SUSFANS, funded for a total of EUR 9 million.

- **Fit4Food2030 - Fostering Integration and Transformation for Food 2030** (2017-2020) CSA, 4M: The project ran under the SFS-2017 call with EUR 4 million funding. The project aimed to establish a sustainable multi-stakeholder, multi-level platform, mobilising a wide variety of stakeholders at the level of cities, regions, countries, and Europe to build a 'FOOD2030 platform' through three interlinked structures: (1) 'EU think tank' to link EC and Member States and Associated Countries; (2) 'Policy labs' to increase and align public/private R&I policies/programmes on FNS, building on and expanding existing national/regional networks; and (3) 'City labs' to develop/pilot action-oriented trainings for students, consumers, researchers and professionals linking Science Centres/Science Shops to networks of Milan Urban Food Policy Pact cities.

- **SUSFANS Studies, metrics, integrated modelling, and foresight development for European sustainable food and nutrition security** (2015-2019) CSA, 5M: SUSFANS' overall objective was to build the conceptual framework, the evidence base and analytical tools for underpinning EU-wide food policies with respect to their impact on consumer diet and their implications for nutrition and public health in the EU, the environment, the competitiveness of the EU agri-food sectors, and global food and nutrition security.

PATHWAY 2 – URBAN FOOD SYSTEMS TRANSFORMATION

1 SYSTEMIC CHALLENGES

This Food 2030 pathway aims to apply R&I to drive urban food systems transformation by improving the understanding, modelling and monitoring of food systems, providing science-backed multi-actor governance processes, establishing systemic frameworks for action that deliver co-benefits and reinforcing the capacity of cities as innovation ecosystems and agents of change.

The aspects related to food waste and diets, even if mentioned here, will be developed in separate pathways.

Today, more than 50 % of the world's population live in urban areas ([5]) and this percentage is predicted to increase to over 70 % by 2050 ([6]) ([7]). Considering that 79 % of all food produced is destined for consumption in cities ([8]), such urbanisation is directly linked to the **changing demand for food** ([9]) that will impact rural areas and agricultural supply chains ([10]); not only because food needs to be easily stored and transported ([11]), but also because of the increased land competition between land-intensive economic sectors (e.g. agriculture) and the living and working space of other sectors ([12]). Therefore, urban areas today face a huge challenge to **ensure nutritious, safe and sustainable food** to their residents ([13]).

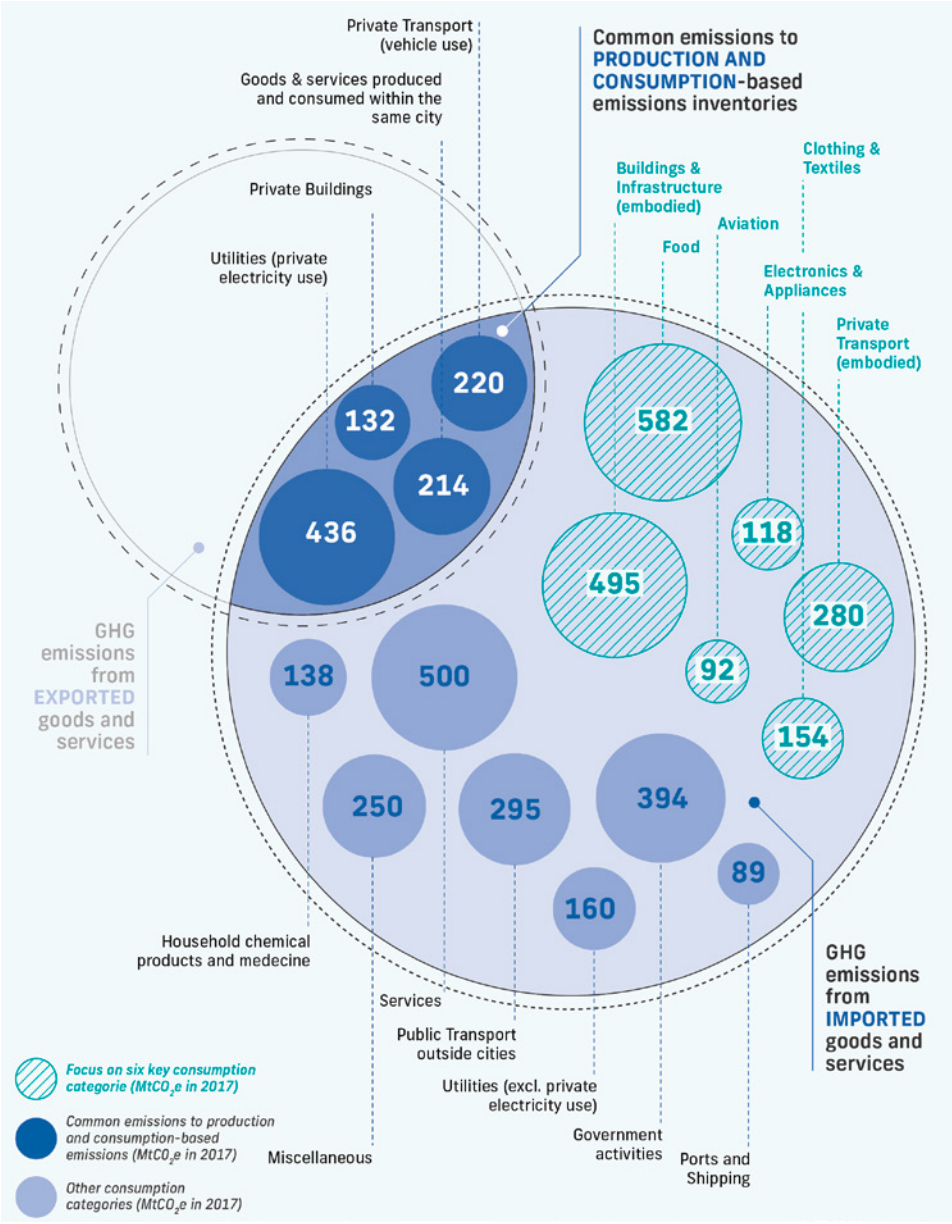
Understanding how food is produced and consumed is one of the major **challenges for sustainable development and food security** in urban and rural areas, especially in the face of climate change and socioeconomic inequalities ([14]). Moreover, **cities have become increasingly disconnected from food**, starting from the process of industrialisation of the 1950s and continuing with the globalisation of the 1980s ([15]). Consequently, **urban policies and regulations often pay little attention to food systems ([16])**, which have been historically managed at the national level ([17]).

A big issue for cities is **food waste** ([18]). Urban areas often experience rising levels of waste ([19]) and between 2007 and 2025 they are expected to see a 35 % increase in urban food waste ([20]).

Cities are the main contributors to **greenhouse gas emissions** ([21]) and in 2017, emissions associated with food were estimated to account for 13 % of total consumption-based emissions across C40 cities. Roughly three quarters of these emissions stem from consumption of animal-based foods, with the remaining 25 % from consumption of plant-based foods. Considering both production and consumption, the food sector is responsible for the largest share of production-based and consumption-based emissions, as shown in the figure below ([22]).

([5]) Several definitions of what constitutes a city or an urban area are in use, with significant variations between countries (UN-Habitat, 2019). For the sake of this pathway, we consider local municipalities varying considerably in terms of size (land area), population (and population density), and administrative or local government arrangements.
([6]) World economic Forum. *Project MainStream. Urban Biocycles.* 2017
([7]) FAO (2019), 'Urban Food Action'.
([8]) FAO (2019), 'Urban Food Action'.
([9]) Scientific Advise Mechanism (SAM) (2020), '*Towards a Sustainable Food System*'.
([10]) Marsden (2013); Sonnino (2009), in IPES-Food. *What makes urban food policy happen?* 2017
([11]) Fraunhofer Institute for system and innovation research (2019), '50 trends influencing Europe's food sector by 2035'.
([12]) Fraunhofer Institute for system and innovation research (2019), '50 trends influencing Europe's food sector by 2035'.
([13]) MUFPP, RUAF, Gain (2019), 'A menu of actions to shape urban food environments for improved nutrition'.
([14]) Stierand (2012); Sonnino (2016), in Doenberg, A. et al. (2019), 'Urban food policies in German city regions: An overview of key players and policy instruments', Elsevier.
([15]) Doenberg, A. et al. (2019), 'Urban food policies in German city regions: An overview of key players and policy instruments', Elsevier.
([16]) FAO (2019), 'Urban Food Action'.
([17]) FAO (2019), 'Urban Food Action'.
([18]) See Pathway on Food Waste.
([19]) FAO (2019), 'The state of food and agriculture'.
([20]) FAO (2019), 'Urban Food Action'.
([21]) FAO (2019), 'Urban Food Action'.
([22]) C40 cities report (2019), 'The future of urban consumption in a 1.5 °C world'.

Figure 4.



Source – C40 cities report, 'The future of urban consumption in a 1.5 °C world', 2019.

Urban lifestyles and dietary patterns have been moving more and more towards the consumption of **packaged and ultra-processed food** ([23]) with low nutrient value ([24]) ([25]). Several factors are responsible for this nutritional transition ([26]) and a poorly planned **urban food environment** ([27]) (see illustration below) is one of them. In fact, consumer choices are usually not based on the best available information but, on the contrary, are influenced by 'norms and conventions, cost, convenience, and habit, and the ways in which food choice is presented' ([28]).

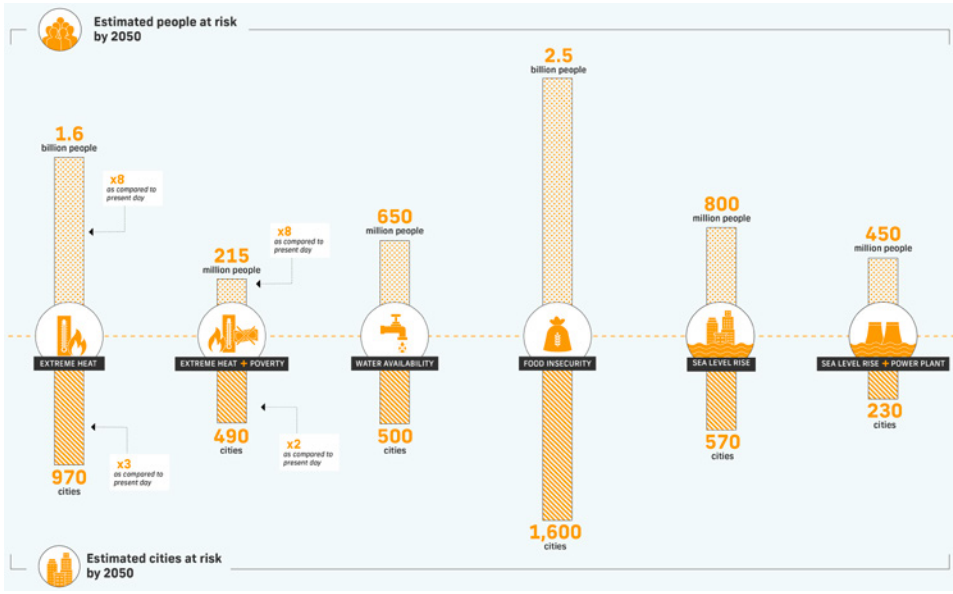
Some neighbourhoods – especially less affluent ones ([29]) – are poorly served by markets and stores ([30]), thus contributing to the spatial and socioeconomic inequality phenomenon of the 'food deserts', while cheap and over-processed items tend to be ubiquitous and are often subjected to heavy marketing practices ([31]). Unsurprisingly, urban environments are often referred to as 'obesogenic' since the large offer, high accessibility and low price of packaged and processed food often leads to **obesity and associated diet-related non-communicable diseases** ([32]) ([33]). In other words, 'while the synergies between the role of healthy food outlets, the overall food environment and access to green spaces and urban forests for healthy lifestyles are well understood, this is not well reflected in urban planning, policies and local regulations.' ([34]).

Global figures about the issue of hunger in urban areas remain scarce. Nonetheless, according to a recent study involving 146 countries ([35]), as much as 19.8 % of the urban world population are moderately food insecure, whereas 7.3 % are considered severely food insecure. Contrary to what may be thought, it is now evident that **food security is predominantly an urban issue in high-income countries**: in 2015, in North America and Europe around 50 million urban dwellers were food insecure ([36]). This is true especially considering the concept of food security has evolved from the simple availability of food: not only does it now include food accessibility, so that the 'production, transport costs and governance are more important than the idea of a planet running out of resources' ([37]), but also food quality.

([23]) FAO (2019), 'Urban Food Action (UFA)'.
([24]) Monteiro et al. Ultra-processed products are becoming dominant in the global food system. Obesity Review 2013
([25]) Fraunhofer Institute for system and innovation research (2019), '50 trends influencing Europe's food sector by 2035'.
([26]) BCFN, MUFPP. *Food & Cities. The role of cities for achieving the Sustainable Development Goals.* 2018
([27]) A person's **food environment** is the combination of availability/accessibility, affordability, convenience and desirability of different foods (Herforth and Ahmed (2015); Taylor et al. (2018), in MUFPP, RUAF, Gain (2019), 'A menu of actions to shape urban food environments for improved nutrition'. These dimensions determine respectively people's physical access to food, their purchasing power, their knowledge about food and their preferences, which in turn determine the nutritional quality of the diets they consume
([28]) Scientific Advise Mechanism (SAM) (2020), '*Towards a Sustainable Food System*'.
([29]) BCFN, MUFPP (2018), Food & Cities. The role of cities for achieving the Sustainable Development Goals
([30]) Russell & Heidkamp (2011); Wringley et al. (2003); Whelam et al. (2002), in IPES-Food (2017), What makes urban food policy happen?
([31]) FAO (2019), IPES-Food (2017), What makes urban food policy happen?
([32]) FAO (2018), *Integrating Food into Urban Planning,* UCL Press
([33]) IPES-Food. *What makes urban food policy happen?* 2017
([34]) FAO (2019), 'FAO Framework for the Urban Agenda'.
([35]) World Bank Group and FAO, 'Food Systems for an Urbanizing World' (2017), in FAO (2018).
([36]) FAO (2018).
([37]) ESPAS (2019), '*Global trends to 2030. Challenges and choices for Europe*'.

Due to their reliance on external markets and on long food chains depending on complex flows of people, **cities are more vulnerable** to supply chain shocks, including those related to climate change ([38]) or pandemics ([39]). It is estimated that 2.5 billion people in 1 600 cities will be at risk of food insecurity by 2050 (see Figure 5) ([40]). In these times of economic crisis and supply disruption ([41]), the urban poor, spending a greater share of their budget on food in comparison to wealthier households ([42]), struggle to provide nutritious food for their families ([43]).

Figure 5.



Source: C40 cities report, 'The future of urban consumption in a 1.5° C world', 2019.

Modernising and transforming current urban food systems to become more competitive, resource efficient, healthy and inclusive is both urgent and complex, also because a one-size-fits-all food planning approach cannot be applied ([44]).

([38]) MUFPP, RUAF, Gain (2019), 'A menu of actions to shape urban food environments for improved nutrition'.
([39]) IPES-Food (2020), 'COVID-19 and the crisis in food systems: Symptoms, causes, and potential solutions'.
([40]) C40 cities report (2019), 'The future of urban consumption in a 1.5 °C world'.
([41]) Bohstedt, 2014; Morgan & Sonnino (2010), in IPES-Food (2017), What makes urban food policy happen?
([42]) FAO (2018).
([43]) Ruel et al. (2017), in IPES-Food (2017), What makes urban food policy happen?
([44]) IPES-Food (2017), What makes urban food policy happen?

Recently (and Europe is very new to this) ([45]) **'city governments (and territorial communities) are emerging as key actors** in fostering more sustainable food systems, although they usually have no clear mandate ([46]). In fact, the institutional and operational responsibility has not been clearly assigned and there are few regulatory tools to implement policy at local level ([47]). Through integrated, cross-departmental action, cities are starting to bring together various stakeholders to design food policies that address pressing food-related problems (such as food insecurity and obesity), but at the same time helping to resolve wider issues, including environmental challenges, social inequalities and poverty. The Milan Urban Food Policy Pact ([48]), signed by over 200 cities worldwide and covering 450 million inhabitants, is an important milestone in this context' ([49]).

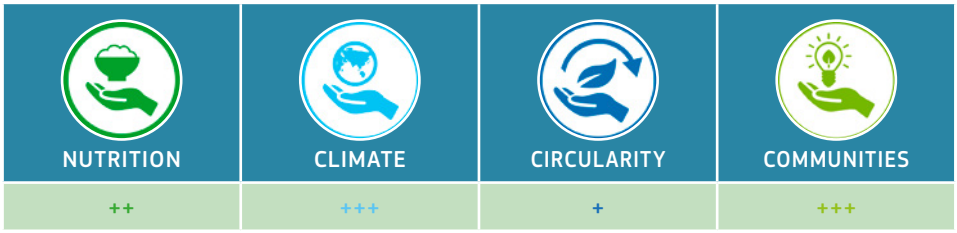
RELEVANT EU POLICIES

- EU Health policy
- EU European Fund for Strategic Investment
- EU Food Safety policy
- EU Adaptation policy
- EU Environment policies (7th EAP, WFD)
- Revised EU Waste Legislation
- Bioeconomy Strategy and Circular Economy Package.

2 CO-BENEFITS

This pathway will have an impact on all four of the Food 2030 priorities, because urban food systems are interlinked with other systems and can therefore contribute to **sustainable urban development** ([50]).

([45]) Doenberg, A. et al. (2019), 'Urban food policies in German city regions: An overview of key players and policy instruments', Elsevier.
([46]) Battersby (2017), in Doenberg, A. et al. (2019), 'Urban food policies in German city regions: An overview of key players and policy instruments', Elsevier.
([47]) Mansfield and Mendes (2013), in Doenberg, A. et al. (2019), 'Urban food policies in German city regions: An overview of key players and policy instruments', Elsevier.
([48]) http://www.milanurbanfoodpolicypact.org/
([49]) EESC Opinion on 'Promoting healthy and sustainable diets in the EU', 2018.
([50]) Doenberg, A. et al. (2019), 'Urban food policies in German city regions: An overview of key players and policy instruments', Elsevier.



NUTRITION AND HEALTH

- Healthier urban food environments
- Reduction of obesity and diet-related NCDs

CLIMATE AND SUSTAINABILITY

- Climate change mitigation. Urban action on food consumption can significantly reduce emissions: 36 % by 2030; 60 % by 2050 ([51])
- Increased climate change adaptation options
- Biodiversity protection

CIRCULARITY AND RESOURCE EFFICIENCY

- Resource-efficient food systems, where food waste is prevented and reduced

INNOVATION AND COMMUNITIES

Cities have the potential to become ecosystems of innovation facilitating **experimentation and multi-stakeholder engagement** to contribute to long-term **evidence-based food policies, strategies** that will ultimately ensure safe, healthy, sustainable and nutritious food to their inhabitants and surrounding communities.

This would contribute to:

([51]) C40 cities report, 'The future of urban consumption in a 1.5 °C world', 2019.

- people's reconnection to food, which is not anymore considered as a 'commodity', but as 'commons', 'human closest link to nature' and 'identity and culture' ([52]);
- improved social inclusion and equity ([53]), people reskilling and communities' empowerment;
- innovation opportunities and sustainable urban development ([54]).

RELEVANT SDGS

3 BARRIERS AND LOCK-INS

Persistent obstacles ([55]) to strengthening urban food systems through integrated food strategies remain to varying degrees in many cities, and include the following:

- **Lack of an EU framework**, which is so far not compensated by the involvement of **national governments** ([56]).
- Weak or non-existent local **governance** structures (both horizontal and vertical).
- Low capacity and minimal **resources** to enable innovation ([57]), including legal and regulatory instruments to ensure the integration of food in urban and territorial planning.
- Lack of **awareness** (often due to the limited collaboration ([58]) between urban authorities and R&I specialists), not compensated by sufficient professional training ([59]) of the ways in which local food systems function, of the potential for action for local governments, and of the real impact of urban food actions and policies ([60])([61])([62]). Furthermore, the degree of actual

([52]) SAPEA (2020), 'A sustainable food system for the European Union'.
([53]) EC Food 2030 Independent Expert Group, 2018.
([54]) CoR Opinion on 'Local and regional incentives to promote healthy and sustainable diets', 2018.
([55]) FAO (2018).
([56]) Report of the EC Food 2030 Independent Expert Group (2018), 'Recipe for change: An agenda for a climate-smart and sustainable food system for a healthy Europe'.
([57]) FAO (2019).
([58]) EC Food 2030 Independent Expert Group, 2018.
([59]) FAO (2019).
([60]) FAO (2019).
([61]) EC Food 2030 Independent Expert Group (2018), 'Recipe for a change. An agenda for a climate-smart and sustainable food system for a healthy Europe'.
([62]) MUFPP, RUAF, Gain (2019), 'A menu of actions to shape urban food environments for improved nutrition'.

embedding of systemic thinking into integrated urban food policies varies greatly among cities due to the fact that often the latter have acted in reaction to specific problems of crises, such as food security, obesity, climate change and waste or slow economy and lack of jobs. Local actors in administrations are still not familiar with the concepts 'food systems' and 'urban food policy', although they implement policies that shape the urban food system. As a consequence, many of the existing fragmented initiatives focus on the production and/or consumption side only ([63]).

- Competences related to food are scattered in different departments and organisations in public authorities ([64]). Persistent conflict and **policy incoherence** between sectors, actors and jurisdictions, where the food system thinking is not yet the mainstream but has often remained at the abstract level ([65]). Furthermore, inevitable trade-off exists and compromise need to be considered, because, for instance, healthy food is not always sustainably produced ([66]).

4 ENABLERS OF CHANGE

In view of the transformation of urban food systems, comprehensive urban food policies are a necessary step and some key factors ([67]) need to be considered to enable the process:

- **Data, monitoring and learning** – Background research is needed to inform policymakers and promote their commitment. Besides, it allows other cities to identify actions that have had the greatest and largest-scale impacts on improved nutrition, and to make the case for replicating them ([68]). Data has to be collected, indicators have to be created and monitored during the implementation and the impact has to be measured, both to renew the political commitment and to inspire other cities. Finally, the policy needs to be reviewed and renewed to improve its efficacy.

- '**Vertical' multi-level governance** – The local city level needs to be empowered with the adequate competencies to advance the policy development and delivery and the national level has to be supportive through structures and programmes.

- **'Horizontal' city-level governance** ([69]) – City governments need to be aware of the importance of a food policy and seek the collaboration with other departments within an

([63]) Sonnino et al. (2018) and FAO (2019).
([64]) EC Food 2030 Independent Expert Group, 2018.
([65]) Sonnino et al. (2018) and FAO (2019).
([66]) H2020 funded 'Inherit' project.
([67]) IPES-Food (2017), What makes urban food policy happen?
([68]) MUFPP, RUAF, Gain (2019), 'A menu of actions to shape urban food environments for improved nutrition'.
([69]) MUFPP, RUAF, Gain (2019), 'A menu of actions to shape urban food environments for improved nutrition'.

ad-hoc governance body that would be responsible for the accountability and efficiency of the policy, ensuring multiple benefits in different policy areas.

- **Participatory policy process and multi-stakeholder engagement** ([70]) – The participation of communities, city governments and actors from the food system to the development of the policy would provide an exhaustive perspective of the issue, enable co-learning, help share ownership and promote innovation capacity. Moreover, when engaging with the private sector, the business case for involvement must be clear ([71]).

- **Funding** – The provision of partial funding by the city government would ensure a minimum of implementation, while other funds, not constrained by other agendas, would enable the complete delivery of the policy.

- **Political commitment** – The involvement of public authorities at all levels of governance ([72]) will be key to give legitimacy to the policy, enable civil servants to implement it, promote its institutionalisation within an overall vision, engage multiple city departments and bypass electoral cycles for a long-term delivery ([73]).

- **International initiatives, lobbying and campaigns** – They can serve as stimulant to increase commitment and awareness at local level and to create a favourable context (e.g. the Milan Urban Food Policy Pact).

- **City networks and working groups** – they represent platforms to develop familiarity with the concepts of urban food systems and policy, promoting knowledge exchange and fostering innovation ([74]). Furthermore, cities can benefit from the initiatives of the other cities, and especially of those from the same region, as they are most likely to be suited to the context and local government powers, and any initial barriers will have been overcome ([75]).

