# Deliverable 3.3

In-depth analysis of 10 pathway areas for food systems transformation

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Task Leader: Tommaso Emiliani

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Authors: Tommaso Emiliani, Jonas Lazaro-Mojica, Matthieu Flourakis, Beatrix Wepner, Jolien Wenink, Kristiaan P.W. Kok, Ingeborg Korme, Floor Geerling-Eiff, Doris Schartinger, Vincent Linderhof

Contributions from Jolanda van den Berg, Muriel Verain, Thom Achterbosch, Barbaros Corekoglu, Rebeca Fernandez.



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# Introduction

In light of the urgent need to identify concrete R&I actions to feed into the upcoming Horizon Europe Programme, the European Commission has developed an approach structured around **10 focus areas** that are considered pathways with the potential to deliver impact on EU food systems transformation (European Commission, 2020). This report aims to deepen and expand the analysis of pathways areas building on the experience and results of previous activities from the FIT4FOOD2030 project, including the findings contained in the policy briefs produced by the EU Think Tank; the training modules developed by City and Policy Labs; and the previous mapping of trends, barriers, enablers & potential breakthroughs for transformation.

**Recent political and policy developments** are paving the way towards food system transformation. The 2019 European Parliament elections and the appointment of the Von der Leyen European Commission, have provided new political guidelines and a renewed impetus for food systems thinking and the sustainability transition. Various recent publications – (1) the European Commission Communication on the **European Green Deal** in December 2019 (European Commission, 2019), (2) the **Farm to Fork & Biodiversity Strategies** in 2020 (European Commission, 2020b & 2020c), and (3) the '**Science Advice for Policy by European Academies' (SAPEA) report on EU sustainable food systems** in April 2020 (SAPEA, 2020) – have produced a coherent outlook to frame current food systems issues establishing clear goals, in some cases with the provision of precise targets and indicators.

The uptake of the **FOOD2030 systems thinking approach** has been made clear by the evolution of the ongoing discussions on strategic partnerships and collaborative initiatives to be taken at the European and international level to tackle complex global problems. At the same time, the ongoing Covid-19 pandemic is underlining that the current food systems are unsustainable, while the importance of Food and Nutrition Security becomes even more apparent in view of achieving economic recovery, mitigating social inequalities and avoiding conflicts within and between societies.

In order to support the urgently needed food systems transformation, it is key to achieve an increased impact of the R&I investments made. In the European Commission proposal for the new **Horizon Europe** R&I programme (European Commission, 2018) – in course of discussion in trilogues with the European Parliament and the Council at the time of writing – there is an increased focus on 'European partnerships' as useful tools to design R&I systemic solutions to support a fair, inclusive and



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competitive transition to sustainability (European Commission, 2020d). In particular, the proposed **Partnership on Safe and Sustainable Food Systems**, to be established with EU and associated countries, the private sector, foundations and other stakeholders, would represent a significant step to deliver on global challenges associated with food systems issues and modernise industry. Such partnership would also function as a connector between other relevant partnerships and the 'missions' established by the new Horizon Europe Programme, which will deal with digital, health and environmental challenges crucial for food systems transformation, and will have a clear mandate to solve concrete issues within a certain timeframe and with a dedicated budget (European Commission, 2020e). Parallel to the partnerships foreseen in the framework of Horizon Europe, the European Commission is devolving considerable resources to the establishment of strategic partnerships with international allies committed to