- **Innovation districts** – In more and more cities, innovation districts are emerging. 'These districts are collaborative environments that facilitate R & D and innovation and promote the development, transfer, and commercialisation of technology by providing a bounded and branded location in which companies, entrepreneurs, and research institutions and their highly skilled talent base operate in close proximity ([76]).

([70]) MUFPP, RUAF, Gain (2019), 'A menu of actions to shape urban food environments for improved nutrition'.
([71]) MUFPP, RUAF, Gain (2019), 'A menu of actions to shape urban food environments for improved nutrition'.
([72]) EC Farm to Fork strategy, 2020.
([73]) E.g. the strong political will of the Mayor of London to set up a transport ban on unhealthy food advertising (2019).
([74]) Piorr et al. (2018), in Doenberg, A. et al. (2019), 'Urban food policies in German city regions: An overview of key players and policy instruments', Elsevier.
([75]) MUFPP, RUAF, Gain (2019), 'A menu of actions to shape urban food environments for improved nutrition'.
([76]) The Global Institute of innovation Districts (GIID) (2020), 'New empirical evidence: how one innovation district is advancing the regional economy'.

5 RESEARCH AND INNOVATION NEEDS

Hereinafter are the key areas for intervention and the possible actions to be taken within those areas:

1. FOOD PRODUCTION

- **New forms of food production:**

R&I is needed to support short food supply chains and environmentally-friendly food practices reconnecting consumers and producers, protecting local biodiversity, a more efficient use of resources and energy and the reduction of packaging, food losses and waste ([77]), while continuing to ensure food safety ([78]).

Vertical farming and all other new forms of urban food production are covered by a specific roadmap.

- **Food sharing economy**

There are several examples of social innovation, particularly in urban areas, promoting 'collaborative consumption', where the shift from 'owning' to 'sharing' and from being passive consumers to co-producers of good and services is taking place. Here, challenges concerning food safety and data protection still need to be solved, taking into account current regulations. Examples of sharing economy in the food sector include: kitchen spaces, meal sharing, food business incubators, collaborative delivery services.

2. FOOD SUPPLY AND DISTRIBUTION

Green public procurement (GPP) for healthy and sustainable meals: Cities can use public food procurement policies to influence the organisation of food supply and distribution ([79])([80]).

([77]) Mundler, P & Rumpus, L. (2012), and Proctor. F. J. & Berdegué, J-A. (2016), in FAO (2019), 'FAO Framework for the Urban Agenda'.
([78]) H2020 funded 'INHERIT' project.
([79]) IPES-Food (2018), 'Towards a Common Food Policy for the EU' Framing paper for the EU Food and Farming Forum.
([80]) H2020 funded 'INHERIT' project.

3. SOCIAL AND ECONOMIC EQUITY

- It is necessary to improve access to affordability and desiderability of sustainably produced and healthy food ([81]). With this aim, the relationship between **urban planning and food choices** needs to be further explored. Furthermore, robust measures of the food environment need to be developed, especially in relation to schools and worksites ([82]).

  It will be necessary to develop insights and solutions based on new interdisciplinary collaborations between urban designers, planners, social, health and nutrition ([83]) scientists and food producers and retailers ([84]). This will also help to define guidelines to redisign healthy food environments ([85]).

- Enhancing **urban social resilience** to constantly ensure urban food and nutrition security also in the case of food supply disruptions (e.g. due to climate change or pandemics ([86])). Tailored solutions, including social innovations, technologies, new or adapted business models as well as new marketplaces, to construct more efficient, sustainable, resilient supply chains and to establish food-related social protection programmes for vulnerable urban populations ([87]) are needed.

- **Education and skill building:** technical and managerial skills and know-how, including curricula for students are needed for a society with informed citizens.

4. GOVERNANCE AND ENABLING FRAMEWORK FOR ACTION

A growing number of city governments are confronting the challenges head on by translating R&I system thinking into pratice and developing integrated urban food policies ([88]). These can be a key factor in enabling food systems transition on a broader level, although not the only one ([89]), since many problems cannot be fully addressed at city level.

([81]) H2020 funded 'INHERIT' project.
([82]) Lytle L. and Sokol, R. (2017), '*Measures of the food environment: a systematic review of the field, 2007-2015'*, Elsevier.
([83]) Lytle L. and Sokol, R. (2017), '*Measures of the food environment: a systematic review of the field, 2007-2015'*, Elsevier.
([84]) Sonnino et al. (2019), The challenge of systemic food change: Insights from cities, Elsevier.
([85]) EC Food 2030 Independent Expert Group (2018), '*Recipe for a change. An agenda for a climate-smart and sustainable food system for a healthy Europe*'.
([86]) IPES-Food (2020), 'COVID-19 and the crisis in food systems: Symptoms, causes, and potential solutions'.
([87]) See note 29.
([88]) IPES-Food (2017), What makes urban food policy happen?
([89]) Barling et al. (2002), in IPES-Food (2017), What makes urban food policy happen?

Several research gaps have to be confronted here ([90]):

- cities have to be supported in the evaluation of the **local food system;**
- cities need to be supported to develop urban food policies and participatory **governance** models and practices to enable participation of stakeholders and new forms of citizenship ([91]);
- last but not least, the **impacts of urban food policies** still need to be fully evaluated. In particular, more knowledge is needed about the effectiveness of different policy instruments ([92]). This ultimately is going to stimulate the development of sustainable innovations in the food systems that are adapted to local environments and citizens' needs ([93]).

6 SHOWCASING SOLUTIONS

Within Horizon 2020 approximately 9 projects have been supported representing an investment of around EUR 80 million. Some key projects include:

- **SHARECITY** - ***Assessing the practice and sustainability potential of city-based food sharing economies*** (2015-2021), ERC-2014-CoG, 1,8 M.

  The project will identify and examine diverse practices of city-based food sharing economies, first determining their form, function and governance and then identifying their impact and potential to reorient eating practices.

- **Strength2Food** – ***Strengthening European Food Chain Sustainability by Quality and Procurement Policy*** (2016-2021), SFS-2015, 7M. The project aims to improve the effectiveness of EU food quality schemes (FQS), public sector food procurement (PSFP) and to stimulate Short Food Supply Chains (SFSC) through research, innovation and demonstration activities.

- **ROBUST** – ***Rural-urban outlooks: unlocking synergies*** (2017-2021), RUR-2016, 6 M.

  The project aims at contributing to a better understanding of rural-urban interactions, and it will at the same time enhance the capacity of relevant actors and institutions to foster mutually beneficial relations along rural – peri-urban – urban trajectories.

([90]) IPES-Food (2017), What makes urban food policy happen?
([91]) EC Food 2030 Independent Expert Group (2018), 'Recipe for a change. An agenda for a climate-smart and sustainable food system for a healthy Europe'.
([92]) Battersby (2017), in Doenberg, A. et al. (2019), 'Urban food policies in German city regions: An overview of key players and policy instruments', Elsevier.
([93]) EC Food 2030 Independent Expert Group, 2018.

- **EdiCitNet – Edible Cities Network integrating edible city solutions for social resilient and sustainably productive cities** (2018-2023), SCC-02-2016-2017, Demonstrating innovative nature-based solutions in cities, 12M.

  EdiCitNet will launch a fully open and participatory network of cities, empowering their inhabitants by a common methodology to systematically explore the wealth and diversity of existing Edible City Solutions (ECS) and to adapt, plan and implement successfully proven ECS in their specific urban context.

- **FOODSHIFT2030 – Food System Hubs Innovating towards Fast Transition by 2030,** (2020-2022), SFS-24-2019, 7.5 M.

  The project will launch an ambitious citizen-driven transition of the European food system towards a low carbon circular future, including a shift to less meat and more plant-based diets. A fast citizen-driven food system transition will be achieved by creating a framework and efficient mechanisms for maturing, combining, upscaling and multiplying existing food system innovations through the operationalisation of nine citizen-driven FoodSHIFT Accelerator Labs and 27 FoodSHIFT Enabler Labs established in existing and emerging city-region food system hubs distributed across Europe.

- **FoodE – Food Systems in European Cities** (2020-2022), SFS-24-2019, 7.2 M.

  The project will accelerate the growth of citizen-led City/Region Food Systems (CRFS) by bringing local initiatives across Europe together, as well as co-developing and disseminating a range of tools – co-designed with academia, citizens, and food system start-ups – to ensure that the most up-to-date cross-sectorial knowledge is applied.

- **FUSILLI – Fostering the Urban Food System Transformation through Innovative Living Labs implementation** (2021-2025), FNR-07-2020, 12.8 M.

  The project will support the cooperation among European cities and their peri-urban areas for knowledge sharing and mutual learning. The main objective is to build an urban food plan for an integrated and safe transition towards healthy, sustainable secure, inclusive, equitable and cost-efficient food systems, through feasible and replicable innovative urban policies and actions throughout all the stages of the food value chain and in line with the four Food 2030 policy priorities. Each city will have a Living Lab and, while a common knowledge community will compile the existing local initiatives into a catalogue of best practises.

- **FOOD TRAILS – Building pathways towards Food 2030-led urban food policies** (2021-2025), FNR-07-2020, 12.2 M.

  The project will translate the MUFPP's shared vision and collective commitment into measurable and long-term progress towards sustainable food systems by providing cities, regional governments and other agents of change with evidence-based policy narratives co-designed and verified thanks to the activities of 11 multi-objective and multi-actor Living Labs addressing the four priority areas of Food 2030. FOOD TRAILS will also establish a pan-European Investors' Living Lab to develop innovative financial instruments that will attract new resources to sustain the urban food policies developed during the project, maximise their visibility and support their replicability across the EU.

- **CITIES2030 – Co-creating resilient and sustainable food systems towards FOOD2030** (2021-2025), FNR-07-2020, 12.4 M.

  The project will create future-proof and effective Urban food systems and ecosystems (UFSE) via a connected structure having citizens at the centre. This objective is achieved via multiple tools delivered by CITIES2030 such as the CRFS Alliance, a community of practice supported by a digital platform, reaching all over Europe and beyond. This approach will enable policy developments, innovation actions within result-driven labs, and enhancements on a pan-European scope with a global reach. Cities and regions will improve resilience and sustainability, and their leadership will create a short food-supply chain and ecosystems enabling local investments, trans-borders and transnational deployment. A blockchain-based data-driven UFSE management platform will secure intelligence and coordination actions by delivering an accurate, almost real-time digital twin of the whole supply chain, but also on key enablers of resilience and sustainability.

PATHWAY 3 – FOOD FROM THE OCEAN AND FRESHWATER RESOURCES

1 SYSTEMIC CHALLENGES

Seafood production through harvesting (fisheries) and farming (aquaculture) is key for European and global food and nutrition security. According to the Scientific Opinion provided by the SAM HLG ([94]) (Scientific Advisory Mechanism High Level Group of Scientific Advisors), sustainable fisheries and aquaculture are primary food-production systems that can substantially contribute to food and nutrition security by 2030. Most seafood is low in carbohydrates but rich in proteins and polyunsaturated fatty acids thus providing nutritional elements that are scarce in food

([94]) EC Website. *Food from the Oceans. Scientific advice in the area of food and biomass from the oceans*

produced on land. Fish make up to 16 % of animal protein consumed globally ([95]) and demand is expected to grow due to rising disposable incomes, particularly in Asia where the middle class is growing.

The EU is massively self-insufficient in seafood with Europeans consuming roughly twice as much as they produce ([96]) with most imports coming from Asian countries. Any change in production and/or demand in these countries will considerably affect seafood security in the EU. Fisheries in the EU have in the recent past faced collapses of major stocks due to overfishing and also to general degradation of marine ecosystems. Efforts to rebuild stocks within their safe ecological limits have in many cases been successful in the N.E. Atlantic and the Baltic Sea. In contrast, only 2 out of 33 stocks (6 %) in the Mediterranean Sea and 1 out of 7 stocks (14.3 %) in the Black Sea meet at least one of the good environmental status criteria ([97]). This is mainly due to the prevalence of overfishing and a significant lack of knowledge of the status of fish and shellfish stocks.

Aquaculture is the obvious way to increase seafood production and could provide close to two thirds of global seafood consumption by 2030 ([98]) but it would only make sense if it is developed in the most sustainable and less impacting manner. This also concerns freshwater aquaculture that is crucial for landlocked countries and can only be sustainable if meaningfully combined with other activities that rely on freshwater resources. Algae farming might be the next big thing for food and feed production, but in Europe its potential is not fully exploited and Asia is currently mainly driving growth in this sector. Although booming globally, aquaculture production in Europe is stagnating due to overregulation, competition for space with other activities and an unjustified negative perception of consumers and citizens in general. The EU is the eighth biggest aquaculture producer behind seven Asian countries (Figure 6). International standard settings and legislation lack harmonisation of standards and regulations, particularly around ecosystem-based farming. European seafood products are internationally recognised to be of very high quality, but the stricter EU legislation results in higher prices, making European seafood less competitive in the global markets.

Seafood security could also benefit from the drastic reduction in the currently massive pre- and post-harvest losses in fish and shellfish biomass with more selective production and more suitable processing, transport, consumption and disposal.

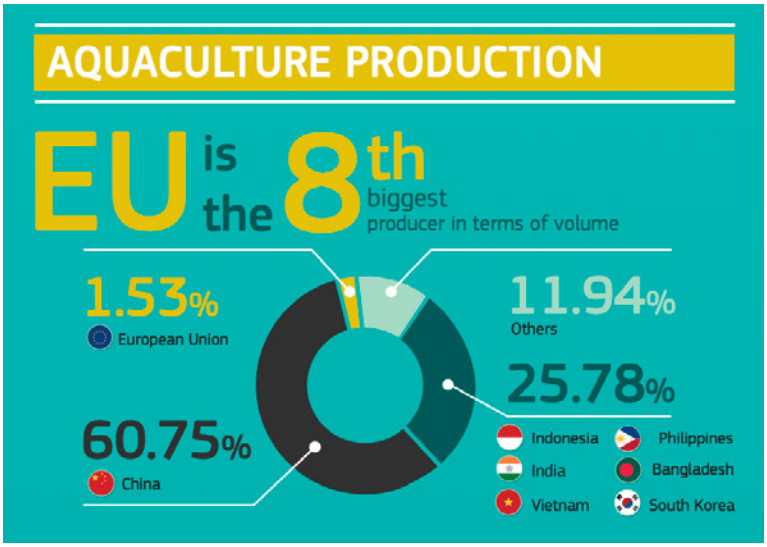
([95]) FAO (1997), 'Review of the State of World Aquaculture', FAO Fisheries Circular No 886, Rev. 1. Rome, Italy.

([96]) Eurostat and Eumofa, 2018.

([97]) Status of marine fish and shellfish stocks in European seas, European Environmental Agency 2019, https://www.eea.europa.eu/data-and-maps/indicators/status-of-marine-fish-stocks-4/assessment

([98]) World Bank and FAO (2014), Fish to 2030. Prospects for Fisheries and Aquaculture

Figure 6. 2015 Most important aquaculture producers globally ([99]).



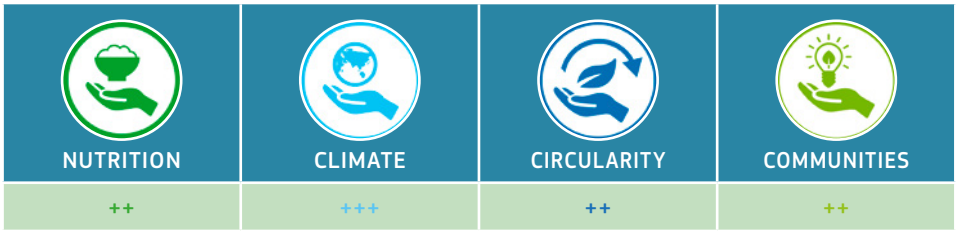
RELEVANT EU POLICIES

- The EU Green Deal including the Farm to Fork strategy and the Algae Strategy
- The EU Common Fisheries Policy
- The Marine Strategy Framework Directive
- The Maritime Spatial Planning Directive
- The Blue Growth Strategy including the update of the sustainable aquaculture guidelines
- The Water Framework Directive
- The Bioeconomy Strategy
- The Biodiversity Strategy
- The Habitats Directive.

([99]) Source: https://ec.europa.eu/fisheries/sites/fisheries/files/docs/body/2015-aquaculture-facts_en.pdf

2 CO-BENEFITS

The Pathway 'Food from the ocean and fresh water resources' would provide co-benefits to all four of the Food 2030 priorities, as described below.



NUTRITION AND HEALTH

- Increasing availability of nutritious proteins and polyunsaturated fatty acids.
- Ensuring the safety of aquaculture products by implementing traceability all along the value chain and supported by technologies such as the internet of things and artificial intelligence.

CLIMATE AND SUSTAINABILITY

- Contributing to carbon sequestration through algae farming and reduction of greenhouse gasses emission through more energy efficient fishing vessels and seafood processing.
- Integrating, planning and assessing all marine and freshwater activities in order to provide equal consideration to the social, ecological and economic implications of different uses. Identification of best practices, win-win activities in multi-use and co-location options.
- Maintaining wild fish stocks under safe biological limits and safeguarding the integrity of marine ecosystems

CIRCULARITY AND RESOURCE EFFICIENCY

- Minimising seafood waste throughout the whole value chain by promoting maximum utilisation and valorisation of marine biomass (trimmings, viscera, algae) for food, feed, nutraceutical and pharmaceuticals.

- Promoting diversification of aquaculture and the use of multitrophic farming systems, recirculating aquaculture systems and aquaponics.

INNOVATION AND COMMUNITIES

- Developing smart aquaculture and fisheries supported by information technologies such as artificial intelligence and the Internet of Things (IoT).
- Triggering growth and jobs creation in aquaculture, seafood processing and in related sectors such as maritime tourism and marine biotechnology while leaving no one behind.

RELEVANT SDGS

- SDG2 – Zero hunger. End hunger, achieve food security and improved nutrition and promote sustainable agriculture.
- SDG4 – Quality Education. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
- SDG5 – Gender equality. Achieve gender equality and empower all women and girls.
- SDG12 – Responsible consumption and production. Ensure sustainable consumption and production patterns.
- SDG13 – Climate Action. Take urgent action to combat climate change and its impacts.
- SDG14 – Life below water. Conserve and sustainably use the oceans, seas and marine resources for sustainable development.

3 BARRIERS AND LOCK-INS

The barriers and lock-ins in achieving sustainable fisheries and aquaculture include the following:

- Insufficient knowledge of basic biology and ecology of fish and shellfish (growth, reproduction, physiology, endocrinology, feeding, behaviour). This is a *sine qua non* for effective management of fish stocks based on the ecosystem approach and also for farming of a wider range of edible species. Gaps in knowledge of algae biochemistry, reproduction, eco-physiology and metabolism are even more pronounced considering the huge variety in traits and life cycles that algae exhibit and the heterogeneity in this group of organisms.

- Disease prevention and treatment for farmed fish and shellfish is an important requirement to sustainably farmed seafood production. Emerging diseases due to climate change and alternative treatments to prevent antimicrobial resistance receive limited attention, due to the relatively small size of aquaculture industry compared to livestock and poultry.

- Weak governance structures for fisheries management particularly in sea basins that are shared by EU and non-EU countries, such as in the Mediterranean Sea and the Black Sea. This weakness is even more pronounced in international waters and in particular in areas where there is no regional fisheries management organisation. There is a 'policy inertia' both inside the EU and outside that holds on to short-term national interest despite the well-documented climatic and other environmental challenges that require major shifts in the way that fisheries resources are managed.

- Lack of technology uptake by the fisheries sector. Fisheries is a traditional sector with difficulty to attract young, educated entrepreneurs and workforce. Fisheries often operate with destructive ineffective fishing methods and gears and are slow in uptaking technology developed in other fields, such as IT, aerospace, biotechnology etc.

- Consumer acceptance of farmed seafood. Beyond any other consideration and barrier, it is the ultimate obstacle to unlock the full potential of aquaculture in the EU, as aquaculture products often do not enjoy a good reputation. Farmed fish are often perceived as artificially-treated and hence unhealthy food. To turn this trend into a favourable one, reliable labelling systems together with explanatory campaigns and targeted communication strategies should be defined and implemented.

- Consumer acceptance of less-known seafood. Only a few fish and shellfish species are consumed while other nutritional marine and freshwater species are faced with consumer suspicion. Zooplankton, mesopelagic fish and algae often seem strange to consumers and are underexploited or discarded, whilst their consumption could ease fishing pressure to depleted species such as tuna.

- Spatial planning and red tape discourage new seafood businesses. There is strong competition on land and sea for space and access to water for aquaculture, in addition to a slow administrative process to grant licenses. Disparities in national licensing systems results in a very heterogeneous distribution of fish farms in the EU.

- Better risk assessment and management in seafood systems. European seafood production and processing systems must ensure the safety of their products. Risk assessment and management are essential components of the consumers' trust. Quality labelling will contribute to inform consumers' choice and build trust.

4 ENABLERS OF CHANGE

The enablers of change that would contribute to sustainable fisheries and aquaculture include the following:

- Convey the message that future protein needs can be covered to a great extent from marine and freshwater food production. The same can be said for the dietary needs in poly-unsaturated fatty acids.
- Encourage and promote the uptake of new technologies in the fisheries and aquaculture sector. Train fishers and fish farmers and make the industry attractive for young scientists, economists, technicians and other workers.
- Encourage orchestrated research efforts across the EU and globally to cover the basic knowledge needed for efficient ecosystem-based fisheries management.
- Promote coordinated management of fish stocks in international waters based on the ecosystem-based approach and the concept of maximum sustainable yield.
- Build on consumers' trust by implementing new technologies to certification and traceability schemes to support informed consumers' choice.
- Keep working on supporting and streamlining best practices on national licensing systems and improve the administrative process for investments in aquaculture.
- Work in international fora for achieving a fair level playing field for the EU seafood industry when competing with countries with less strict environmental, hygienic and social standards.
- Invest in research and innovation to de-risk economically, socially and environmentally sustainable aquaculture systems by addressing and managing main risks such as water pollution, animal health and welfare, access to space and high-quality water, etc.
- Connect with entrepreneurs to attract attention and investment and trigger growth in the seafood sector.
- Unlock the potential of algae as an effective, sustainable, unlimited and almost entirely untapped resource for bio-based processes and products, in particular for food and feed, and implement circularity in the processing and valorisation of marine and freshwater biomass.

5 RESEARCH AND INNOVATION NEEDS

The following priorities and related needs for research and innovation have been identified as meriting further consideration for achieving sustainable fisheries and aquaculture.

- Boost sustainable European aquaculture production. European aquaculture needs to increase its economic competitiveness while ensuring animal health and welfare. R&I should consider consumers' demand and concerns and ensure sustainability and resilience in a challenging context of climate change, greater competition for natural resources and conflicting interests for space and markets. Development of fish feeds where proteins and essential fatty acids are replaced by non-animal sources is key for the sustainability of the sector.

- Increase availability of aquatic biomass. R&I is needed to evaluate the impacts of increased harvesting at lower trophic levels, to unlock the potential of algae farming and to develop new technologies and methods for valorising aquaculture and fisheries production and waste streams.

- Improve biological knowledge and management tools for fisheries in order to maximise wild fish production sustainably, in line with the FAO technical guidelines for responsible fisheries and the principles of ecosystem-based management.

- Make space for European aquaculture by developing innovative tools to meaningfully implement the Maritime Spatial Planning Directive and ensure access to space and high quality water for sustainable aquaculture. Research is also needed in the field of environmental legislation to achieve a level-playing field in licencing that is often hindering the growth of European aquaculture.

- Develop monitoring programmes for threats to animal and human health, including plastics, harmful algae blooms and alien species, but also for climate change resilience, mitigation and adaptation. Ocean heatwaves, ocean acidification, changes in currents and biological and chemical parameters will influence aquaculture and fisheries. Risk assessment and mitigation must be part of the planning to ensure food security and safely.

- Reinforce capacity-building by training a competent and adaptable workforce that will be key to the future competitiveness of the sector. Intensified mobility between academia and industry, as well as the alignment of formal and informal training and capacity building programmes to current and future industry needs are vital in this respect. Building the necessary human capital in the complete aquaculture and fisheries value chains requires the ability to attract talented individuals with skills in a wide range of biological, technological economic and social science fields.

- Work on social and behavioural sciences to effectively engage with citizens and improve public perception for farmed seafood. Explaining and highlighting the high standards of the seafood industry is key to ensure 'social license' for the sector. Ocean literacy programmes and societal and market research to stimulate more openness of the industry towards society at large are needed.

- Include aquaculture and fisheries priorities within international research and innovation initiatives to trigger key synergies across the Atlantic Ocean, the Mediterranean Sea, the Baltic Sea and the Black Sea. Coordination of research efforts is needed to create a research community with a critical mass of excellent researchers to address issues of common interest.

6 SHOWCASING SOLUTIONS

Within Horizon 2020, approximately 250 projects have been supported representing an investment of around EUR 280 million. Some key projects include the following:

- **CryoPlankton2** – **Cryopreservation of marine planktonic** (2016-2018), SME, EUR 1.4 M. Cryopreservation of marine planktonic nauplii to be used as innovative and cost-effective live feed for fish juvenile in aquaculture. The SME Planktonic has succeeded in cryopreserving nauplii and to revive them as live individuals after thawing.

- **The Blue Growth Farm** – **Development and demonstration of an automated, modular and environmentally friendly multi-functional platform for open-sea farm installations** (2018-2021), IA, EUR 7.6 M. The aim of the Blue Growth Farm project is to produce advanced industrial knowledge with a fully integrated and efficient offshore multipurpose floating platform, which provides a central protected pool to host an automated aquaculture system, capable of producing high-quality fish, as well as large storage and deck areas to host a commercial 10 MW wind turbine and a number of wave-energy converters.

- **VIVALDI** – **Preventing and mitigating farmed bivalve diseases** (2016-2020), RIA, EUR 4.5 M. The overarching goal of VIVALDI is to increase the sustainability and competitiveness of the European shellfish industry by improving the understanding of bivalve diseases and by developing innovative solutions and tools for the prevention, control and mitigation of the major pathogens affecting the main European farmed shellfish species.

- **PANDORA** – **Paradigm for novel dynamic oceanic resource assessment** (2018-2022), RIA, EUR 6 M. The project aims at creating more realistic assessments and projections of changes in fisheries resources by utilising new biological knowledge including, for the first time, proprietary data sampled by pelagic fishers. Case-studies areas include the North Sea, the Bay of Biscay and the straits of Sicily.

- **ParaFishControl – Advanced Tools and Research Strategies for Parasite Control in European farmed fish** 2015-2020), RIA, EUR 8M. The goal of ParaFishControl is to increase the sustainability and competitiveness of European aquaculture by improving understanding of fish-parasite interactions and by developing innovative solutions and tools for the prevention, control and mitigation of the major parasites affecting Atlantic salmon, rainbow trout, common carp, European sea bass, gilthead sea bream and turbot.**PERFORMIFISH – Integrating Innovative Approaches for Competitive and Sustainable Performance across the Mediterranean Aquaculture Value Chain** (2017-2022), RIA, EUR 7M. This project aims to improve competitiveness of the Mediterranean aquaculture, focusing on optimisation of sea bass and sea bream production, including breeding, welfare and disease prevention issues.**SMARTFISH – Innovation for Sustainable Fisheries** (2018-2021), IA, EUR 7 M. This project aims to develop, test and promote a suite of high-tech systems for the EU fishing sector. The goal is to optimise resource efficiency, improve automatic data collection for fish-stock assessment, provide evidence of compliance with fishery regulations and reduce the ecological impact of the industry. Technologies tested include ICT and the Internet of Things (IoT), hydroacoustics and sonar technology, machine learning and artificial intelligence, remotely operated vehicles, machine vision and 3D camera technology, big data analysis and LED technology.

PATHWAY 4 – ALTERNATIVE PROTEINS AND DIETARY SHIFT

1 SYSTEMIC CHALLENGES

Changing and diversifying our dietary habits can be an effective way to tackle the issues of climate change and natural resource scarcity (e.g. land use), and help providing sufficient, nutritious, safe, accessible and affordable food to a fast-growing population.

CLIMATE AND OTHER ENVIRONMENTAL ISSUES

Facts and figures

The livestock sector produces 14.5 % of the global anthropogenic greenhouse gas (GHG) emissions: 41 % of the sector's emission comes from beef production, 20 % from cattle milk, 9 % from pig and 8 % from poultry. 45 % of the sector's emissions comes from feed production

and processing, 39 % from ruminants' enteric fermentation, and 10 % from manure storage and processing ([100]). 11.3 % of EU GHG emissions comes from food production ([101]). Globally, about one third of the land surface and three quarters of freshwater resources are used for crop or livestock production ([102]). Food production and consumption is one of the main drivers of biodiversity loss and changes in ecosystem services (e.g. land-use change). The nitrogen and phosphorus cycles, essential for plant growth, have radically changed due to industrial and agricultural processes (e.g. excessive use of fertilisers and pesticides leads to pollution of waterways and has negative impacts on soil productivity and fertility) ([103]). Some animal-based products, which are imported from outside the EU, do not always follow the same sustainability standards in terms of production as those defined in the EU. This can lead to important environmental issues such as deforestation and land-use change. Our current animal production system also puts increasing pressure on animal welfare.

Solution

The analysis of the Commission's Communication 'A Clean Planet for All' ([104]) has shown that a moderate decrease in animal-based calorific consumption, in line with the World Health Organisation (WHO) recommendations, can significantly reduce emissions from agricultural production. The Intergovernmental Panel on Climate Change (IPCC) reported that balanced diets (including plant- and animal-based food produced in a sustainable way) can contribute to climate-change adaptation and mitigation while also providing co-benefits for human health ([105]), and 'dietary shifts could contribute one fifth of the mitigation needed to hold warming below 2 °C' ([106]). EAT-Lancet ([107]) explains that improving production practices (-10 % of GHG emission) is less effective in abating food-related GHG emissions than shifting to healthier diets (-80 % of GHG emissions). Westhoek et al. (2014) ([108]) found that, if we consider that food production changes accordingly, 'halving the consumption of meat, dairy products and

([100]) Gerber, P.J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, et al. (2013), 'Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities', Food and Agriculture Organization of the United Nations (FAO), Rome.

([101]) European Commission (2019), 'Reflection Paper Towards a Sustainable Europe by 2030'.

([102]) Díaz, S., Settele, J., Brondízio, E.S., Ngo, H. T., Guèze, M., Agard, J., et al. (2019), *Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.*

([103]) EEA (2019), *The European environment – state and outlook 2020 Knowledge for transition to a sustainable Europe.*

([104]) European Commission (2018), 'In-depth analysis in support of the Commission Communication COM(2018) 773 – a clean planet for all – a European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy'.

([105]) IPCC (2019) 'Summary for policymakers', in *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems.*

([106]) de Coninck, H., Revi, A., Babiker, M., Bertoldi, P., Buckeridge, M., Cartwright, A. et al. (2018), 'Strengthening and implementing the global response', in *Global Warming of 1.5 °C. An IPCC Special Report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.*

([107]) Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S. (2019), *Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems.*

([108]) Westhoek, H., Lesschen, J. P., Rood, T., Wagner, S., De Marco, A., Murphy-Bokern, et al. (2014), 'Food choices, health and environment: effects of cutting Europe's meat and dairy intake', *Global Environmental Change 26*, pp. 196-205.

eggs in the EU would achieve a 40 % reduction in nitrogen emissions (…) and 23 % per capita less use of cropland for food production'. Both the Global Biodiversity Outlook report and the Scientific Advise Mechanism report on a sustainable food system ([109]) are calling for a transition to healthier and more sustainable diets, including a moderate consumption of red and processed meat and greater emphasis on plant-based foods. A flexitarian diet (less animal-based diets) and shifting diets toward quality products will also have positive impacts on animal welfare.

HEALTH ISSUES

Facts and figures

Excess red and processed meat consumption has significant negative effects on human health, especially in western diets. According to the WHO and the International Agency for Research on Cancer (IARC), the high accessibility and low price of processed animal protein food, as well as the large quantities consumed can lead to diet-related diseases, in particular non-communicable diseases (NCDs), such as cancer, cardiovascular diseases, obesity and diabetes. The IARC has classified processed meat as carcinogenic and red meat as probably carcinogenic to humans ([110]).

Solution

As further explained by Fit4Food2030, humans need to consume sufficient amounts of protein for muscle-mass maintenance and overall health. Many sources of proteins other than meat (e.g. alternative proteins) already exist within the current assortment of food products (e.g. plant-based products). Still, investing in identifying and introducing other alternative protein sources into the human diet (e.g. edible insects, cultured meat, fungi and microalgae) could deliver the needed protein dietary intake without the potential negative health effects associated with the consumption of red meat and processed meat foods. However, this entails health, societal and regulatory considerations. Alternative protein sources may be novel foods ([111]) in the EU thereby requiring a pre-market authorisation based on the assessment of any health risks that may be associated with their consumption by the European Food Safety Authority (EFSA). As such, there is a need for further research on the impact of diets with food products containing alternative proteins on human health ([112]). Dietary shifts have to be both environmentally (as explained above) and socially responsible. The production of alternative protein sources needs to be sustainable and healthy (quality over quantity, avoiding highly processed products).

([109]) European Commission. (2020), 'Towards a sustainable food system. Scientific Advice Mechanism', Group of Chief Scientific Advisors.

([110]) Bouvard, V., Loomis, D., Guyton, K.Z., Grosse, Y. El Ghissassi, F., Benbrahim-Tallaa, L., et al. (2015), 'Carcinogenicity of consumption of red and processed meat', *The Lancet Oncology*, Volume 16, Issue 16, pp. 1599-1600.

([111]) Regulation (EU) 2015/2283 on novel foods.

([112]) Wepner, B., Giesecke, S., Kienegger, M., Schartinger, D., Wegner, P. (2018), 'Report on baseline and description of identified trends, drivers and barriers of EU food system and R&I – Description of Trends', Fit4Food2030. Attachment 6.5 to Deliverable 2.1. WP 2.

SOCIETAL AND POLITICAL CHALLENGE

Facts and figures

Diet is a deeply engraved societal and cultural attitude that is difficult to change despite the potential benefits for human health and the environment. Consumers may be unsure about what 'alternative proteins' mean, whether these products are safe and healthy (trust issues), and how they are regulated. They also expect these products to be tasty. To consumers, healthy food products mean clear labels, with few and understandable ingredients. Healthy and sustainable diets and food choices need to have affordable prices for all (still high for some sources of alternative proteins), so that no citizen is left behind. Shifting demand will unavoidably be a challenge for some businesses, who need to be supported in the transition to new business opportunities and jobs.

Solution

The IPCC suggests a combination of behaviour-oriented pricing policies such as combining supply-side measures with value-driven communication, and better financing options and instruments ([113]). Since the main drivers of total meat consumption per capita are the income per capita, availability and the rate of urbanisation, as well as other factors that are also difficult to influence through direct policy intervention, Milford et al. (2019) ([114]) suggest to indirectly target consumers' preferences and consumption habits (e.g. information, education and availability of ready-made plant-based products). The JRC showed that the ability of dietary shifts towards less animal-based food to reduce the environmental impact of food consumption depends on the European citizens' willingness to change their diet, which relies on consumer understanding, prices, food purchasing habits, product availability, perceived personal benefit, and policies ([115]). Consumers' choices thus depend on the food environment that ensures the availability and access to food. This environment, which makes the link between food supply and diets, is one of the determinants of consumers' choices and food production, and consumers can also influence and shape it.

([113]) de Coninck, H., Revi, A., Babiker, M., Bertoldi, P., Buckeridge, M., Cartwright, A., et al. (2018), 'Strengthening and Implementing the Global Response', in *Global Warming of 1.5 °C. An IPCC Special Report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.*

([114]) Milford, A.B., Le Mouel, C., Bodirsky, B.L. & Rolinski, S. (2019), 'Drivers of meat consumption', *Appetite 141* (2019) 104313.

([115]) Castellani, V., Fusi, A., & Sala, S. (2017), *Consumer Footprint. Basket of Products indicator on Food, EUR 28764 EN*, Publications Office of the European Union, Luxembourg, ISBN 978-92-7973194-5.

RELEVANT EU POLICIES

- The European Green Deal (Farm to Fork, Biodiversity strategies)
- Common agricultural policy (CAP) and Common Fisheries Policy (CFP)
- EU Regulation on novel foods
- Report on the development of plant proteins in the EU
- White Paper 'A Strategy for Europe on nutrition, overweight and obesity related health issues'
- Updated Bioeconomy strategy
- Our life insurance, our natural capital: an EU biodiversity strategy to 2020
- Towards a sustainable Europe by 2030
- Communication 'A clean planet for all'

2 CO-BENEFITS

The Pathway 'Alternative proteins and dietary shift' would provide co-benefits to all four of the Food 2030 priorities, as described below.

 NUTRITION	 CLIMATE	 CIRCULARITY	 COMMUNITIES
+++	+++	++	+++

NUTRITION AND HEALTH

- Reducing diet-related mortality and NCDs (depending on the dietary shift).
- Diversification of the offer in proteins.
- Place-based dietary shift to meet diverse and specific needs.

CLIMATE AND SUSTAINABILITY

- Reducing GHG emissions and biodiversity loss.
- Better air and water quality (e.g. less nutrient and pesticide losses).
- Decreasing dependence on imports and less deforestation

CIRCULARITY AND RESOURCE EFFICIENCY

- Better Consumer Footprint.
- Savings in energy, land and water (depending on the dietary shift).

INNOVATION AND COMMUNITIES

- Triggering innovation, new jobs, business models and value-added products, goods and services.
- Meeting the needs, values and expectations of society in a responsible and ethical way.
- Increasing farmers' resilience and image (e.g. focus on quality, improving animal welfare).

RELEVANT SDGS

3 BARRIERS AND LOCK-INS

- *Disruption of major economic sectors:* food, feed, and livestock sectors.
- *Difficult scaling up of the development of plant-based and other alternative protein production:* lower volumes could lead to higher production costs, insufficient breeding resources in minor crops, non-negligible upfront investments in equipment and machinery both for farms and supply chains.

- *Non-negligible share of public finance and some agricultural subsidies directed towards unsustainable and unhealthy foods*.

- *Regulatory issues*: authorisation procedures (e.g. for novel food) can take a long time and can be viewed as burdensome (administrative burden) especially for SMEs; legal text can be quite complex or difficult to interpret and apply, it can be costly to comply with new regulatory requirements.

- *Confusion and misunderstandings regarding the provision of data and communication* on the health benefits of alternative proteins (to consumers and medical class); lack of clear labelling guidelines.

- *Difficulty to make consumers change their preferences and demand*, which are often based on their culture, education, social norms and the public-health sector.

- *Alternative proteins are not always cost-competitive with meat* (true cost of proteins not reflected in current prices, so externalities are not accounted for); interest in supporting alternative proteins might stop if their prices are too high for consumers.

- *Lack of political commitment*: lock-in by current animal-based industries among other things (e.g. trade agreements), lack of effective policy interventions to achieve large-scale dietary shifts, lack of alignment of agricultural, public health, trade and environmental policies.

- *Lack of research* on reasons for a positive consumer response to specific regulations or dietary shift, and on big data analysis, artificial intelligence and social science to understand consumer trends, close information gaps on nutrition, test innovations that could influence consumer demand.

4 ENABLERS OF CHANGE

- *New job opportunities*: guaranteeing a sufficient income for producers (farmers and fishermen), public support needed to accompany workers in the transition, including enhanced access to information and production factors.

- *More direct and indirect subsidies and differentiating tax regimes* for the provision of sustainable proteins, supporting production techniques that are using less land, chemicals and energy inputs with important environmental benefits.

- *More research and communication* to consumers on the benefits of alternative proteins for the environment, climate, land use, resources, animal welfare and human health, to help them make an informed choice.

- *Increased willingness among consumers/citizens to change their diets* (alternative proteins products need to be tasty and visually appealing) and realise significant co-benefits for climate change mitigation and other sustainability issues, human health, animal welfare and broader ethical concerns.

- *Raising awareness* through education, media campaigns and/or food guidelines for all actors of the food system.

- *Recent political commitment to a positive change:* Green Deal and the Farm to Fork strategy, where it is clearly stated that 'A key area of research will relate to (...) increasing the availability and source of alternative proteins such as plant, microbial, marine and insect-based proteins and meat substitutes' and 'the transition [to sustainable food systems] will not happen without a shift in people's diets'.

- *Highlighting the importance of the food environment and private sector* (e.g. food industry): public-private partnership, better regulations and right incentives can provide benefits to the private sector.

5 RESEARCH AND INNOVATION NEEDS

1. ON THE IMPACT OF ALTERNATIVE PROTEINS AND DIETARY SHIFTS ON THE ENVIRONMENT AND HEALTH

- **Research** on **the impact of the alternative protein production and dietary shifts overall on natural resources and climate**. The alternative proteins to be considered are (both old and new sources): plant-based proteins, microbial-based proteins, marine-based proteins, insect-based proteins, meat and fish meat alternatives (animal stem cells from living animals for cultured meat and fish meat), synthetic proteins from CO_2 or other chemical sources.

- **Research** on **the impact of climate change and resource scarcity on alternative proteins' production**.

- **Research** on the **nutritional quality** (e.g. **bio-availability**) of protein sources, and on the **impact of the alternative proteins and dietary shifts overall on health** (e.g. possible allergies) and **food safety** (e.g. no toxic aggregates or excessive amount of toxic compounds).

- Based on the above, a **comparative life-cycle analysis** of conventional and alternative protein sources needs to be developed. This would include a global dimension and could

lead to new PEF-based categories (Product Environmental Footprint) and diet assessment frameworks for health impacts.

- These R&I activities will also highlight the need for '**future proof' new technologies** to anticipate potential resource availability and pollution issues.

2. ON THE FOOD ENVIRONMENT

- **Research on ways to develop healthier and more sustainable food environments that can also tackle future disruptions in supply chains** (e.g. in case of pandemics)**.** Actors of the food environment (e.g. industry, processors, retailers, food services, cooks, caterers, etc.) have a key role to play. Research is needed to get an easier access to sustainable and healthy diets (as defined in national dietary recommendations) everywhere (rural and urban areas).

- **Research on** improving the **processing of alternative proteins** (including in terms of costs), which includes sophisticated biotechnology routes providing nutritional and sensory food quality as well as environmental sustainability.

- Based on the above, an **analysis** of different tools and instruments (e.g. policy measures, incentives, new marketing approaches, pricing policies, etc.) on alternative proteins provision needs to be developed to find the best way to stimulate and support actors of the food environment for the production and provision of alternative proteins.

3. ON CONSUMPTION HABITS AND DIETARY SHIFT

- **Research** activities to **understand and monitor dietary choices**, as well as their **drivers and barriers**, the consumer demand and **how to engage in behavioural transition** (which includes the acceptance of innovative foods/diets and depends on parameters such as age, sex, culture, etc.).

- **Research** on **how dietary shifts can be realised**.

- **Research** on the **needs of societal and population groups** as well as their resources to access and utilise alternative protein sources.

- Based on the above, we need to shape the 'new normal', leaving no one behind (fairness for producers and all consumer groups, vibrant rural areas). A **comparative analysis** of different tools (e.g. policy/regulatory measures, new business models, communications strategies, etc.) that have the potential to remove the barriers and enhance the drivers of

change, and then increase alternative protein consumption, is also needed (viable policy options of what societies can accept and what is necessary to preserve planetary resources).

4. ON HORIZONTAL ISSUES

- **Strengthen education and access to information (e.g. labelling) on food systems and diets.**
- **Review regulatory standards** for alternative proteins (consumer trust).
- **Improve and increase the production and availability of different alternative protein sources** (markets, impact on small farms, etc.), including through technological development.
- **Develop a platform** for the **collection and collation of food consumption data**: new methods for the collection of national food consumption data to support a pan-European dietary survey, to contribute to the assessment of the European citizens' dietary habits and the creation of a **dietary data hub**.

6 SHOWCASING SOLUTIONS

Within Horizon 2020, approximately 15 projects have been supported representing an investment of around EUR 70 million ([116]). Some key projects include:

- **Protein2Food (2015-2020), RIA, EUR 8.8 M**

  Development of high-quality food protein through sustainable production and processing. The project will create innovative protein-rich food crops, to sustain human health, the environment, and biodiversity.

- **SUSFOOD2 (2017-2021), ERA-NET-Cofund, EUR 4.7 M.**

  The ERA-Net Cofund on Sustainable Food production and consumption focuses on sustainability in post-harvest food production, covering relevant fields such as natural sciences, food engineering, social sciences.

- **TRUE (2017-2021), RIA, EUR 5 M.**

([116]) Some projects focused specifically on alternative sources of proteins, other focused, among other things, on dietary shift.

The project is a balanced practice-research partnership of 24 institutions, which aims to identify the best routes, or 'transition paths' to increase sustainable legume cultivation and consumption across Europe.

- **NEXTGENPROTEINS (2019-2023), IA, EUR 7.9 M.**

  Bioconversion of underutilised resources into next-generation proteins for food and feed. The project will address key barriers that limit the use of microalgae, single cell protein and insects in food/feed. It will, among other things, find means to improve consumers' acceptability and trust.

- **SUSINCHAIN (2019-2023), IA, EUR 7.9 M.**

  Sustainable Insect Chain. The project contributes to novel protein provision for feed/food in Europe by overcoming the barriers to increasing the economic viability of the insect value chain and opening markets.

- **PROFUTURE (2019-2023), IA, EUR 7.7 M.**

  Microalgae protein ingredients for the food and feed of the future. The project focuses on the market uptake of innovative, healthy and sustainable food/feed products with protein-rich microalgae ingredients.

- **SMART PROTEIN (2020-2023), IA, EUR 8.1 M.**

  The project aims to industrially validate and demonstrate innovative, cost-effective and resource-efficient, EU-produced, nutritious plant and microbial biomass proteins from edible fungi by up-cycling side streams from pasta residues, bread crust and beer industries.

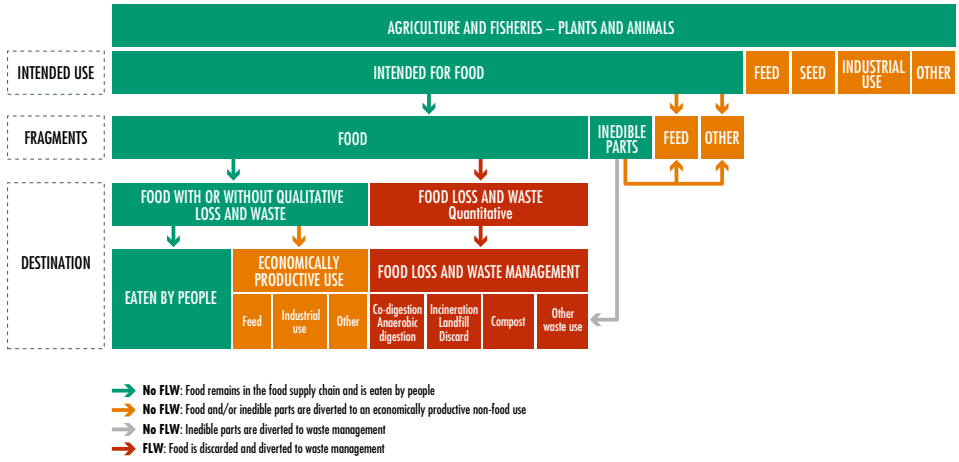
PATHWAY 5 – FOOD WASTE AND RESOURCE EFFICIENCY

1 SYSTEMIC CHALLENGES

Food intended for human consumption that is eventually lost or wasted represents a complex challenge, as its reduction requires change of established business practices and citizens' habits. Furthermore, until recently, there was no commonly agreed definition of food losses and waste, nor harmonised measuring methods, which has always made it difficult to develop targeted strategies. The situation is slowly improving after the revision of the EC Waste Framework Directive adopted in May 2018, introducing a 'food waste' definition based on the definition of 'food' from the General Food Law and of 'waste' from the Waste Directive. The Directive also obliges Member States to prepare national food waste prevention programmes, monitor and report on food waste according to a common EU methodology contained in the Delegated Decision (Commission Delegated Decision (EU) 2019/1597), which entered into force in October 2019.

The Food and Agriculture Organization of the United Nations (FAO), that has been advocating on the theme since 2011, has also been working towards the harmonisation of the concept and has **defined food loss and food waste** as, respectively: '*the decrease in the quantity or quality of food resulting from decisions and actions by food suppliers in the chain, excluding retail, food service providers and consumers',* and '*the decrease in the quantity or quality of food resulting decisions and actions by retailer, food services and consumers*' ([117]). In other words, and as shown in the figure 7 ([118]), food losses are considered as occurring along the food supply chain (FSC) from harvest/ slaughter/catch-up to, but not including, the retail level; food waste, instead, occurs at retail and consumption level. In particular, food diverted to other economic uses (e.g. for animal feed), or inedible parts are not considered food losses or waste (FLW).

Figure 7. A conceptual framework for food loss and waste (FLW).



Source: Food and Agriculture Organization of the United Nations, 2019, The State of food and agriculture, http://www.fao.org/state-of-food-agriculture/en/. Reproduced with permission.

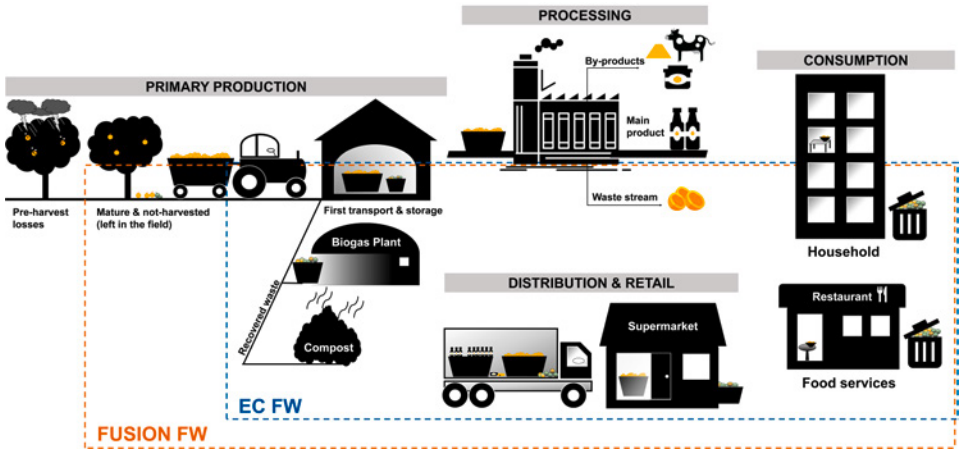
According to the EU legislation, instead, food waste covers all stages of FSC from farm to fork (except for the crops ploughed in/not harvested), while food loss is not defined at all. The FUSIONS' ([119]) framework is almost completely in line with such definition, as shown in the following figure.

([117]) FAO (2019), 'The state of food and agriculture'.

([118]) FAO (2019), 'The state of food and agriculture'.

[119] () FUSIONS (Food Use for Social Innovation by Optimising Waste Prevention Strategies) was a project on the estimation of food waste generation in the EU (https://www.eu-fusions.org/), implemented in 2007-2012 with financial support by the EU's Research and Innovation 7th Framework Programme.

Figure 8. Boundaries of food waste (FW) definitions ([120]).



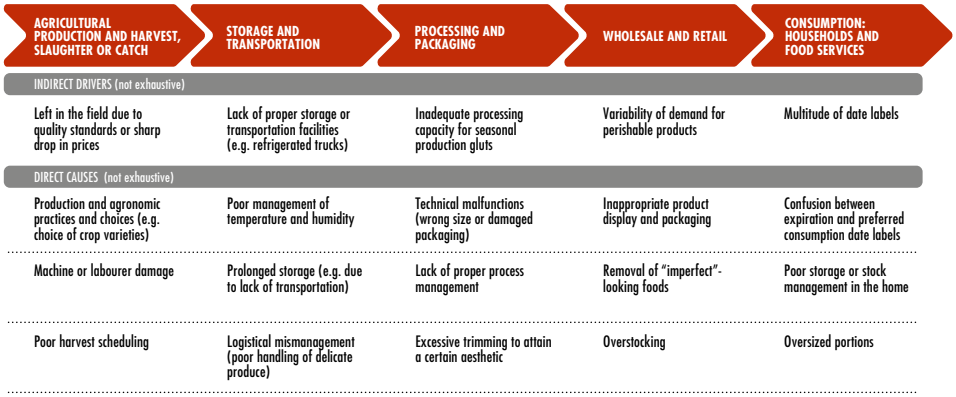
Besides working on the harmonisation of the definition of the two concepts, the FAO and the United Nations Environment Program (UNEP) have been working on developing two separate indexes to measure them: the **Food Loss Index** (FLI) and the **Food Waste Index** (FWI). While the latter is still in the process of being finalised, the former estimates that around 14 % of food produced is lost from post-harvest up to, but not including, the retail level ([121]). This new estimate is more precise than the previous one dating back to 2011, according to which approximately one third of all food produced in the world in 2009 was lost or wasted ([122]) along the whole FSC from farm to fork. In fact, while having global estimates it is important to raise awareness, do advocacy and monitor progress towards the accomplishment of the SDG 12 (target 12.3), specific information on the variability of FLW across different contexts, different stages of the FSC and different causes is needed in order to draw up effective interventions ([123]).

Meanwhile, the EU funded project 'FUSIONS' estimated that in the EU, around 88 million tonnes of food waste are generated annually, corresponding to 20% of the food produced.

Food waste is a systemic challenge because it occurs **all along the FSC,** varying across different stages, regions and commodities. Furthermore, the causes themselves differ widely along the FSC and could be **direct** – associated with actions of actors of the FSC – or **indirect** – as related to the economic, cultural and political environment of the food system under which the actors operate and by which they are influenced ([124]).

([120]) FUSIONS (2014) and EC (2018), in EC Knowledge Centre for Bioeconomy, 2020
([121]) FAO (2019), 'The state of food and agriculture'.
([122]) FAO (2012), 'Global food losses and food waste – extent, causes and prevention'.
([123]) FAO (2019), 'The state of food and agriculture'.
([124]) FAO (2019), 'The state of food and agriculture'.

Figure 9. FAO, Potential direct causes and indirect drivers of food loss and waste, 2019.



Source: Food and Agriculture Organization of the United Nations, 2019, The State of food and agriculture, http://www.fao.org/state-of-food-agriculture/en/. Reproduced with permission

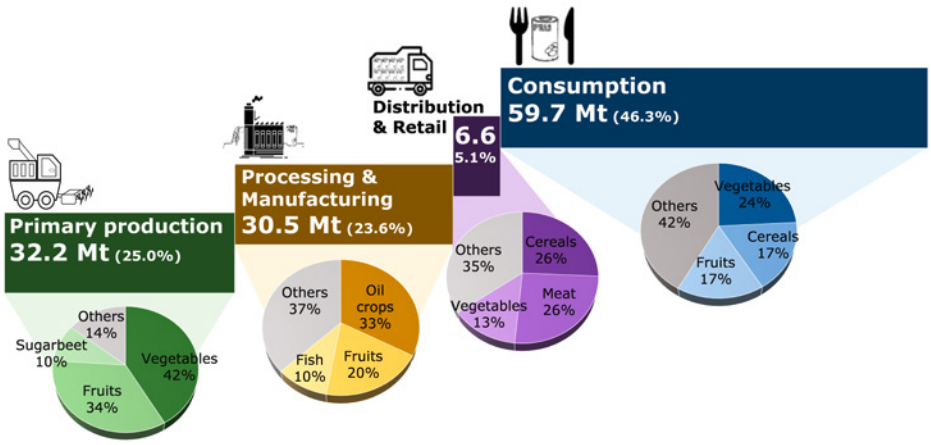
The EU-funded project REFRESH identified the **three main groups of drivers** for food waste at each stage of the FSC for certain categories of products:

- product specific (specific to the selected food products at a particular stage of the supply chain);
- generic (concerning two or more selected products, e.g. labelling errors or limited shelf life);
- systemic (inter-linked drivers concerning more than one step of the supply chain, e.g. minimum orders or last minute cancellation, often due to lack of cooperation and/or power imbalances) ([125]).

The consumption stage is the main responsible for food waste generation, counting for 46% of the total, followed by primary production (25%) and processing and manufacturing (24%). The distribution and retail stages, instead, only account for 5% of the food waste generated along the entire supply chain ([126]) (see Figure 10).

([125]) REFRESH H2020 Project 'Final results' 2020.
([126]) The European Commission's Knowledge Centre for Bioeconomy, "Brief on food waste in the European Union", 2020

Figure 10. Amount of food waste (in fresh weight) generated during the different stages of the food supply 14 chain (bars) and break down by main food groups (pie charts) ([127]).



In low-income countries food losses and food waste occur mainly at early stages of the FSC and can be related to financial, managerial and technical constraints in harvesting techniques as well as limited storage and cooling facilities. In medium- and **high-income countries**, food is wasted or lost mainly at later stages in the supply chain (i.e. particularly at consumption level, both in households and food services). Here, the behaviour of consumers, whose contribution accounts for 53 % ([128]), and the lack of coordination between actors in the supply chain, play a key role.

Food loss and waste have **negative impacts on the society, the environment and the economy.**

FLW is a **societal paradox** because it contributes to food insecurity and hinders nutrition – in a world where one in nine people are undernourished ([129]).

It has been estimated that the food currently wasted in Europe could feed 200 million people ([130]).

FLW is an **environmental** problem because food production is resource-intensive, especially considering that, without change in dietary habits and reduction of food waste, the expected growing population and incomes will lead to an increase in demand of agricultural products of 50 % by 2050. The environmental impact of FLW, which ultimately affects biodiversity, can be quantified considering a number of metrics (e.g. climate change, eutrophication, acidification,

([127]) Caldeira et al., 2019, in EC's Knowledge Centre for Bioeconomy, 2020
([128]) Stenmark et al. (2016), in 'REFRESH Policy brief: reducing consumer food waste', 2019.
([129]) World Food Programme (2016), Hunger Statistics.
([130]) FAO (2012), Global food losses and food waste – extent, causes and prevention.

pressure on land) by using Life-Cycle Assessment (LCA). To communicate the impacts of FLW, three footprint are often used ([131]):

- carbon footprint: GHG emissions. Food that is harvested but ultimately lost or wasted generates about 8 % of global greenhouse gas emissions annually ([132]). In Europe, the production and disposal of food waste leads to the emission of 170 million tonnes of CO_2 and consumes 26 million tonnes of resources ([133]), accounting for 6 % of the EU GHGs emissions ([134]). To give a visual example, if food waste were a country, it would be the third-largest emitter of greenhouse gases (GHGs) in the world ([135]);

- land footprint: the pressure on land; food that is harvested but ultimately lost or wasted requires a cropland area greater than the size of China ([136]);

- water footprint: the pressure on water; food that is harvested but ultimately lost or wasted consumes about one quarter of all water used by agriculture each year ([137]).

Finally, FLW is an economic problem because such inefficiency has a negative effect on consumer incomes ([138]) and results in roughly EUR 870 billion in **economic losses** globally per year ([139]) and EUR 143 billion ([140]) in costs within the EU.

Another challenge, directly related to food waste but also to food in general, is how to decrease the amount of **packaging** that is eventually discarded with – or without – the food. There are several trade-offs in this regard, because on the one hand plastic (the most common packaging material) helps reduce food waste by increasing the product shelf-life and ensuring its physical integrity during transportation, while on the other hand, and especially with regards to 'disposable' single-use plastic, it harms health and livelihood and irreversibly pollutes the environment ([141]); by 2050 the oceans could contain more plastic than fish by weight ([142]).The issue of FLW is thus multi-faceted and will need coordinated action from diverse sectors such as academia, SMEs, industry, civil society, and from diverse fields like R&I, education, and social sciences.

([131]) FAO (2019), 'The state of food and agriculture'.
([132]) FAO (2015), 'Food wastage footprint and climate change', Rome: UN FAO.
([133]) EP Press (2017), http://www.europarl.europa.eu/news/en/press-room/20170509IPR73930/cutting-food-waste
([134]) EU-funded H2020 project 'FUSIONS.
([135]) World Economic Forum (2017) Project MainStream – Urban Byocycles, in collaboration with the Ellen MacArthur Foundation
([136]) CAIT (2015), 'Climate Data Explorer', World Resources Institute https://www.wri.org/blog/2015/12/whats-food-loss-and-waste-got-do-climate-change-lot-actually
([137]) FAO (Food and Agriculture Organization of the United Nations) (2013), 'Food wastage footprint: impacts on natural resources', Rome: UN FAO.
([138]) BCFN (2018), 'Fixing food'.
([139]) World Resources Institute (2017), *The business case for reducing food loss and waste.*
([140]) EU-funded H2020 project FUSION, 2016.
([141]) Tearfund (2019), *No time to waste. Tackling the plastic pollution crisis before it is too late.*
([142]) Smet, M. et al. (2020), in 'Science for Environment Policy': European Commission DG Environment News Alert Service, edited by SCU, The University of the West of England, Bristol.

FOOD WASTE AND EU POLICIES

Food waste is linked with many existing EU policies:

- Fisheries
- Industrial Policy and internal market
- Taxation
- Economic and monetary policy and free movement of capital
- Environment, consumers and health protection
- Common Agricultural Policy

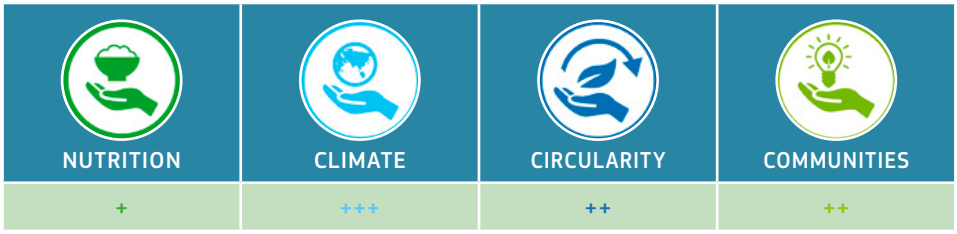
In 2016, DG SANTE established a Platform dedicated to food waste prevention upon the Communication on the Circular Economy call to support achievement of the SDG 12.3 target on food waste and maximise the contribution of all actors. The *EU Platform on Food Losses and Food Waste* (FLW) brings together EU institutions, experts from EU countries and relevant stakeholders selected through an open call for applications. It aims to support all actors in defining measures needed to prevent food waste, sharing best practice, and evaluating progress made over time.

Furthermore, in May 2020 the EU Commission launched the Farm to Fork strategy, where the need to take action to curb food waste is constantly stressed ([143]).

([143]) EC Farm to Fork strategy, 2020.

2 CO-BENEFITS

Reducing food loss and waste will have an impact on all of the four Food 2030 priorities, as illustrated below.



NUTRITION AND HEALTH

The recovery and redistribution of surplus food that would otherwise be wasted has an important social dimension ([144]).

- **Food security:** if we consider absolute values, recent modelling found that reducing FLW would close the gap between the amount of food needed to adequately feed the planet in 2050 and the amount of food available in 2010 by more than 20 % (see Figure 11) ([145]).

Meanwhile, it has been demonstrated that some specific measures such as food recovery and redistribution programmes have the potential to increase access to fresh food for the most vulnerable members of society and thus contributing to guarantee the 'right to food' ([146]), even if only as a 'safety net'.

([144]) EC Farm to Fork strategy, 2020.
([145]) WRI (2019), 'Reducing Food Loss And Waste. Ten interventions to scale impact'.
([146]) FAO (2019), 'The state of food and agriculture'.

Figure 11. Reducing Food Loss and Waste Can Play an Important Role in Closing the Food Gap between 2010 and 2050 without Expanding Cultivated Area.

Source: World Resource Institute, 2019, Reducing Food Loss and Waste. Ten interventions to scale impact, https://www.wri.org/publication/reducing-food-loss-and-waste-ten-interventions-scale-impact Reproduced with permission.

CLIMATE AND SUSTAINABILITY

Reduction in food waste is among the most impactful measures to reduce emissions ([147]).

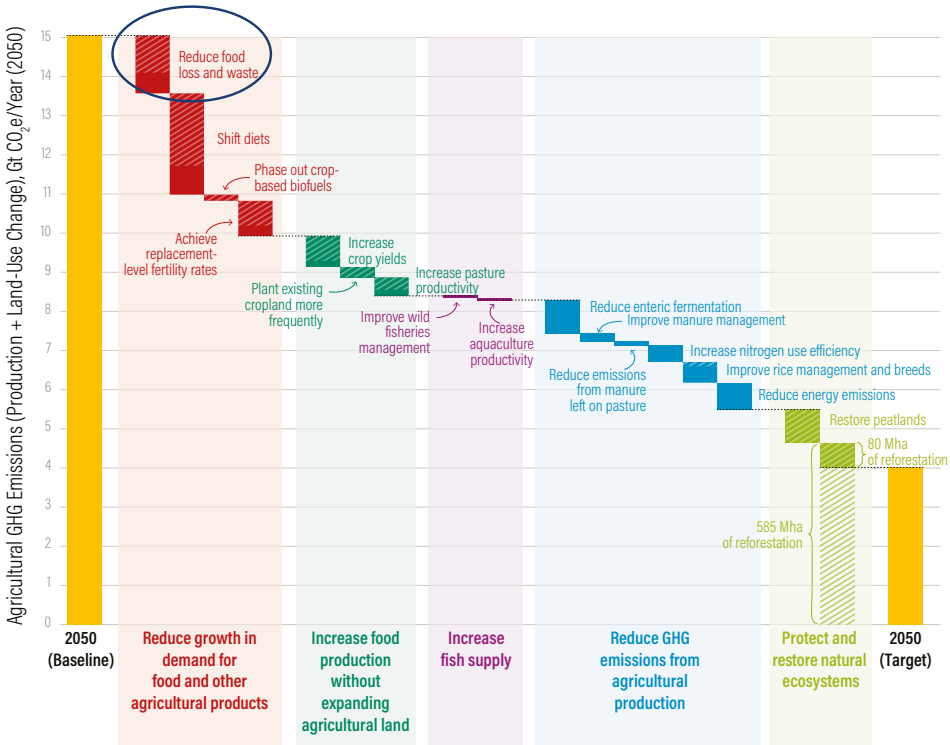
In particular, tackling food loss and waste can:

- Reduce the pressure on **land and water** ([148])
- **Mitigate** ([149])([150]) climate change
- Improve climate change **adaptation** strategies ([151])

([147]) McKinsey & Company (2020), 'Agriculture and climate change'.
([148]) FAO (2019), 'The state of food and agriculture'.
([149]) Project Drawdown
([150]) WRI (2019), 'Reducing food loss and waste. Ten interventions to scale impact'.
([151]) Drawdown project

Modelling found that a 50 % reduction in the rate of food loss and waste would reduce the food system's projected business-as-usual GHG emissions in 2050 by 10-14 % (see Figure 12) ([152]), while a more recent study suggests that the reduction of food loss and waste to under 30 percent by 2030 and 20 percent by 2050 would result in a reduction of overall emissions from food waste by about 40 percent globally ([153]).

Figure 12. Reducing Food Loss and Waste Could Eliminate ~1.5 Gt of the Projected 15 Gt of Greenhouse Gas Emissions from Agriculture and Land Use in 2050 (CO2 Equivalent).



Source: World Resource Institute, 2019, Reducing Food Loss and Waste. Ten interventions to scale impact, https://www.wri.org/publication/reducing-food-loss-and-waste-ten-interventions-scale-impact Reproduced with permission.

([152]) WRI (2019), 'Reducing food loss and waste. Ten interventions to scale impact'.
([153]) McKinsey & Company (2020), 'Agriculture and climate change'.

The redesign of FSCs and the introduction of sustainable technologies and improved retail models, which are needed to reduce food losses and waste, may also make food systems more energy-efficient and indirectly reduce emissions. **More efficient food systems** also recycle resources more effectively and require less transport and storage ([154]) (which also reduces risk of food being bruising and eventually discarded) ([155]).

CIRCULARITY AND RESOURCE EFFICIENCY

- Food **redistributed** to people in need
- Food surplus **valorised** (i.e. reused and recycled; this will be dealt with by a specific pathway, beyond this document)

INNOVATION AND COMMUNITIES

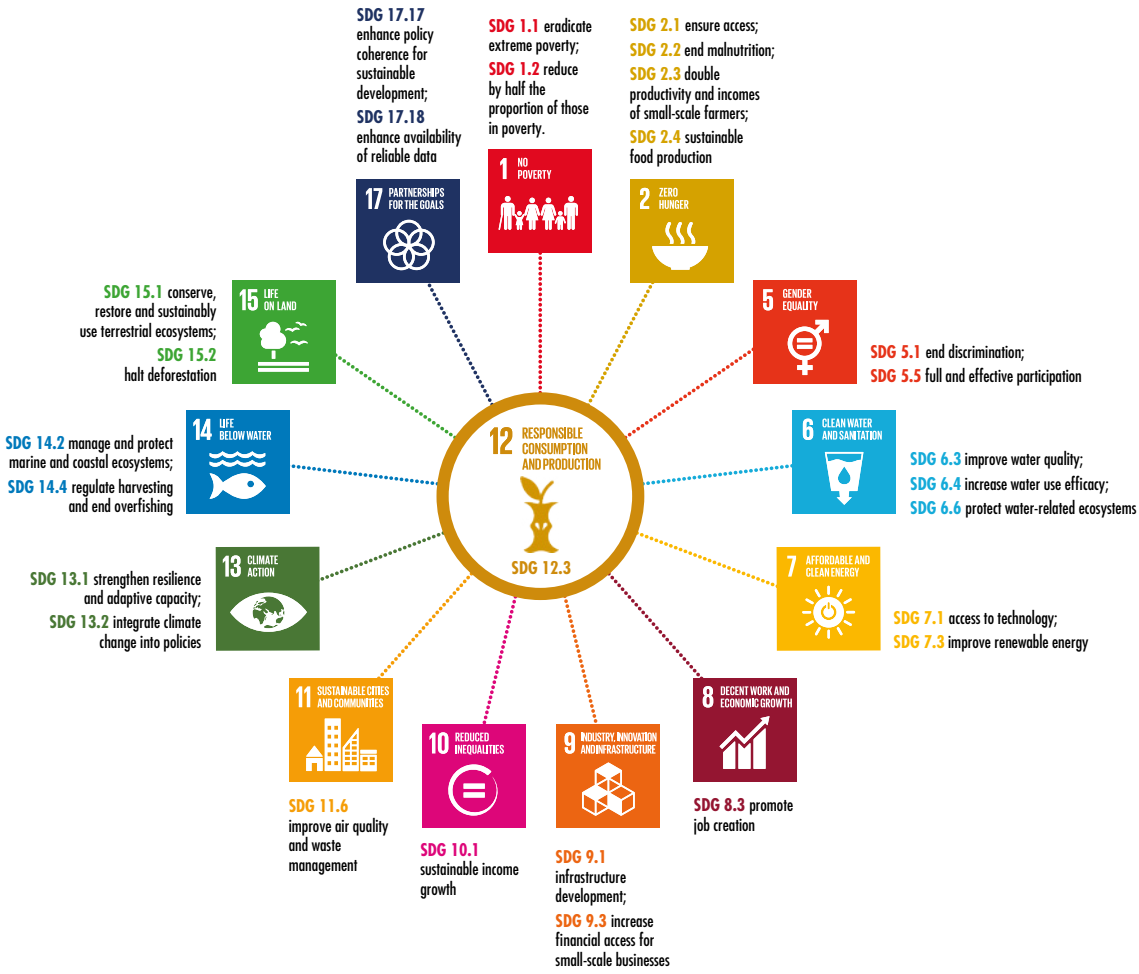
- Reduced **food poverty**
- Improved **social innovation**

RELEVANT SDGS

Reducing FLW is enshrined in one of the specific targets of SDG 12, because it has been prioritised as a means towards inclusive and sustainable food systems. At the same time, progress on the other SDGs could have positive impact on reducing FLW, as shown in the figure below.

([154]) FAO (2017), The future of food and agriculture. Trends and challenges.
([155]) Drawdown project

Figure 13 – Food loss and waste and the SDGs. FAO, 'The state of food and agriculture', 2019.



Source: Food and Agriculture Organization of the United Nations, 2019, The State of food and agriculture, http://www.fao.org/state-of-food-agriculture/en/. Reproduced with permission.

3 BARRIERS AND LOCK-INS

A number of factors may prevent actors to take actions to fight FLW:

LACK OF DATA:

- As already mentioned, a robust estimate of FLW at European and global level is currently not available.

- Food operators and consumers do not have adequate information on how much they waste, nor on the possible options to reduce FLW ([156]).

- Existing estimations partly lack important information for the accomplishment of specific FW interventions and policies ([157]). Information is missing also on the effects of tailored innovations aiming at prevention and reduction of food waste, since they are usually not large-scaled but have more of the local character ([158]).

In fact, despite the fact that many interventions have already taken place, both bottom-up and top-down, very few of the studies concerned are evaluating the impact of such interventions and, if assessment methodologies do exist, they are often not comparable ([159]).

The lack of data is directly linked to the challenge of data collection: divergent methods, self-reporting which usually underestimate the problem, costly and time-consuming measurements represent some of the constraints. Moreover, monitoring consumer waste, among others, is particularly challenging for two main reasons: on the one side, consumers often underestimate the amount of food they actually waste; on the other, municipal waste measured usually includes both food and non-food waste.

- **Lack of access to credit**:

  Lack of access to credit is a problem which mainly concerns low-income countries, where food operators may lack financial help to implement possible solutions to prevent FLW ([160]).

([156]) FAO, 'The state of food and agriculture', 2019.
([157]) S. Corrado, S. Sala (2018), '*Food waste accounting along global and European food supply chains: State of the art and outlook*', Elsevier.
([158]) REFRESH H2020 Project (2019), 'D4.5 Behavioural economics assessing food waste innovations diffusion through ABM models – insights from Italy and the Netherlands'.
([159]) REFRESH H2020 Policy brief: reducing consumer food waste, 2019.
([160]) FAO (2019), 'The state of food and agriculture'.

- **Lack of willingness of actors to adopt innovations:**

  This barrier is influenced by a number of factors, which are not only of a strictly economic nature. For instance, the presence of strong connections among retailers and, to a lesser extent, a high level of awareness about the existence of food waste reducing innovations among consumers have a prominent role in the retailers' decisions to adopt food waste reduction innovations ([161]).

- **Trade-off considerations:**

- Food safety considerations

  Especially in the case of redistribution of surplus food, retailers do not want to take the associated responsibility of guaranteeing the safety of such products. In order to cope with this issue, Italy was the first country to pass a law removing, among others, health and safety regulations restricting the donation of food that is marginally beyond the sell-by date ([162]). As part of the Circular Economy Action Plan, in October 2017 the Commission adopted EU food donation guidelines in order to facilitate the recovery and redistribution of safe, edible food to those in need ([163]).

- Food waste can also be used as a raw material for the bio-based industry.

4 ENABLERS OF CHANGE

EU STRATEGIES AND GUIDELINES

- An integrated food policy and food systems approach ([164]) where food waste is one of the priority areas for EU action. It can be expected that food waste prevention will remain an important part of the planned Farm to Fork strategy. Moreover, by 2023, the Commission will consider establishing a Union-wide target for Member States for food waste reduction.

- Guidelines on redistribution of surplus food (DG SANTE).

- Improving the understanding of date marking and labelling on food packaging. The choice between 'use by' and 'best before' needs to be appropriate and the suitable storage

([161]) REFRESH H2020 Project (2019), 'D4.5 Behavioural economics assessing food waste innovations diffusion through ABM models – insights from Italy and the Netherlands'.
([162]) https://www.bbc.com/news/world-europe-36965671
([163]) https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=OJ:C:2017:361:FULL&from=EN
([164]) REFRESH H2020 Project 'Final results' 2020.

information could prevent food from becoming waste. The FLW platform has set up a sub-group dedicated to this issue.

NATIONAL STRATEGIES

- National strategies for preventing and reducing food loss and waste which are aligned, in term of objectives, with policies from different domains, so to guarantee policy coherence.
- Scaling up food loss and waste prevention action in the FSC ([165]).

BETTER DATA AND MONITORING SYSTEMS

- Improve availability and quality of data on food loss and waste levels and their related impacts (e.g. develop voluntary agreements in which businesses are asked to communicate their food waste and by-products generation, as in the Courtauld Commitment ([166])).
- Improve action design, monitoring, evaluation and knowledge sharing regarding food waste prevention interventions.

EDUCATION AND AWARENESS

- Integrate food loss and waste reduction in school education and professional training, both in the public and private sectors. Promoting the value of food and working to shift social norms so that wasting food is no longer acceptable.
- Strengthen capacity for innovation, promoting circularity and new market opportunities.

ECONOMIC INCENTIVES

- Incentivising food waste prevention through taxes and subsidies or regulations, so that it is more economically viable than treatment as waste. For instance, in some Member States, the implementation of corporate tax credits has been successful in promoting the donation of surplus food from food business operators to charities. Integration of food waste prevention in public procurement specifications is also an effective means of scaling up actions to prevent food waste in contract catering for schools and hospitals ([167]).

([165]) EU Platform on Food Losses and Food Waste, Draft key recommendations for action to prevent and reduce food waste, 2019.
([166]) http://www.wrap.org.uk/sites/files/wrap/Food-Waste-Reduction_Roadmap_Progress-Report-2019.pdf
([167]) EU Platform on Food Losses and Food Waste, Draft key recommendations for action to prevent and reduce food waste, 2019.

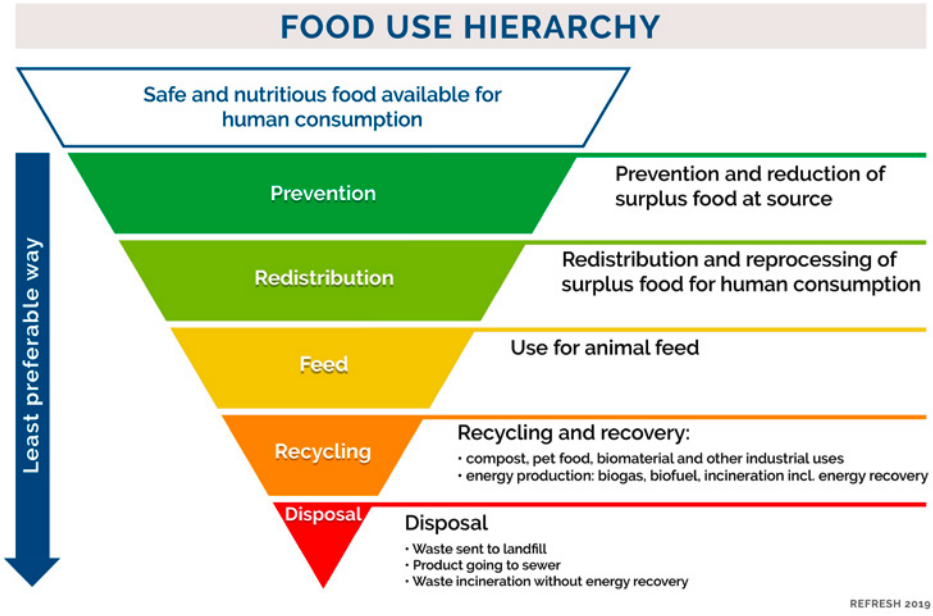
FINANCIAL SUPPORT

- All relevant EU and national financial instruments could be utilised to support food loss and waste prevention. As regards SMEs, public authorities should implement targeted programmes in order to help these companies integrate food waste prevention in their business models. Member States could establish a national Food Waste Prevention Fund (financed both by the private and public sectors) in order to provide sustained financial support for national initiatives, projects and organisations in their fight against food waste ([168]).

5 RESEARCH AND INNOVATION NEEDS

Actions aimed at tackling food waste should follow the **food use hierarchy** and thus prioritise prevention, followed by redistribution of surplus food to people in need, production of animal feed, other industrial uses (e.g. bioenergy generation), composting, up until landfill/incineration.

Figure 14. Hierarchy for prioritisation of food surplus, by-products and food waste (FW) prevention 10 strategies ([169]).



([168]) EU Platform on Food Losses and Food Waste, Draft key recommendations for action to prevent and reduce food waste, 2019.

([169]) Adapted from Teigiserova et al. 2020, Papargyropoulou et al. 2014 and UNEP2014, in the European Commission's Knowledge Centre for Bioeconomy, "Brief on food waste in the European Union", 2020

Therefore, **the focus of this pathway is on prevention and reduction**, followed by redistribution, rather than valorisation of food waste into new bio-based products (this is the object of a specific pathway beyond this document). In particular, it will be needed to:

1. OVERCOME THE DATA DEFICIT ([170])([171]):

Measurement and reporting:

Existing data on food waste and reporting schemes are characterised by a high level of uncertainty ([172]) across the EU.

Therefore, it is necessary to:

- **Support EU measurement** and reporting obligations both at the level of individual business and organisation across the food value chain ([173]), as well as on the level of industrial sector, country/region ([174]) to further identify and monitor waste streams and their drivers, including those of liquid waste (e.g. soups, milk);

- Carry out further research on the causes of FW and especially on **marketing standards** and their relationship with food waste;

- Analyse existing behavioural science research and experience gained in other sectors (e.g. public health) and continue research on **consumer behaviour** to influence social norms and support behavioural changes ([175]). In fact, convincing people that 'it is normal not to waste' has been proved to be a much more effective strategy compared to only focusing on raising consumer awareness ([176]). Furthermore, 'strategies to strengthen consumers' skills and knowledge, as well as to improve the accessibility of goods supply and to help consumers reduce the chance and impact of unforeseen events on their household food management are also promising' ([177]);

- Promote and facilitate assessment of the effectiveness of food waste prevention interventions, including **cost-benefit analysis of food waste prevention actions** and their

([170]) Food and Loss Platform, Cross-cutting recommendations for actions, October 2019.
([171]) WRI (2019), 'Reducing food loss and waste. Ten interventions to scale impact'.
([172]) The European Commission's Knowledge Centre for Bioeconomy, "Brief on food waste in the European Union", 2020
([173]) The European Commission's Knowledge Centre for Bioeconomy, "Brief on food waste in the European Union", 2020
([174]) WRI (2019), 'Reducing food loss and waste. Ten interventions to scale impact'.
([175]) Food and Loss Platform, Cross-cutting recommendations for actions, December 2019.
([176]) REFRESH H2020 Project 'Final results' 2020.
([177]) REFRESH H2020 Project 'Final results' 2020.

impacts ([178]), open access data sharing and collaborative action development. It will be critical to create new strategies and policy decisions ([179]).

- Create tools to help inform about future interventions and promote replicability across Member States ([180]).

In this context, JRC has recently developed a basic tool ([181]), but an upgrade and development could be envisaged, in particular providing:

- an analysis of the different impacts (e.g. environmental, financial, nutritional and social) of the actions
- an analysis per country and per municipality
- an analysis per commodity.
- Key **success factors, barriers and data** should be identified and shared, to support development of future actions, enhance replicability and long-term sustainability of interventions ([182]). This would include developing **sector-specific guidance** to provide motivation and technical information for business and consumers to take action ([183]).

2. DEVELOP TAILORED INNOVATIONS

- Improving technology to improve the **flow of information and coordination** among the actors of the FSC ([184]) (e.g. concerning road and traffic conditions, as well as timing of pickup and delivery) to optimise movement of food during transportation and logistics ([185]).
- Improving **processing and preservation** facilities ([186]).
- Optimising **shelf life length** while preserving food safety and quality ([187]), e.g. new packaging systems ([188]) improving food management or through the development of new crops.

([178]) REFRESH H2020 Project Policy brief: reducing consumer food waste, 2019.
([179]) REFRESH H2020 Project Policy brief: reducing consumer food waste, 2019.
([180]) Food and Loss Platform, Cross-cutting recommendations for actions, December 2019.
([181]) http://publications.jrc.ec.europa.eu/repository/handle/JRC118276
([182]) Food and Loss Platform, Cross-cutting recommendations for actions, December 2019.
([183]) WRI (2019), 'Reducing food loss and waste. Ten interventions to scale impact'.
([184]) Food and Loss Platform, Cross-cutting recommendations for actions, December 2019.
([185]) WRI (2019), 'Reducing food loss and waste. Ten interventions to scale impact'.
([186]) WRI (2019), 'Reducing food loss and waste. Ten interventions to scale impact'.
([187]) WRI (2019), 'Reducing food loss and waste. Ten interventions to scale impact'.
([188]) Food and Loss Platform, Cross-cutting recommendations for actions, December 2019.

- Innovative product design to **reduce the plastic** content of products or improve recyclability ([189]).

- Improve understanding and use of **date marking** by food business operators and consumers, supported by consumer research evidence.

- Addressing the logistical challenge linked to the collection of small quantities of food in multiple locations, in order to make it possible to **redistribute surplus food** ([190]). With regards to redistribution, several examples of social innovations already exist which only need to be scaled up.

- Developing **innovative products** from perishable food commodities, to promote whole food utilisation ([191]) (this will be tackled by a specific roadmap).

However, a single innovation cannot solve the problem of food waste, but **a combination of different and complementary innovations**, which tackle specific aspects of the food waste in each segment of the FSC and which consider possible trade-offs with food safety requirements and with other environmental objectives ([192]), could significantly contribute to solve the problem.

5 SHOWCASING SOLUTIONS

During Horizon 2020, the EC has invested approximately EUR 25 million in this area, by supporting 14 projects including studies and little projects. Some key projects include:

- **REFRESH** – '***Resource efficient food and drink for the entire supply chain***' (2015-2019), WASTE-2-2014, EUR 9.4 million.

  The overall aim of the REFRESH project was to contribute significantly towards the objective of reducing food waste across the EU by 30 % by 2025 and maximising the value from unavoidable food waste and packaging materials. To achieve this ambitious goal, the project adopted a systemic approach and used cutting edge science to enable action by businesses, consumers and public authorities. A central ambition of the REFRESH project was to develop a 'Framework for Action' model that is based on strategic agreements across all stages of the supply chain (backed by governments), delivered through collaborative working and supported by evidence-based tools to allow targeted, cost-effective interventions.

([189]) Tearfund (2019), '*No time to waste. Tackling the plastic pollution crisis before it is too late*'.
([190]) Food and Loss Platform, Cross-cutting recommendations for actions, December 2019.
([191]) WRI (2019), 'Reducing food loss and waste. Ten interventions to scale impact'.
([192]) FAO (2019), 'The state of food and agriculture'.

- **LOWINFOOD** – ***'Multi-actor design of low-waste food value chains through the demonstration of innovative solutions to reduce food loss and waste'*** (2021-2026), RUR-07-2020, EUR 6 million.

  The project will co-design, together with actors of the food chain, low-waste value chains by supporting the demonstration of a portfolio of innovations in the fruits and vegetables, bakery products and fish value chains, as well as an in-home and out-of-home consumption. The impact of the innovations will be evaluated by providing evidence of: (i) their efficacy in reducing food loss and waste in different food value chains; (ii) their capability of improving the socioeconomic performance of these value chains; and (iii) of reducing the environmental impact of the value chains concerned.

- **FOODRUS** – ***'An innovative collaborative circular food system to reduce food waste and losses in the agri-food chain'*** (2021-2025), RUR-07-2020, EUR 6.7 million.

  The project will deploy technological, social, financial, legal, educational, political, labelling and organisational innovative solutions involving more than 40 different type of actors. In particular, FOODRUS will screen the value chains of three specific types of food in Europe: vegetables and salads; meat and fish; and bread.

PATHWAY 6 – THE MICROBIOME WORLD

1 SYSTEMIC CHALLENGES

Microbiomes are in, on, and all around us. Understanding what microbiomes do, what they are, and how they interact is a new scientific frontier now made reachable by rapid advances in genomics. What we know and understand so far is that the microbiome has essential impacts on our health and on the food we produce, on plants and animals and on ecosystems in general. Unravelling their complexity offers huge potential for innovation and will be a major game changer in the way we manage our planet's resources to obtain our food and improve our health. Even if more than EUR 500 million ([193]) were invested through the Horizon 2020 framework programme of the European Commission to address microbiome research relevant to health, we are still lacking significant knowledge in this area. For example, it is estimated that more than half of the budget worldwide is dedicate to human gut microbiome research and yet

([193]) Hadrich, D. (2018), *Frontiers in Genetics*, 13 June 2018.

approximately 40-50 % ([194]) of human gut species lack a reference genome. We know more about the stars and the planets in the universe than about the DNA of our own planet

The systemic challenges directly addressed include:

- ascertaining what constitutes a healthy microbiome through a deeper understanding of the host-microbiome nexus;
- engaging the relevant stakeholders, food and healthcare professionals, industry, regulatory opinion leaders, and media and policymakers;
- developing an open science and open frontiers global approach to overcome the barriers of scale, reach sufficient critical mass, data sharing, and the linking and training of different disciplines.

RELEVANT EU POLICIES

A better understanding of microbiomes will enable developments, innovation, and co-benefits in policy areas such as:

- health, food and nutrition security, addressing policy objectives of Green Deal ([195]) and Farm to Fork strategy ([196]);
- energy security and climate change, delivering on climate ambition ([197]) and targeted impact on climate neutrality and adaptation to climate change addressing the new bioeconomy strategy ([198]) for a sustainable Europe;
- higher yield and nutritious food can come from the beneficial symbiosis provided by certain microbiomes. Focusing on sustainable and circular management and use of natural resources while improving soil health, delivering at the Soil Health and Food mission ([199]) and others;
- furthermore, infestation of food products (e.g. vegetables and fruits) from a protecting microbiome layer could help to tackle food waste ([200]) by prolonging their shelf life;

([194]) Nayfach et al. (2019), *Nature*, 568 (7753), pp. 505–510.
([195]) https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en
([196]) https://ec.europa.eu/food/farm2fork_en
([197]) https://ec.europa.eu/clima/policies/strategies/2050_en
([198]) https://ec.europa.eu/commission/news/new-bioeconomy-strategy-sustainable-europe-2018-oct-11-0_en
([199]) https://ec.europa.eu/info/horizon-europe-next-research-and-innovation-framework-programme/mission-area-soil-health-and-food_en
([200]) https://ec.europa.eu/commission/presscorner/detail/en/IP_03_762

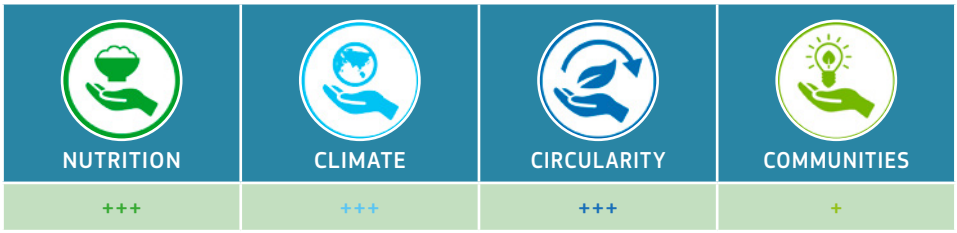
- neutral or beneficial microbiomes can shelter the health of humans/animals/plants by occupying the space where pathogens could thrive ([201]);

- circular economy loops can be closed by certain microbiome communities, which can indicate the presence of natural fossil fuels, while others can produce biofuel from by-products.

2 CO-BENEFITS

Microbiome research and innovation has the potential to touch upon many horizontal areas, from primary production and sustainable agriculture to food production and food science, to human health and waste management. Thereafter, the co-benefits span from reduction of GHGs emissions to increased adaptation options to climate change, from reduction of risk factors for NCDs to protection of biodiversity.

The Microbiome World thematic area would have an impact on all four of the Food 2030 priorities, as described below.



NUTRITION AND HEALTH

The human gut microbiome plays an important role in many if not most non-communicable diseases (NCDs) ([202]). However, the causal relationship and mechanisms causing diseases are still not well understood ([203]). Given the burden of these diseases, the potential impact of developing therapies or preventative approaches based on knowledge of the microbiome is enormous.

Public health is facing huge challenges caused by the rise of complex diseases, linked to changing demographics. Non-communicable diseases (NCDs) comprise 63 % of the major cause of global deaths ([204]), while 25 % of people dying from NCDs are younger than 60 years old. The

([201]) https://ec.europa.eu/health/amr/action_eu_en
([202]) https://www.ewi-vlaanderen.be/sites/default/files/bestanden/microbiome_issues_paper_kathleen_dhondt.pdf
([203]) https://bioimmersion.com/
https://www.nytimes.com/2013/05/19/magazine/say-hello-to-the-100-trillion-bacteria-that-make-up-your-microbiome.html
([204]) https://www.who.int/features/factfiles/noncommunicable_diseases/facts/en/index9.html

burden of NCDs on healthcare systems is further illustrated by the fact that NCDs are causing 48 % of healthy life years lost, while for other diseases, this is only 40 %. According to a study by the World Economic Forum in 2011, NCDs were expected to cost USD 47 trillion by 2030 or 75 % of the annual global GDP in 2010 (Bloom et al., 2011).

CLIMATE AND SUSTAINABILITY

According to a recent World Economic Forum report ([205]), Microbiome technologies could reduce GHG emissions by up to 30 megatonnnes of CO_2 equivalent and restore soil health and water quality.

CIRCULARITY AND RESOURCE EFFICIENCY

We need to determine what constitutes a healthy microbiome. The restored ocean microbiome after the Deepwater Horizon disaster oil spill is very different from what was there before ([206]). Yet some microbial ecosystems like the Wisconsin lakes are resilient to major disturbances and rapidly return to their original state after major stresses.

There are 100 to 1 000 times more bacteria on the surface of coral compared to the same area of human skin. Therefore, microbiome engineering will be an important management solution to ensure the future of coral reefs ([207]).

RELEVANT SDGS AND COMMUNITIES

The microbiome covers a vast range of scientific fields, from health, agriculture, environment, climate change, etc. Thus, advancing microbiome knowledge can deliver results across several SDGs: namely 2, 3, 12, 13, 14 and 15. However, it is not feasible for one country to tackle all, or even individual SDGs, in a complete and satisfactory manner, hence an international effort is needed.

([205]) http://www3.weforum.org/docs/WEF_Innovation_with_a_Purpose_VF-reduced.pdf
([206]) https://oceanservice.noaa.gov/hazards/deepwaterhorizon/
([207]) https://www.forbes.com/sites/linhanhcat/2019/03/23/microbiome-engineering-coral-reefs/?fbclid=IwAR1fELV3wvM_H_P0Ihlua59emeti4N9LkyTGYS_na9-aaK1FQ3la0GKH2gU#43f79a6e2d66

3 BARRIERS AND LOCK-INS

- **Microbiome** knowledge production and exploitation is not yet a key priority in EU-wide national research plans or strategic R&I agendas. **There are significant barriers** to innovation that apply to microbiome research. For example:

- Lack of global coherency, weak translational science (lab models for experimental verification), crowdsourcing and citizen science, public funding and return on investment and intellectual property rights are some of the issues inhibiting innovation in this field.

- Additionally, **the regulatory framework** suffers from a lack of harmonisation and often releases confusing microbiome food health claims.

- **Researchers need to work** with funders, policymakers and society to **improve R&I** microbiome awareness and engage in community-led collaborations.

- Finally, microbiome research is a relatively new field and the lack of **training networks** and **infrastructures,** together with the need to **establish rigorous standards** for **data access** and **interoperability** are considerable bottlenecks for the field.

4 ENABLERS OF CHANGE

The microbiome can provide innovative solutions to increase food and nutrition security by harnessing microorganisms, which are key constituents of every food chain known on earth. They have a key role in carbon, nitrogen, and phosphate cycles, and are the only organism capable of fixing atmospheric nitrogen into ammonium for further use in protein production. Microbes can metabolise nearly every known toxic compound or negative agent, which can reduce food quality and quantity. Plant growth promoting microorganisms can be used to increase plant productivity and health and reduce the use of chemical fertilisers. Marine Microbiomes can boost algal biomass production or produce fermented feed or food products from plant or aquatic biomass. Application of marine microbiomes to facilitate healthy rhizospheres for salt-tolerant crops and for macro- and micro-algae that can be grown under brackish or marine salt conditions in otherwise infertile land without the need for fresh water.

With these facts in mind, developing a Food System Microbiome focus has huge potential to widen our understanding of the whole food supply chain from nutrition to climate to circularity, safety and security and to how we produce, obtain, prepare and consume our food, and manage our resources.

Key enablers include:

- Microbiome studies fit perfectly within the Framework programme scope towards Open Science and innovation, Open data, and Open to the world.
- Improving microbiome coherency across such a vast range of scientific fields would have major benefits in a better understanding of microbiome composition and applicability.
- The European Commission through past and current framework programmes has extensively funded microbiome studies amounting to around EUR 1.4 billion over 500 diverse projects.
- This constitutes a leading global network of scientists now working under the Microbiome Support action aimed at bringing greater coherence to EU and global microbiome studies and part of an overall EU microbiome initiative responding to a number of recent calls by organisations like the OECD, WEF, FAO and NGOs for specific actions in this area.
- The huge hidden diversity of 100 trillion bacteria in the human gut, the power of metagenomics and its expansion into other areas, the maturity of analytical technologies, and the potential for exploitation and use of abundant microbiome data.
- Microbiomes can be considered as nutraceuticals which will have a market size of up to USD 420 billion with a projected growth rate of 7 % over the next couple of years ([208]).
- According to the World Economic Forum report, ([209]) microbiome technologies enhancing crop resilience could generate up to USD 100 billion in additional farmer income, and increase production by up to 250 million tonnes.
- Innovative communities could be developed for two of the largest and most influential global microbiome projects, the Human Microbiome Project ([210]), and the EC International Human Microbiome Standards IHMS ([211]), who currently work independently under different protocols.

([208]) https://www.alliedmarketresearch.com/nutraceuticals-market
([209]) http://www3.weforum.org/docs/WEF_Innovation_with_a_Purpose_VF-reduced.pdf
([210]) https://www.hmpdacc.org/
([211]) https://www.microbiome-standards.org/

5 RESEARCH AND INNOVATION NEEDS

Research and innovation actions are divided into two subgroups: the **technical**; and **non-technical** interventions. Tackling the challenges ahead of us, microbiome technical interventions should focus upon:

- **increasing agricultural sustainability and productivity,** to address the increasing demand for food while coping with the forecasted climate change.
- Improving **soil health and restoration** through bioremediation of degraded or contaminated habitats, enchasing soil carbon sequestration, and helping to protect erosion of top soils.
- **Improving food quality** for producing higher nutritional quality foods, and promoting the reduction of microbial contaminants, preventing the outbreaks of diseases such as COVID-19.
- Microbiome research could reduce our reliance on fossil fuel inputs in agriculture and decreasing the N_2O flux and thereafter help with **climate change mitigation**.
- Microbiome research and innovation is a relatively new area and is attracting the attention of **new industrial sectors** who are trying to develop new inoculants and enzymes for the industry.
- Finally, is it important to move from the extensive cataloguing of microbiomes towards designing **better microbial characterisation** of a healthy gut, plant, soil, ocean etc. along with **established biomarkers**, and with better understanding and insights into physical processes, functionality, and novel applications.
- An element considered most essential for the **non-technical inter**ventions is **Citizen engagement** and co-creation with citizens. This will provide better understanding and education of citizens which can ensure the endorsement of microbiome benefits.
- Secondly, the **education** of a new generation of scientists on systemic microbiome research will ensure a holistic/systemic approach and could provide the public and policymakers with life-cycle analysis of microbiome-based solutions.
- Equally important is an honest **public-private partnerships,** targeting **microbiome standards**, reference material, and data linked with **large data infrastructures**.

6 SHOWCASING SOLUTIONS

During the Seventh Framework Programme (FP7) and Horizon 2020, the EC invested approximately EUR 1.4 billion related to microbiome research, by supporting over 500 projects. In the FP7 ([212]) programme, 370 projects were supported with an investment of EUR 850 million. In Horizon 2020 ([213]), over 366 projects were supported with an investment of more than EUR 500 million. Some key projects include:

- **CIRCLES** (2018-2023)–- IA – EUR 10 M.

  Controlling Microbiomes Circulations for Better Food Systems. CIRCLES will establish a new integrated economic system of products and services, proposing new food value chains based on microbiome knowledge.

- **HOLOFOOD** (2019-2022), IA, – EUR 10 M.

  Holistic solution to improve animal food production through deconstructing the biomolecular interactions between feed, gut microorganisms and animals in relation to performance parameters.

- **MASTER** (2019-2023), IA, EUR 10 M.

  Microbiome Applications for Sustainable food systems through Technologies and Enterprise

- **SIMBA** (2018-2022), IA EUR 10 M.

  Sustainable innovation of microbiome applications in food system

- **MicrobiomeSupport** (2018-2022) – - CSA, EUR 3.5 M.

  Platforms for collaboration and coordination of microbiome-related R&I programmes in Europe and worldwide. Carry out a mapping exercise at international level.

([212]) For FP7 the majority of projects were mobility fellowships followed by ERC grants and collaborative projects in different themes; the first of the themes being the Bioeconomy, closely followed by health, environment and space.

([213]) For Horizon 2020 The majority of projects are fellowships, followed by ERC grants. Thirdly, are collaborative projects under the H2020 societal challenges, in the areas of health and bioeconomy (food, agriculture, forestry and the marine) and climate.

PATHWAY 7 – HEALTHY, SUSTAINABLE AND PERSONALISED NUTRITION

1 SYSTEMIC CHALLENGES

The triple burden of malnutrition (undernutrition, over-nutrition and micronutrient deficiencies), climate change, resource scarcity, growing (ageing) population and urbanisation, and food poverty are major challenges facing global and EU food systems. Globally, the supply of vegetable oils and meat per capita has more than doubled since 1961 and the supply of food calories per capita has increased by about one third. Changes in food production, processing and consumption patterns have contributed to an estimated 800 million people who are undernourished, while 2 billion are affected by micronutrient deficiencies and 2 billion are

overweight or obese ([214]). These changes also contribute to global environmental and climate changes with additional GHG emissions and 25-30 % of total food produced which is lost or wasted ([215])([216]).

Unsustainable and unhealthy diets with increased demand for livestock products, and calorie-dense, nutrient poor and (ultra) processed food are a leading NCD risk factor and a driver of obesity rates ([217]). Despite much effort, no EU country has managed to reduce obesity rates over the last decades ([218]). In Europe, at present, more than half of the adult population is overweight or obese and children and poorer population groups are the most severely affected. The costs linked to NCDs represents 70-80 % of European healthcare costs ([219]).

At the same time, today, one in four Europeans are at risk of poverty or social exclusion and 9.1 % of the EU population are only able to afford a quality meal every second day ([220]). Malnutrition affects health, wellbeing, and ability to work. The elderly, people with chronic disease and poorer population groups or persons socially isolated are particularly at risk.

Europeans consume a large proportion of meals prepared outside their home. Processed food and beverages now account for approximately half of all consumer spending in the West ([221]). However, there is a loss of trust in our food system and confusion exists around health and food. What is good for one person is not always good for another. This is why personalised nutrition and smart food can play an increasing role. In the context of increasingly ageing, urbanised and diverse populations (including migrants) and climate change, transformation towards healthy and sustainable diets will require substantial dietary shift by consumers and changes in the food production which mitigate environmental impacts ([222])([223]). Food systems must be more responsive to the needs and interests of communities, as well as to empower people with a stronger influence in local food environments ([224]). Personalising nutrition and lifestyle for different target groups can reduce risk factors for NCDs, reduce micronutrient deficiencies and can empower consumers to adhere to a long-lasting, healthy, pleasurable, nutritional and sustainable diet when tailored to individual parameters. Policymakers, communities with the

([214]) IPES FOOD (2019), International panel of experts on sustainable food systems, *Towards a common food policy for the European Union*.
([215]) Intergovernmental Panel on Climate Change (IPCC), Climate change and land report, Summary for policymakers, 2019.
([216]) Nordic food system for improved health and sustainability, 2019, Stockholm Research Center.
([217]) Scientific Advice Mechanism (2019), 'Scoping review report: Towards an EU sustainable food system'. https://ec.europa.eu/research/sam/pdf/meetings/hlg_sam_032019_scoping_report_sustainable-food.pdf#view=fit&pagemode=none
([218]) Ng et al. (2014), Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: a systematic analysis for the Global Burden of Disease Study 2013, *The Lancet*.
([219]) WHO, Obesity Factsheets, 2020.
([220]) Eurostat (2017), 'Europe 2020 indicators – poverty and social exclusion', https://ec.europa.eu/eurostat/statistics-explained/index.php/Europe_2020_indicators_-_poverty_and_social_exclusion
([221]) WRR (2014), *Towards a food policy*, https://english.wrr.nl/publications/reports/2016/12/13/towards-a-food-policy
([222]) ECIPE (2016), *Europe's Obesity Challenge*.
([223]) Willett et al. (2019), Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems, *The Lancet*.
([224]) Achterbos, Thom et al. (2019), *Synthesis of existing food systems studies and research projects in Europe*.

help of the food industry have an essential role to play in facilitating dietary change in providing healthy, safe, affordable, accessible and convenient food with good nutritional and sensorial qualities, including a move away from highly processed food and high meat consumption practices, as well as reduced losses and wastage along food supply chains.

RELEVANT EU POLICIES

- European Green Deal and the Farm to Fork strategy
- EU Health and Nutrition policy (for infants, children, special medical purposes, health and nutrition claims)
- White paper 'A strategy for Europe on nutrition, overweight and obesity related Issues'
- Common agricultural policy (CAP) and the Common Fisheries Policy (CFP)
- EU global food security.

2 CO-BENEFITS

The thematic area 'Healthy, sustainable and personalised nutrition' would have an impact on all four of the Food 2030 priorities, as described below.

NUTRITION	CLIMATE	CIRCULARITY	COMMUNITIES
+++	++	+	++

NUTRITION AND HEALTH

- Promotion of good health and a healthy lifestyle
- Reduction of risk factors for NCDs with a focus on most vulnerable groups
- Development of quality and healthy food products

- Zero hunger and eradication of micronutrient deficiencies.

CLIMATE AND SUSTAINABILITY

- Responsible and sustainable consumption and production while ensuring economic sustainability and mitigating climate change
- Develop an eco-design food chain with environmentally friendly agriculture and local and seasonal practices improving food product quality, sustainability and biodiversity

CIRCULARITY AND RESOURCE EFFICIENCY

- Resource-efficient food systems at all stages (production, processing, distribution, packaging, recycling) in developing sustainable and smart packaging, improving circularity and food-related waste (e.g. reduction of food portions).

INNOVATION AND COMMUNITIES

- Trigger innovation (new products/markets/business models) + jobs
- Improved social inclusion and equity.

RELEVANT SDGS

3 BARRIERS AND LOCK-INS

- **Lack of political commitment and policy coherence** due to fragmentation of health-related policies across Europe ([225]). This is largely because health policy is of Member States' competence, therefore, only soft law instruments can be proposed at EU level.

([225]) IPES-Food (International Panel of Experts on Sustainable Food Systems) (2019), Towards a common food policy for the EU http://www.ipes-food.org/_img/upload/files/CFP_FullReport.pdf

- **Lack of education on the link between lifestyle including nutrition, health and environment**. The education system is not placing sufficient emphasis on lifestyle including nutrition, health and well-being. In addition, people are not sufficiently aware of the 'true cost' of food and about aspects such as environmental impacts, public health burden, climate change, sustainability, biodiversity, negative externalities, production and fair trading socially.

- **Lack of interdisciplinary, multidisciplinary and transdisciplinary research and innovation in nutrition**. More social and behavioural sciences are needed to understand the factors influencing motivation, decision-making and behavioural change towards food.

- **Lack of appropriate research infrastructures/standardised methodologies/monitoring systems** to collect, connect, compare and share relevant data.

- **Lack of consumer engagement and acceptability** particularly on the use of personal data before developing new market opportunities for novel concepts/tools/products or services in personalised advices.

- **Lack of dietary assessment methods** to measure dietary intake and metabolic patterns.

4 ENABLERS OF CHANGE

- **More integration across policy areas:** to address more coherently climate change, halt biodiversity loss, curb obesity, and make farming viable for the next generation.

- **More political commitment** to support the Green Deal and the Farm to Fork strategy.

- **More effective and social policies against unhealthy food** e.g. taxes and subsidies applied differently to healthy and unhealthy food groups; advertising bans for marketing products with high fat, sugar and salt (HFSS) and highly-processed foods; ban on HFSS products in public vending machines and supermarket checkouts; no-HFSS perimeters around schools; and digital marketing restrictions.

- **Nutrient profiles** under EU Claims Regulation to prevent misleading health claims.

- **Develop EU and national food-based dietary guidelines** for a healthy and sustainable diet that takes into account sustainability aspects.

- **Align price/availability of foods with healthy diets** by reforming production policies: removing coupled livestock payments, supporting diversified agro-ecological systems and leguminous crops, and capturing social and environmental externalities of food production.

- **More research on factors influencing consumer choice** to empower them to make a conscious and responsible choice and to make the healthy choice the easy choice.

- **Improve education, training and communication throughout food systems** for various groups of the population with methods adapted to different cultures, values and beliefs at different levels (e.g. governments/public authority, healthcare providers, education systems from school to university level).

- **Open science**, exchange of data, research infrastructures to collect, connect, compare and share relevant data in food and nutrition.

5 RESEARCH AND INNOVATION NEEDS

The following actions will contribute to the development of innovative solutions for healthy, sustainable and personalised nutrition to achieve optimal health and well-being for all and to adopt long-term healthy and sustainable diets and reduce non-communicable diseases (NCDs).

1. **Combating NCDs**: More multidisciplinary research (including epidemiological, genetic and socioeconomic studies) to better understand the relation between lifestyle (including nutrition and alcohol), geographical (national/regional and rural/urban zone) and environmental factors, biological parameters, and the risk of NCDs. Make the connection of all aspects of nutrition with health and diseases. Identify high-risk/vulnerable populations and better understand their predisposition.

2. **Consumer behaviour**: Better understand factors influencing consumer choice such as influencers of dietary behaviour at home from birth (e.g. religious backgrounds, poverty levels, education levels), food environments (e.g. availability, accessibility, price, promotion, choice architecture in shops), policies (e.g. taxes and subsidies applied differently to healthy and unhealthy food groups, coherence between different policies on sustainability), gender, information (e.g. harmonised nutrition labelling), education and communication, media and marketing.

3. **Combating hunger and micronutrient deficiencies**: Deepen knowledge and develop innovative products, solutions and strategies tackling the causes of food and nutrition insecurity, identifying a food crisis and delivering emergency responses to reduce hunger, malnutrition and micronutrient deficiencies at different level (e.g. cities and regions) and for different communities (e.g. vulnerable groups such as infants, the elderly, migrants and low-income groups).

4. **Personalised nutrition**: Keep people healthy and reduce the incidence of NCDs and the burden of healthcare costs (health, social and economic burden). Personalised nutrition

should be focusing individuals or groups of individuals taking into account all relevant factors such as age, gender, genetic background, potential diseases risks (health indicators), nutritional requirements, lifestyle, preferences, environment (i.e. cultural and socioeconomic). Smart products, tools and technologies to be developed to deliver personalised nutrition.

5. **Unravelling neurological triggers**: Deepen knowledge on human neurobiological pathways influencing food choice, lifestyle, motivation, and decision-making to empower people to change their dietary patterns and make healthier choices.

6. **Dietary assessment methods**: Development of new methods, smart tools and technologies to measure dietary intake and metabolic patterns.

7. **Develop food-based dietary guidelines** and updated existing ones at national or/regional level that take into account seasonal, cultural, socioeconomic and environmental aspects.

8. **Improve food systems communication and education** of various population groups and actors throughout the food system with methods adapted to different cultures, values and beliefs at different levels (governments/public authorities, healthcare providers, educational systems, etc.). Develop innovative and digital tools to better inform consumers through food labelling/campaign/strategies on the link between healthy and safe food consumption practices with other aspects such as sustainability, environment, climate change, diversity to empower them to make a conscious and responsible choice.

9. **Better use of big data and development digital tools** in the area of nutrition and health. Increase the utilisation of big data to combine data from different domains and artificial intelligence to study consumer behaviour, dietary intake, the food environment and their impact on health and environment sustainability.

10. **Expand microbiome knowledge** and develop innovative solutions with a view to improve health. Study the effects of factors (such as diet, physical activity, etc.) on human gut microbiome and its impacts on immune system, mental and NCDs.

11. **New food products, services and processes** to be developed from (non-) conventional and organic production systems that optimise nutritional, structural and functional food properties of raw materials (including reformulation of food products and mild food processing) with low impact on the environment and in accordance with trending consumption preferences (e.g. fresh, 'clean label', vegetarian, vegan and ethically produced food, extended shelf life, ready to eat meals, personalised food, local and diverse foods, sustainable and smart packaging, resource efficient, circular and zero waste).

6 SHOWCASING SOLUTIONS

Within Horizon 2020, the EC has invested about EUR 80 million in the area of nutrition, by supporting about nine projects. Some key projects include:

- **PROMISS**– Prevention of Malnutrition in Senior Subjects in the EU (2016-2021), EUR 7 M
- **Eat2beNICE** – Effects of Nutrition and Lifestyle on Impulsive, Compulsive and Externalising behaviours (2017-2022), EUR 11 M
- **SWEET** - Sweeteners and sweetness enhancers: Impact on health, obesity, safety and sustainability(2018-2023), EUR 9 M
- **STOP**– Science and technology in childhood obesity policy(2018-2022), EUR 10 M.
- **CO-CREATE** - Confronting Obesity:Co-creating policy with youth (2018-2023), EUR 10 M
- **PREVENTOMICS** - Empowering consumers to prevent diet-related diseases through omics sciences(2018-2021), EUR 7 M
- **NUTRISHIELD**– Fact-based personalised nutrition for the young(2018-2021), EUR 7 million
- **STANCE4HEALTH** - Smart Technologies for Personalised Nutrition and Consumer Engagement(2018-2021), EUR 7 M
- **PROTEIN** – Personalised Nutrition for Healthy Living(2018-2021), EUR 7 M

PATHWAY 8 – FOOD SAFETY SYSTEMS OF THE FUTURE

1 SYSTEMIC CHALLENGES

In the political context of the European Green Deal, and in particular of the Farm to Fork strategy to ensure food and nutrition security while addressing environmental and social factors, ensuring food safety throughout the food chain is crucial.

Food safety, being an integral part of food and nutrition security, is an underlying element of good health and it is crucial for sustainable development. The Sustainable Development Goals (SDGs) call for actions among others to end hunger, improve nutrition while promoting sustainable agriculture to achieve food security.

The EU has one of the world's safest food systems assuring high level of food safety and animal health and welfare, and plant health. This is achieved through the General Food Law and related legislation, ensuring an integrated approach to food safety 'from farm to fork' and adequate monitoring and compliance, while guaranteeing effective internal market and trade relations with third countries. The European Food Safety Authority (EFSA), responsible for scientific advice

and support, is constantly developing its risk assessment methodologies particularly towards the expectations of citizens on the safety of new and emerging substances and technologies.

While major improvements are continuously been made in terms of EU food safety and traceability, food safety remains a global concern, with related social and economic costs unacceptably high. The World Health Organisation estimates ([226]) that food-borne bacteria, parasites, toxins and allergens cause about 23 million cases of illnesses and 5 000 deaths in Europe every year. Furthermore, the European citizen is not fully confident or trusting the food supply systems ([227]).

The following key drivers demonstrate why we need to invest in food safety science, in order to ensure the best performing and innovative food safety system of the future to protect human, animal and plant health and the environment.

Climate change has complex associations with a number of food safety hazards, potentially leading to increased risks of foodborne illnesses and affecting access to safe and nutritious food for millions of people around the globe. The current COVID-19 pandemic has no connection to food safety in the EU, but such crisis can place both food security and livelihoods at risk. It is an example on the need to remain proactive on human health biological hazards, and in the case of the food system on those that could emerge throughout the food chain. Changes in food and farming systems may also increase food safety risks. The recently published FAO document ('Climate change: Unpacking the burden on food safety', 2020) ([228]) stresses that scientific research is pivotal in deepening understanding of climate change and finding novel approaches that solve challenges.

In addition, rapid technological advancements and emerging technologies in various areas of the food chain are not always aligned among the actors and stakeholders, thus affecting systemically on leveraging the impact of innovation so to advance with providing solutions to address food chain challenges and empower consumers.

Innovation in the food chain needs to be addressed while fostering regulatory science. This will lead to integrated and improved risk assessment methodologies and new evidence to support robust food safety regulatory frameworks, including those addressing new and emerging food safety risks.

The challenge of transforming the food system safely towards increased sustainability must also include the assessment of new technologies and fulfil EU citizens concerns and expectations in terms of transparency and trust.

([226]) World Health Organisation (2015), *WHO estimates of the global burden of foodborne diseases: foodborne disease burden epidemiology reference group 2007-2015*, WHO Library Cataloguing-in-Publication Data, printed in Switzerland, ISBN 978 92 4 156516 5.

([227]) https://ec.europa.eu/info/consultations/public-consultation-transparency-and-sustainability-eu-risk-assessment-food-chain_en

([228]) FAO (2020), 'Climate change: Unpacking the burden on food safety', *Food Safety and Quality Series No 8*, Rome, http://www.fao.org/3/ca8185en/CA8185EN.pdf

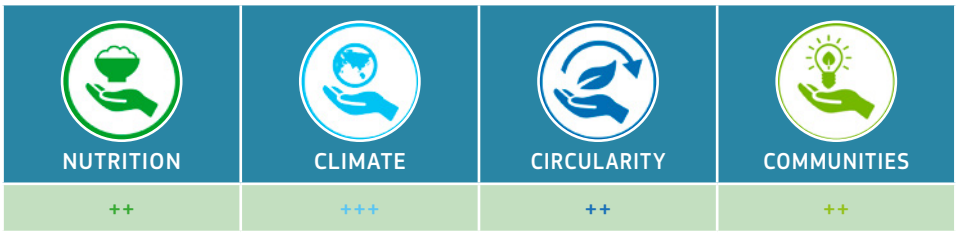
These advocate continued investment in food-safety related issues.

RELEVANT EU POLICIES

- EU General Food Law and related risk-based food safety regulatory frameworks
- The EU Green Deal and in particular the Farm to Fork strategy, the Biodiversity strategy and the strategy for sustainable Chemicals
- Common agricultural policy (CAP)
- EU consumer policy
- EU environment policy
- EU global food security

2 CO-BENEFITS

As food safety is at the centre of Food 2030 and linked to all its pathways, the thematic area 'Food Safety Systems of the Future' would provide co-benefits and have an impact on all four priorities of Food 2030, as described below.



NUTRITION AND HEALTH

- Ensuring food safety along the entire food system, among all food system sectors
- Developing and implementing traceability systems across the food chain supported by available and new safe technologies.

CLIMATE AND SUSTAINABILITY

- Building climate-smart food systems resilient to climate change, conserving natural resources and biodiversity and contributing to climate change mitigation.
- Ensuring diversity in food systems (including production, processing, distribution and consumption) while considering cultural and environmental diversity.
- Managing increased complexity in agri-food production and supply chain processes.

CIRCULARITY AND RESOURCE EFFICIENCY

- Implementing resource-efficient and safe circular economy principles across the whole food system while reducing its environmental footprint.
- Innovative technologies will aim at making food waste management efficient and safe.

INNOVATION AND COMMUNITIES

- Scientific evidence and knowledge from a wide diversity of actors underpinning the development and implementation of regulatory science and risk assessment to support policymaking.
- The development of new assessment methodologies, traceability and labelling systems will empower risk assessors, users, innovators and communities, and will address their concerns. Models of collaborating will create a new food safety ecosystem fostering economies and communities.

RELEVANT SDGS

While elements of this pathway have direct links to SDGs, they can also interact with other goals in complex ways. The specific SDGs that relate to the food safety pathway or elements that underpin food safety are the following:

3 BARRIERS AND LOCK-INS

- Limited investment in research and innovation to advance regulatory science and innovate in risk assessment.
- The consumer disconnect in the science supporting risk assessment and policymaking.

4 ENABLERS OF CHANGE

- Recent political commitment to foster safe and sustainable systems: EU Green Deal in particular the Farm to Fork strategy, the strategy for sustainable Chemicals and the Biodiversity strategy.
- Enhance transparency of and engagement in EU food safety risk assessment data and processes, and enhanced risk communication: Transparency regulation amending the General Food Law.
- Social sciences and communication science for food safety: development of new models of how to communicate science-based evidence.
- Digital innovation: will aid increase in areas such as traceability, transparency and risk communication.
- Development of novel assessment methodologies such as cumulative effects of toxic and biological agents, risk-benefit assessment methodologies.
- Precision farming – with the purpose of serving food safety across the food system.
- Novel technologies: foster use of existing and emerging technologies that will help improve the safety of food systems.
- Education and training.

5 RESEARCH AND INNOVATION NEEDS

In order to make the Food 2030 policy framework instrumental to future-proof food systems and food safety throughout Europe and to be ready for future challenges as climate change and new technologies, all food safety risks have to be assessed and managed along the entire food system, given the cross-sectoral character of food safety.

Many research and innovation actions under Horizon Europe will address the aforementioned opportunities and challenges, and build on the work of ongoing projects of H2020, for example on relevant existing European Join Programmes and on coordination actions seeking the development of a research and innovation platform for collaboration and coordination across food safety stakeholders ([229]).

Focused R&I investments in food safety regulatory science are lacking since most of the investments are driven by a bottom-up approach, thus not necessarily directed towards fostering R&I for regulatory science, risk assessment and ultimately impact on evidence-based policy making.

Research and innovation areas meriting further investments include:

1. Focused research in food safety regulatory science for the future
2. Innovation in risk assessment
3. Identification and management of existing and emerging food safety issues across the food chain and considering role of different actors
4. Research supporting crisis management
5. Improved systems for authenticity and traceability in the food system
6. Integrating food safety, food security and nutrition
7. Engaging citizens in the science behind food safety policies and foster food safety risk communication
8. Fostering targeted education and capacity building for future food safety experts and risk assessors

6 SHOWCASING SOLUTIONS

Within Horizon 2020, approximately 15 projects have been supported representing an investment of around EUR 120 million. Some key projects include

In Horizon 2020 the following projects explicitly contributed to food safety.

([229]) The future project funded from the 'FNR-08-2020: Supporting the food safety systems of the future' topic of H2020 2018-2020.

- **One Health EJP** – Promoting One Health in Europe through joint actions on food-borne zoonoses, antimicrobial resistance and emerging microbiological hazards (2018-2022) EJP, EUR 44.9 M.
- **SafeConsumE** – Safer food through changed consumer behaviour: effective tools and products, communication strategies, education and a food safety policy reducing health burden from foodborne illnesses (2017-2022) RIA, EUR 9.5 M.
- **EU-China-Safe** – Delivering an effective, resilient and sustainable EU-China Food Safety Partnership (2017-2021) RIA, EUR 4.9 M.
- **EuroMix** – A tiered strategy for risk assessment of mixtures of multiple chemicals (2015-2019) RIA, EUR 7.9 M.
- **MyToolBox** – Safe food and feed through an integrated ToolBox for Mycotoxin Management (2016-2020) RIA, EUR 4.9 M.
- **MycoKey** – Integrated and innovative key actions for mycotoxin management in the food and feed chains (2016-2020) RIA, EUR 4.9 M.
- **COMPARE –** Collaborative management platform for detection and analyses of (re-emerging and foodborne outbreaks in Europe (2014-20191) RIA, EUR 20.8 M.
- **AUTHENT-NET** – Food Authenticity Research Network (2016-2018) CSA, 0.5M.
- **OLEUM** – Advanced solutions for assuring the overall authenticity and quality of olive oil (2016-2020) RIA, EUR 4.8 M.
- **i3-Food** – Process integration for rapid implementation of sustainable innovative food processing (2015-2018) IA, EUR 2.1 M.
- **FieldFOOD** – Integration of PEF in food processing for improving food quality, safety and competitiveness (2015-2018) IA, EUR 1.9 M.
- **HIPSTER** – Deployment of high pressure and temperature food processing for sustainable, safe and nutritious foods with fresh-like quality (2015-2017) IA, EUR 1.9. M.

PATHWAY 9 – FOOD SYSTEMS AFRICA

1 SYSTEMIC CHALLENGES

Africa has the world's fastest growing population. It doubled since 1990; it should nearly double again over the same 30-year period, by 2050. While in recent years, fertility rates have declined in Africa from 5.1 births per woman in 2000-2005 to 4.7 in 2010-2015 Sub-Saharan Africa is the last region in the world to enter into the demographic transition involving lower birth and death rates ([230]).

As a consequence the market for food in Africa is expanding rapidly, fuelled by urbanisation, growing incomes and an increasing middle class. By 2030, food demand is projected to increase by 55 %, bringing the size of Africa's food and agribusiness to USD 1 trillion and opening

([230]) United Nations Department of Economic and Social Affairs (2017), *World Population Prospects: The 2017 Revision.*

up employment opportunities all along the value chain ([231]). African supply still dominates the domestic food markets with an estimated 90 % of all consumed food supplied by local producers. Nevertheless, the African Development Bank projects that African food imports will triple from USD 35 billion in 2017 to about USD 110 billion in 2025 ([232]).

Despite these new opportunities for economic growth Africa is a place beset by global and local challenges which include climate change, disease, and corruption. For example the recent COVID-19 crisis is exposing African food systems to an existential shock. Lock-downs to contain the transmission of the COVID-19 virus could lead to the widespread threat of hunger from food supply chain disruption.

Malnourishment in all its forms (stunting, wasting, micronutrient deficiency, overweight and obesity) also remains a big challenge. In Africa, south of the Sahara, the 2015–2017 undernourishment rate is still at 22 percent ([233]) (FAO, 2018d) and it is the highest regional rate of all regions. Malnutrition constitutes one of the greatest obstacles to equitable economic and social development, and is probably the greatest global health challenge the world currently faces ([234]). No single country is on track to achieve all the global nutrition targets by 2030 ([235]). Malnutrition in Africa is the cause of a 10 % loss of gross domestic product every year ([236]). Different forms of malnutrition can coexist within the same country or community, and sometimes within the same household or individual, and can even be linked: they thus must be addressed together ([237]). Food security is not only a matter of quantity but also of access and nutritional quality.

In addition, The FAO estimates that one third of food is wasted across the whole supply chain. Such waste occurs close to the farm in Africa while it is much closer to the consumer in Europe ([238]).

Despite increasing investment, achieving food and nutrition security is extremely challenging especially in the face of climate change, dwindling natural resources, and extremely volatile energy costs. It underpins a number of Sustainable Development Goals and most importantly SDG 2, which strives to 'end hunger, achieve food security, improve nutrition, and promote sustainable agriculture'.

([231]) World Bank (2013), (2015).
([232]) African Development Bank Group (2017), Remarks delivered by Akinwumi A. Adesina, President of the African Development Bank at the Centre for Global Development, Washington DC, 19 April.
([233]) FAO (2018), Food Security Indicators, http://www.fao.org/faostat/en/#data
([234]) Lancet – data from Institute of Health Metrics and Evaluation at University of Washington (NCDs result in 72 % global deaths). 'Unhealthy diets and overweight lead to NCDs (cardiovascular diseases, diabetes and some cancers)'.
([235]) An Investment Framework for Nutrition: Reaching the Global Targets for Stunting, Anemia, Breastfeeding, and Wasting (World Bank, 2016 – http://documents.worldbank.org/curated/en/758331475269503930/pdf/108645-v2-)
([236]) An Investment Framework for Nutrition: Reaching the Global Targets for Stunting, Anemia, Breastfeeding, and Wasting (World Bank, 2016 – http://documents.worldbank.org/curated/en/758331475269503930/pdf/108645-v2-)
([237]) Committee on World Food Security (2017), HLPE report 12, Nutrition and food systems.
([238]) FAO (2011), Global food losses and food waste.

The EU-Africa Research and Innovation Partnership on food and nutrition security and sustainable agriculture (HLPD FNSSA) is an example of such investment. It is currently pursuing a ten year roadmap (2016-2026) with four priorities: (1) Sustainable intensification; (2) Agriculture and food systems for nutrition; (3) Expansion and improvement of agricultural trade and markets; and (4) A group of cross-cutting topics.

The HPLD FNSSA initiative is intrinsic to helping transform our Food systems to become more sustainable, deliver better nutrition, avoid undernutrition and obesity, reduce food losses and waste, adapt to and mitigate climate change, and create jobs for young people through place-based innovations, in both rural areas and in cities.

RELEVANT EU POLICY

- The European Green Deal (Farm to Fork Strategy) EU-Africa Strategy
- EU-African Partnership roadmap on Food and Nutrition Security and Sustainable Agriculture
- Task Force: Jobs and Growth for Rural Africa

2 CO-BENEFITS

NUTRITION	CLIMATE	CIRCULARITY	COMMUNITIES
++	++	++	+++

NUTRITION AND HEALTH

- Reducing hunger, diet-related mortality and NCDs (depending on nutrition-oriented food systems)
- Nutrition-sensitive agriculture

CLIMATE AND SUSTAINABILITY

- Reducing GHG emissions by reducing food losses and waste
- Less food transport by strengthening local food systems

CIRCULARITY AND RESOURCE EFFICIENCY

- Decreasing food waste
- Decreasing dependence on imports, thus decreasing environmental footprint

INNOVATION AND COMMUNITIES

- New food business models and value-added products, goods and services
- Triggering innovation
- Providing new jobs

RELEVANT SDGS

3 BARRIERS AND LOCK-INS

HOW TO ESTABLISH

- COVID-19 resilient research and innovation cooperation towards sustainable food systems.
- Better research on food environment, food culture and household food choices which support healthy nutrition choices.

HOW TO BUILD A BETTER LINKAGE BETWEEN

- Research and food system actors/innovators
- Projects funded by research and innovation and development cooperation
- EU/African Union (AU) Member States initiatives
- Agricultural and health policies towards nutrition sensitive food policies

HOW TO FIND THE RIGHT BALANCE BETWEEN

- Place-based solutions and scaling-up opportunities
- Fostering local food markets and the export of high quality food products for income generation
- Supporting local production and markets, and for example low mycotoxin contaminant levels
- Tax border regimes for food and agricultural inputs and the need for open borders and support for local production.

4 ENABLERS OF CHANGE

- *New job opportunities*: revitalised rural–urban food connections provide jobs and income for farmers and other actors in the rural/urban food system.
- *Research and innovation cooperation in the Food and Nutrition and Sustainable Agriculture Priority in the EU-African Union Collaboration based on EU/AU Members.*
- *Recent political commitment to a positive change:* Green Deal and the Farm to Fork strategy.
- *Highlighting the importance of the food environment and private sector* (e.g. food industry): public-private partnership, better regulations and right incentives can provide benefits to the private sector.

5 RESEARCH AND INNOVATION NEEDS

Many research and innovation actions under Horizon Europe will address the aforementioned opportunities and challenges, and build upon the work of ongoing projects of the HLPD-FNSSA partnership. These projects are compiled in the HLPD-FNSSA database ([239]). They are funded by complementary instruments such as:

1. The African Union Research Grants (AURG): Funded by the Pan-African Budget line of DG DEVCO and managed by the African Union Commission. Two calls for proposals resulted in the funding of close to 20 projects with a budget of around EUR 1 million per project. Coordinators are mainly from Africa.

2. The LeapAgri ERA-Net is a joint funding scheme of Horizon 2020 with funding agencies from 11 European and 9 African Union Member States. 27 projects are funded with partners from Africa and Europe.

3. Targeted Horizon 2020 projects, which are rather big projects with budgets of several million euros built on African and European partnerships. Coordinators are either from Europe or coordination is shared between African and European coordination.

4. The DeSira Initiative which is based on bottom-up projects on national level in AU Member States, is contributing to the funding of African Coordination, to dedicated emergency initiatives such as the control of the 'fall armyworm', a new expanding maize pest in Africa, and to the funding of the CGIAR system.

The HLPD-FNSSA priority is steered by the FNSSA Working Group with nominated expert representatives from the African Union Commission, the European Commission, and four African and four European Union Member States. The FNSSA working group takes initiatives towards clustering and monitoring and evaluation towards impact. The working group is supported by a secretariat provided by the Horizon 2020 coordination and the support action LEAP4FNSSA.

The R&I support to the implementation of the FNSSA partnership under Horizon Europe will continue to help address priority areas to achieve food and nutrition security and sustainable agriculture. The R&I activities under the partnership will also contribute to the Farm to Fork strategy by strengthening EU-AU efforts in building resilient food systems tackling climate change, protecting the environment and preserving biodiversity. A safe and sustainable African food system is particularly important in light of the African Continental Free Trade Agreement which will bring to bear the world's largest free trade zone, by country, offering a great opportunity for agri-food systems in Africa.

([239]) https://library.wur.nl/WebQuery/leap4fnssa-projects?q=*

In particular, the implementation of the FNSSA roadmap under Intervention Area 5 will focus on:

- Food systems and nutrition,
- Food safety for food markets and trade, and
- Support the coordination and working towards impact of the FNSSA priority.

Future R&I could be relevant to:

FOOD SYSTEM GOVERNANCE IN CRISIS SITUATIONS – FOOD SECURITY AND MAPPING

The COVID-19 crisis has revealed the weakness of food system governance. In addition to the risks of pandemics there is strong evidence that higher temperatures, droughts, floods, and changing weather patterns expected from climate change will exacerbate the disaster risks. Undernutrition could further increase in African regions affected by infectious diseases and weather disaster risks. Development of innovative methodologies/models are needed to improve food security risk scenarios which also take into consideration climate change. Better established and implemented food policies of cities can help to strengthen citizen access to healthy and nutritious food from local supply chains. Such a food cities approach is promoted by the Milan pact of cities, and builds on the recommendations of the Rural Africa Task Force report. Research and innovation is needed to strengthen actors, innovators and food businesses in such approaches. It should include rural small cities, strengthen their links to small-scale and family farms in rural areas. It will help in understanding the connectivity between European and African food systems and promote innovation for certification/traceability/standards/controls and strengthen innovations for markets for sustainable/organic products, including the trade aspects of sustainable food systems.

COMBATING MALNUTRITION – SAFE, NUTRITIOUS, AFFORDABLE AND AVAILABLE FOOD FOR SUSTAINABLE (AFRICAN) DIETS

Research and innovation is needed to develop and test approaches to improve nutrition by a deep understanding of the unmet nutritional needs, aspirations, behaviours and preferences of consumers who remain under-served by markets and face limited access to affordable nutritious foods.

IMPROVED FOOD SAFETY FOR AN AFRICAN CONTINENTAL FREE TRADE AGREEMENT

Researching evidence, by analysing contamination risks in view of national food laws supporting the development of an African Food Safety Authority, will contribute to establishing a common international understanding and trust of standards and certification of food health accepted and agreed by both sides. Also, establishing Risk Alert systems in case of any unforeseen risk/problem. Policy labs with stakeholders, researchers and citizens will support the process.

ALIGNING PREDICTIVE CLIMATE MODELS, ON FOOD SECURITY, SUPPORTING DATA-DRIVEN DECISION-MAKING

Advanced food security early warning systems or other digital tools to prevent and effectively address food security risks, including improved weather observatory. Development of innovative digital tools to support vulnerable households and communities to establish household community systems that can respond to emergencies.

RESOURCE EFFICIENCY AND THE CIRCULAR ECONOMY FOR SUSTAINABLE VALUE CHAINS

Research and innovation to test approaches to avoid food losses and food waste. It will contribute to understanding the connectivity between European agrifood systems and African agri-food systems. This will link farm level action to post-harvest level action. It will foster innovation in sustainable storage and packaging, in water resource efficiency, energy efficiency, nutrient cycling, sustainable energy sources and biomass valorisation. And it will promote citizen/consumer engagement and producer responsibility with regards to GHG reduction and traceability with certification schemes in the food system.

INNOVATION ACCELERATOR FOR AFRICAN FOOD ENTREPRENEURS

Innovative tools are needed to identify and scale-up business ideas from ongoing research and innovation projects. The Innovation Accelerator will also use the EU-AU business forum, EU-AU food entrepreneurs and business ideas for public goods provisions. It will use methodologies such as the World Food Programme Innovation Accelerator and reach out to innovation hubs which are linked to the Fourth Priority on Innovation of the EU-AU High Level Policy Dialogue.

6 SHOWCASING SOLUTIONS

Under Horizon 2020 the EC is investing around EUR 100 million in projects related to agri-food systems Africa. Some key projects are listed below, while there are still other project about to begin.

Ongoing research and innovation projects of the HLPD-FNSSA partnership are funded by complementary instruments and funds. These projects are compiled in the HLPD-FNSSA database:

- **The LeapAgri ERA-Net -** A long-term EU-Africa research and innovation partnership on Food and Nutrition Security and Sustainable Agriculture (2016-2021), total budget EUR 33 M., EC contribution: EUR 11 M. LEAP-Agri ERA-Net is a joint funding scheme of Horizon 2020 with funding agencies from 11 European and 9 African Union Member States. 27 projects are funded with partners from Africa and Europe.

- **The African Union Research Grants (AURG):** Funded by the Pan-African Budget line of DG DEVCO and managed by the African Union Commission. Two calls for proposals resulted in the funding of close to 20 projects with a budget of around EUR 1 million per project. Coordinators are mainly from Africa.

- **Horizon 2020 projects**, rather big projects with budgets of several million Euros built on African and European partnerships. Coordinators are either from Europe or coordination is shared between African and Europe.

- **The DeSira Initiative** which is based on bottom-up projects at national level in AU Member States, is contributing to the funding of African Coordination, to dedicated emergency initiatives.

PATHWAY 10 – FOOD SYSTEMS AND DATA

1 SYSTEMIC CHALLENGES

Digital technologies are transforming our economy and society, affecting all sectors of activity and the daily lives of all Europeans. **Changes are fast and fundamental**. The volume of data produced in the world is growing ever more rapidly, from 33 zettabytes in 2018 to an expected 175 zettabytes in 2025 ([240]). Across and beyond food systems, there is a sharp increase in the number of smart connected objects ([241]) (e.g. farm machinery, robotics, home appliances, wearables), which — thanks to new technologies like artificial intelligence — host more and more of the data processing and analysis. Unsurprisingly, this level of innovation is having profound effects on value chains and business models ([242]). For example in the 'last mile' of

([240]) IDC, 2018.

([241]) Today, 80 % of the processing and analysis of data takes place in data centers and centralised computing facilities, and 20 % in smart connected objects. By 2025, these proportions are likely to be inverted (Gartner, 2017).

([242]) Examples of such impacts are described in 'Big Data in Smart Farming' (2017).

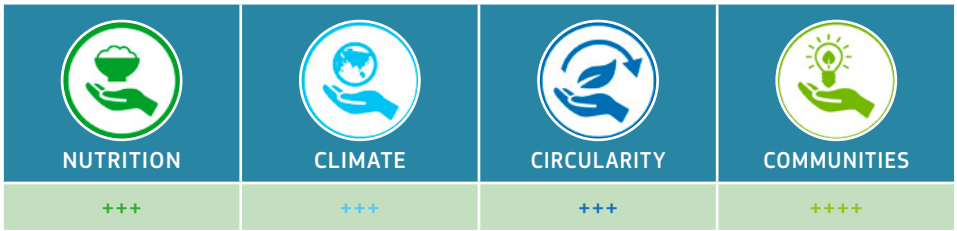
our food system, where innovative food retail, meal delivery and food-service concepts ('grab and go' stores, online grocery, online meal delivery, cloud kitchens, meal kits) are bringing fundamental change for companies and consumers.

Data-driven innovation is bringing **enormous benefits for citizens, farmers, food businesses, researchers and society**. It is reshaping the way we produce, consume, and share food and how we do research on it. Benefits are felt in every single aspect of our lives, ranging from more personalised and healthy diets, to more transparency about the food we are offered, to a more customised, local and sustainable food production. If managed correctly, many of these innovations will contribute to policy ambitions like those embedded in the EU Green Deal, the Farm to Fork strategy towards sustainable food, or the common agricultural policy, and have the potential to advance the concept of 'food citizenship' ([243]).

Data is the currency to boost data-driven innovation in EU food systems. **An innovative and well-functioning data economy** that helps to deliver on EU policy objectives is therefore of strategic importance. However, many **problems remain** and act as a barrier to achieving this goal ([244]). Problems range from low awareness of the potential of data driven innovation and of sharing data, over lack of infrastructure, applied technologies and cybersecurity to low skills and limited investment capacity. In addition, there is a growing call to give individuals, farmers and small businesses the tools and means to decide what is done with their data, to address the oligopolistic characteristics of today's data economy, and to improve its governance so that its development contributes in practice to sustainable, safe, resilient, fair, inclusive and healthy food systems.

2 CO-BENEFITS

Actions under this pathway will provide insights to improve the **functioning and fairness of the data economy** and develop capacities and approaches to allow a **wider adoption of data driven-innovation** to accelerate the transition to sustainable food systems, while also improving competiveness and resilience. These actions will therefore (directly/indirectly) deliver results to several of the four priorities of Food 2030. Key co-benefits are:



([243]) The term 'food citizenship' is defined as the practice of engaging in food-related behaviours that support, rather than threaten, the development of a democratic, socially and economically just, and environmentally sustainable food system.

([244]) See European Commission Communication 'A European Strategy for Data' – COM(2020)66 final, pp. 6-10.

NUTRITION AND HEALTH

- Make it easier for consumers to adopt a healthy diet
- Reduce obesity and other NCDs (e.g. through smart, personalised nutrition)
- Ensure food is safe and not subject to fraud (e.g. by food sensing, better traceability)
- Achieve a more customised and nutrition-sensitive food supply.

CLIMATE AND SUSTAINABILITY

- Make it easier for consumers, farmers and businesses to understand and reduce the climate and environmental impact of their actions
- Enable real-time supply chain transparency
- Manage increased complexity in agri-food production and supply chain processes
- Contribute to targets of Farm to Fork strategy and Green Deal

CIRCULARITY AND RESOURCE EFFICIENCY

- Optimise resource efficiency (e.g. energy, water, nutrients, land) and

reduce food waste from farm to fork

- Reduce administrative burden linked to nutrient use
- Enable circular approaches involving different supply chains and processes

INNOVATION AND COMMUNITIES

- Improve the uptake of data driven innovations in food systems
- Address digital divide and boost data/digital skills

- Embed the concept of data as a public good ('data commons') to improve governance of food systems, ensure food and nutrition security and improve resilience ([245])
- Improve the trade-off between the need for data-driven innovation and the need for personal data protection and data sovereignty
- Ensure fairer competition in the data economy and mitigate power asymmetries
- Engage more citizens as active participants in their food systems

RELEVANT SDGS

3 BARRIERS AND LOCK-INS

Several barriers limit the potential of data-driven innovation:

- **Lack of data governance**: organisational approaches and structures are missing to provide insights in the functioning, resilience and fairness of the data economy linked to EU food systems, and to propose measures to improve its outcomes versus EU policy objectives (ensuring food and nutrition security for all ([246]); transiting to a more sustainable, competitive, healthy, inclusive and resilient EU food system). In addition, the negative impacts of data-driven innovation are insufficiently monitored.
- **Imbalances in market power**: a small number of players (e.g. food retailers, data aggregators like Google or Facebook, equipment manufacturers, ERP platforms) accumulate large amounts of data. New approaches are needed to ensure fair competition (towards SMEs, farmers and citizens) and to tackle the oligopolistic characteristics of today's data economy ([247])([248]).

([245]) See also the plan for a Common European Green Deal Data Space in the EC Communication 'A European Strategy for Data', COM(2020) 66.
([246]) See 'Common Agricultural Policy, European Green Deal'.
([247]) https://ec.europa.eu/jrc/en/publication/semicircular-flow-data-economy
([248]) Competition Policy for the Digital Era, European Commission, DG COMP (2019).

- **Need to empower individuals to exercise their 'data rights':** Since increasingly large amounts of data are generated by consumers, they might be faced with risks of discrimination, unfair practices, and lock-in effects. There is a growing call to give individuals the tools and means (including regulatory means like GDPR and ePrivacy) to decide at a granular level what is done with their data ([249]). Those tools and means include consent management tools, personal information management apps, as well as personal data cooperatives or trusts acting as novel neutral intermediaries in the personal data economy. These approaches have a significant potential and are of high relevance to food systems, which often deal with sensitive and private data, and which include many micro-companies and SMEs.

- **Low availability of data**: there is not enough data available for innovative reuse, and there is low awareness of the benefits of sharing data. Some data is held by private actors and public authorities but is not shared, or the interconnectivity it is missing to do so. Other data faces problems of interoperability and quality within sectors and beyond. Some of that data could be used for public good (e.g. combat emergencies, improve nutritional health, improve governance, sentiment analysis), and should be part of a 'data commons' for EU food systems.

- **Low awareness of the potential of data-driven innovation and low skills and low uptake:** in 2017, there were approximately 496 000 unfilled positions in the area of big data and analytics in the EU-27 ([250]). Also in EU food systems, the general data literacy in the workforce and across the population is low. There is also a need to test and demonstrate cost-effective solutions at the farm and post-farm, and to increase uptake through purpose-driven investment support ([251]). Post-farm-gate businesses understand the importance of digitalisation but the concrete path to digitalisation is a lot less clear to many of them ([252]), which negatively affects the uptake of data-driven innovations. The 2020 EU SME strategy also highlighted the delay in digitalisation among SMEs in general. In fact only 17 % of SMEs have successfully integrated digital technologies into their businesses, compared to 54 % of large companies ([253]).

- **Lack of data infrastructures and technologies; lack of cybersecurity**: the digital transformation depends on the availability and uptake of secure, energy-efficient, affordable and high quality data processing capacities (e.g. cloud services). However, problems persist on both the supply and demand side of these services. For example, with regards to supply the EU remains technologically dependent on non-EU-players; and in terms of uptake it has

([249]) See mydata.org; Horizon 2020 Decode and LEDGER projects; solid.mit.edu; radicalxchange.org
([250]) IDC 2019.
([251]) Feeding future generations: How finance can boost innovation in agri-food, EIB (2019), p. 12.
([252]) S3 Food-project, Inventory of the challenges and needs of the food sector with regard to the digitalisation in the value chain and the related technologies (2020).
([253]) 2018 report by Digital Innovation Hubs Working Group; see also COM(2020) 103 'An SME Strategy for a sustainable and digital Europe'.

to be noted that only one in five SMEs uses cloud services ([254]). With regards to cybersecurity, data value chains are facing new, additional challenges as data moves closer to the user and smart connected devices grow in popularity.

4 ENABLERS OF CHANGE

The following enablers can make it possible to achieve the above-mentioned impacts and co-benefits.

GOVERNANCE

European governance of the data economy, data access and data use is being strengthened ([255]). It uses an **agile approach** that favours experimentation, iteration and differentiation over ex-ante regulation, to shape the context and to allow lively, dynamic and vivid ecosystems to develop in this fast evolving part of our economy. Future initiatives will further improve governance substantially by setting **clear and fair rules** on access and reuse of data, and by giving users the rights, tools and skills to stay in **full control of their data**. New insights on the development of the data economy in strategic sectors like food systems will be needed to shape these future governance frameworks.

R&I INVESTMENT

EU investment in research and innovation related to digitalisation in food systems has increased sharply under Horizon 2020, in Member States and in the private sector ([256]). A significant part has been in the area of **precision agriculture**, where enormous opportunities exist to address the needs of farming and improve both its competitiveness and sustainability. Towards the future, **more investment is needed** – in agriculture but also beyond – to build R&I capacities, to federate the many ongoing digital platforms, standards and initiatives at EU level, and to build data driven solutions that are effective, fair and inclusive. **Public R&I investment** is key. It devises routes and solutions to grow the data economy in food systems in such way that it also serves public policy goals including the EU Farm to Fork strategy for sustainable food and the EU Green Deal, and that it also takes into account the rights and needs of citizens, communities and vulnerable groups.

([254]) Eurostat, cloud computing statistics on the use by enterprises (2018)
([255]) See European Commission Communication 'A European Strategy for Data' – COM(2020) 66 final.
([256]) https://www.rolandberger.com/publications/publication_pdf/roland_berger_precision_farming.pdf, page 10.

COMPETENCES

By 2025 the EU and Member States should have halved the current gap of 1 million digital specialists, including by putting a focus on increasing the participation of women. This makes **investments in skills and general data literacy** a key enabler, overall and within food systems, which form an important part of our economy. Many EU initiatives are ongoing. The Digital Europe programme ([257]) will contribute to narrowing the gap in terms of big data and analytics capacities. The Reinforced skills agenda ([258]) will set out a pathway to increase the proportion of the EU population with basic digital skills (now at 57 %). The Digital Education Action Plan ([259]) will reinforce better access to and use of data as one of its key priorities, and include support to **Open Science** and **Citizen Science**. The SME strategy ([260]) sets out measures to improve **digital skills in SMEs**.

INFRASTRUCTURE

A thriving digital innovation ecosystem needs technologies, standards, tools and infrastructures to store and process data, and to ensure the interconnectivity and interoperability that is required for new solutions. EU and other investments are ongoing to advance these. This includes infrastructure for edge and cloud, 5/6G, artificial intelligence, blockchain, IOT, earth observation, sensors, robotics, and so on. Horizontal actions are under way at EU and Member State level, but equally there is **need for investments that valorise these for use in food systems**.

COLLABORATION

Collaboration across the different parts of our food systems is instrumental to enable integrated approaches to issues that that are of mutual concern to all such as stepping up transparency, securing traceability and safety of products and processes, better decision-making in food systems at macro- and micro-level. **Common European Data Spaces** in strategic sectors and domains of public interest will be implemented, and will demonstrate the potential of collaboration in this area.

([257]) https://ec.europa.eu/digital-single-market/en/europe-investing-digital
([258]) https://ec.europa.eu/social/BlobServlet?docId=19362&langId=en
([259]) https://ec.europa.eu/education/education-in-the-eu/digital-education-action-plan_en
([260]) EC Communication 'An SME Strategy for a sustainable and digital Europe' COM(2020) 103.

5 RESEARCH AND INNOVATION NEEDS

The following type of R&I actions will contribute to realising the impacts and co-benefits of this pathway.

1. Actions that improve insights and understanding with regards to the data economy for food systems, its functioning, its development and its impact, and with regards to data-driven innovation. Actions that examine different strategies and frameworks to advance data driven solutions in food systems, and clarify their potential for food system transition, fairness and competitiveness.

2. Actions that valorise emerging technologies, tools, standards and infrastructure for use in food systems. Actions that enable their deployment to solve issues and challenges or opportunities that are specific to food systems, that improve trust and data ownership, and that can deliver impacts that are relevant in the context of EU policies, in particular the EU Farm to Fork strategy and the EU Green Deal.

3. Actions that strengthen the research and innovation ecosystem for data-driven-solutions, and that thereby contribute to boosting the capacity to innovate. Actions that advance Open Science in the scientific fields that relate to food systems.

4. Actions that advance skills and education and address digital divide among consumers, scientists and other food system actors.

6 SHOWCASING SOLUTIONS

Within Horizon 2020 the EC has invested in excess of EUR 200 million ([261]) in projects related to digitalisation and data in food systems. Some key projects are listed below. It needs to be noted that a significant part of Horizon 2020 investments have been related to agriculture and precision farming.

- **IOF 2020 – Internet of food and farm 2020** (2017-2020), IoT-01-2016, EUR 30 million. The project aims to accelerate the adoption of Internet of Things (IoT) for securing sufficient, safe and healthy food and to strengthen competitiveness of farming *and* food chains in Europe. Includes many use cases as well as trials with end users from the arable, dairy, fruits, vegetables and meat verticals.

([261]) For agriculture and rural areas, further information is available under https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/farming/documents/factsheet-agri-digital-transformation_en.pdf

- **S3FOOD – Smart Sensor System for food safety, quality control and resource efficiency in the food processing industry**, (2019-2022), INNOSUP-01-2018-2020, EUR 5 million. The project will facilitate the modernisation and digitalisation of the food processing industry. It stimulates the integration of IoT and related technologies via the implementation of smart sensor systems in the food production processes.

- **PROTEIN: Personalised nutrition for healthy living** (2018-2022), DT-SFS-14-2018, EUR 7 million. The project develops an end-to-end ecosystem that will engage people to a healthy, pleasurable, nutritional and sustainable diet by offering a daily programme adapted to their needs and driven by their personal preferences, physical and physiological characteristics as well as their health status. It creates an ICT-based system for providing personalised nutrition based on the collection and analysis of large volumes of data related to users' dietary behavioural patterns, physical activity and individual parameters.

- **ERA-NET Cofund ICT-AGRI-FOOD – ICT technologies for sustainable food systems** (2019-2024), SFS-31-2019, EUR 5 million. This co-fund will boost cooperation between EU Member States. It will organise and fund joint calls for transnational research projects on an annual basis. Its aim is to ensure the insertion of digital technology into the agri-food sector.

- **FNS CLOUD – Food Nutrition Security Cloud** (2019-2023), DT-SFS-26-2019, EUR 10 million. The project will overcome fragmentation by federating data on diet, health, and consumer behaviour as well as on sustainable agriculture and on the bio-economy. This will increase the exploitation of food nutrition security knowledge and reduce knowledge gaps that inhibit public health and agricultural policy. It will support the food industry in reducing development and production costs and increasing sustainable production. Ultimately, it will facilitate informed and healthy choices by consumers.

- **DECODE – Decentralised Citizens Owned Data Ecosystem** (2016-2019), ICT-12-2016, EUR 5 million. The project aimed to increase digital sovereignty of European citizens by enabling them to produce, access and control their data and exchange contextualised information in real-time, and in a confidential, and scalable manner. It developed a modular privacy-aware IoT hub with a free and open-source operating system backed by a state of the art blockchain infrastructure supporting smart-contracts and privacy protections.

ANNEX - HORIZON 2020 PORTFOLIO ANALYSIS

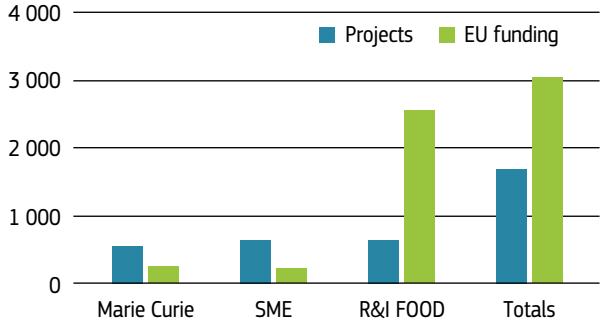
MAPPING OF EU FOOD SYSTEMS RELATED RESEARCH & INNOVATION

1. PROGRAMMES FUNDING FOOD SYSTEMS RELATED R&I

Analysis of the H2020 CORDIS database indicates that **1631** food-related projects were supported under Horizon 2020 during the period 2014-2020. These are projects where there is a definable food application relevant to one or more parts of the food chain. It should be added that many of the projects relate to the application of generic technologies to help solve food production or processing issues. These food projects can be grouped into three groups- **Marie Curie (MC), SMEs, and R&I FOOD**.

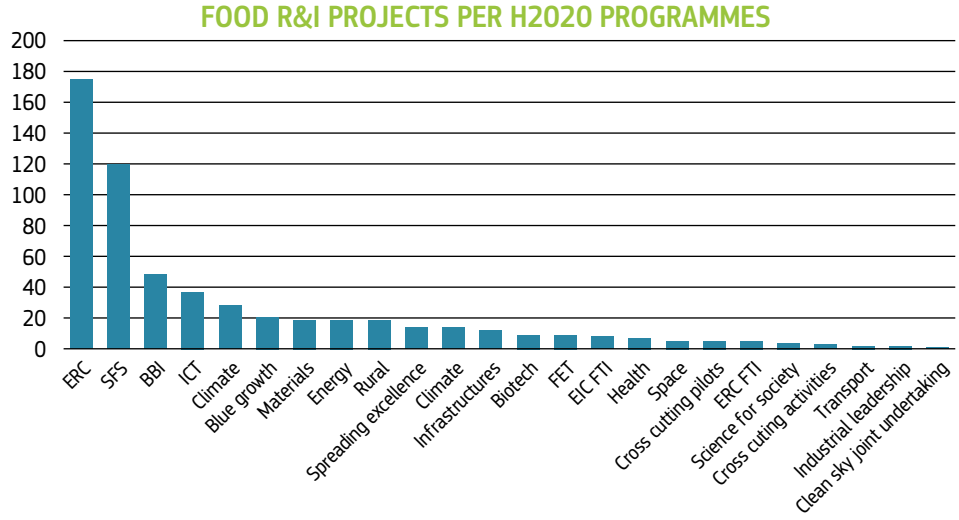
Project Groups	Projects	EU funding
Marie Curie	470	280 M€
SME	575	250 M€
R&I FOOD	586	2 532 M€
TOTALS	**1631**	**3 062 M€**

H2020 FOOD SYSTEMS RELATED PROJECTS

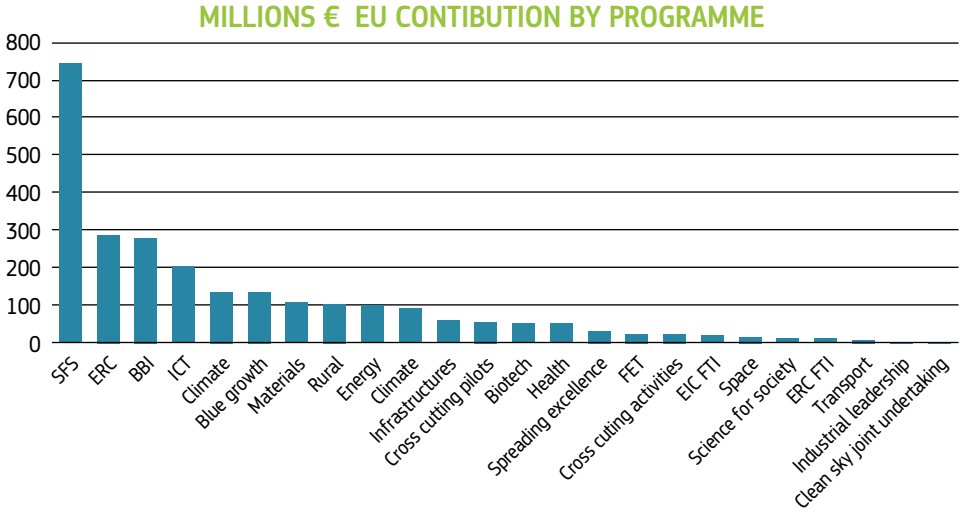


Both the **MC** and **SME** groups have large number of projects but many of the SME grants are based upon phase 1 type projects which test the feasibility of an idea, or in the case of MC they are based on individual grants to single entities to carry out post graduate research. All projects in both groups deal with food but their financial contribution is only around 17% of the total. The **R&I FOOD** group refers to the **586** contracts representing **83%** of research funding where we find broader pan- European collaborative research projects.

The **R&I FOOD** group is the subject of the remaining analysis within this report. The graphic below shows the wide diversity of R&I food projects found across 24 different programmes of the 3 H2020 pillars, with most food projects found in the **ERC** programme of pillar 1 followed by Sustainable Food systems (**SFS**), and BBI (Biobased Industries Joint Undertaking).

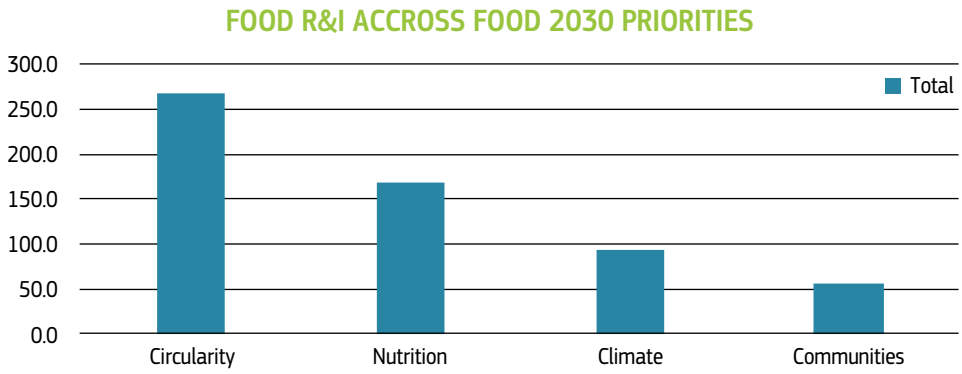


This graphic below shows the distribution of EU funding across the 24 programmes and where the **SFS** is by far the biggest contributor with **30%** of the total with **EUR 746 million**, out of a total of **EUR 2532,3 million**.



2. RELEVANCE TO FOOD 2030 PRIORITIES

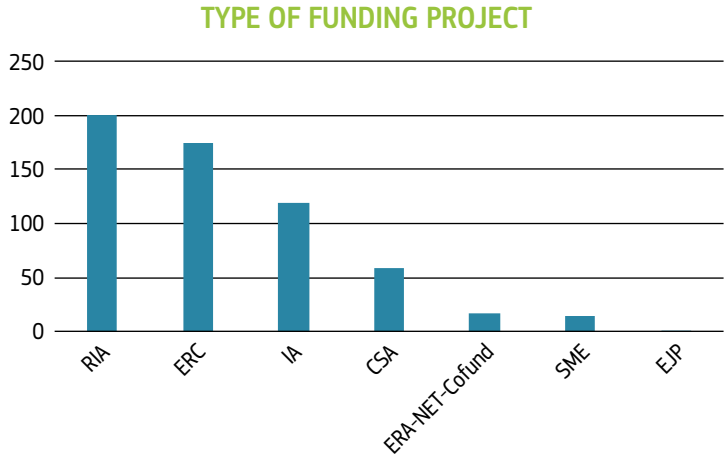
The graphic below relates to distribution of the projects across the four **FOOD 2030 priorities** where circularity is 49% of the total. Circularity in this case relates to all processing and production inputs



3. TYPES OF PROJECTS

The following graphic reveals the breakdown of **R&I Food** projects into 7 different types of actions, most of which are Rand Innovation Actions.

Type of funding	Count
RIA	200
ERC	175
IA	119
CSA	59
ERA-NET-Cofund	17
SME	15
EJP	1
Grand Total	**586**

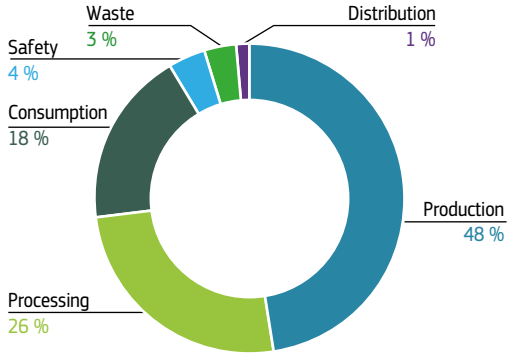


4. DIVERSITY OF ISSUE ADDRESSED

The R&I Food projects have been assigned to the following main food system sectors: primary production, food processing, consumption (including consumers and nutrition), food safety, food waste and food distribution (logistics, food services). The chart below reveals that nearly half or the funding in Horizon 2020 targeted primary production, and a quarter was supporting advances in food processing methods and technologies.

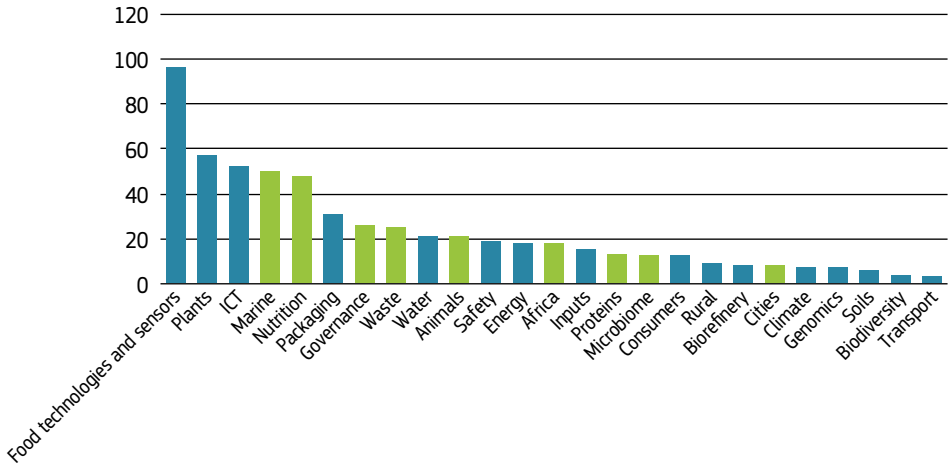
Distribution of R&I Food projects across food system sectors

FOOD CHAIN DISTRIBUTION	Count of call
Production	279
Processing	150
Consumption	108
Safety	22
Waste	19
Distribution	8
Grand Total	**586**



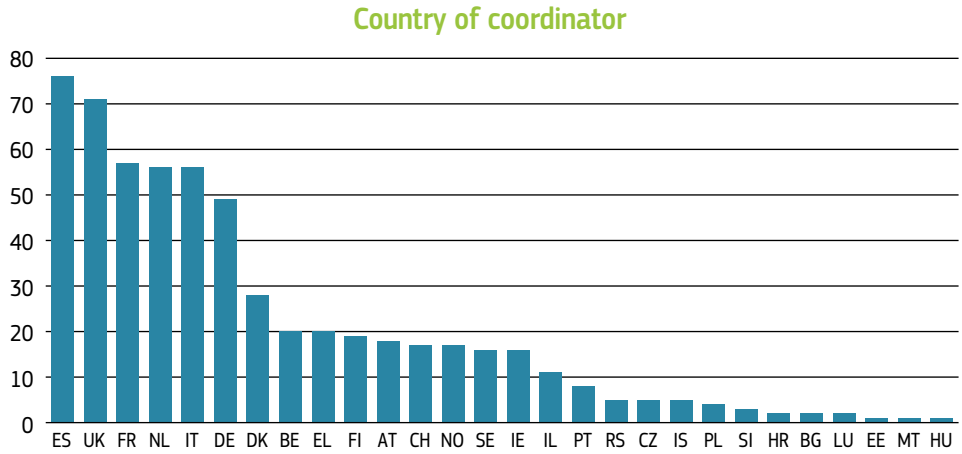
The R&I Food projects were further classified according to which main **issue** they addressed. The graph below represents their distribution. The one in **green** reflect issues that are particularly relevant to the build-up of the ten Food 2030 Pathways to be deployed within Horizon Europe's Cluster 6 Intervention Area 5 " Food Systems".

Distribution of R&I Food projects across issues and Food 2030 Pathways (in green)

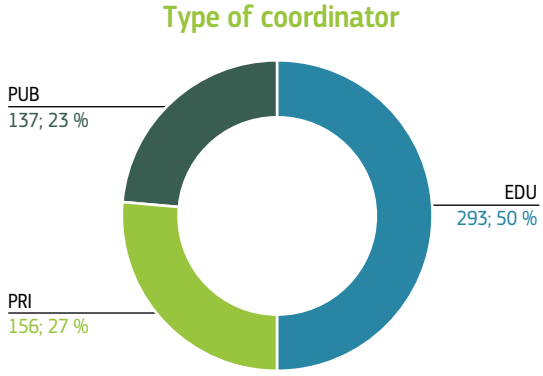


5. PROJECT COORDINATION

Below is the breakdown of the coordinators, by country, with ES, UK, FR, NL, IT and DE in the lead.



The following graphic shows the further breakdown of the types of coordinators for R&I food projects. It reveals that half are led by education establishments (EDU), and approximately one fourth by private sector establishments (PRI) and public sector establishments (PUB), respectively.



This portfolio analysis has been carried out by reviewing Horizon Europe project data available in the EC's CORDA data warehouse. The degree of alignment of projects with respect to food systems issues, sectors and food 2030 pathways was assessed by reading project titles and abstracts and assigning projects to the most relevant categories.

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This publication frames the deployment phase of the European Commission's Food 2030 initiative and is meant to guide future research and innovation policy reflections relevant to Horizon Europe, the Farm to Fork strategy and European Green Deal, and beyond. The report sets out 10 Pathways where research and innovation can concretely deliver co-benefits to nutrition, climate, circularity and communities, at multiple levels: from local to international. It also underlines that a systemic and transdisciplinary approach to research and innovation is crucial for success and improved impact. The COVID-19 crisis has shown that transformations are not only technical and academic; they also encompass social, legal, economic, financial, ethical, and philosophical dimensions, which need to be fully embedded in future R&I policy and programmes.

Research and Innovation policy

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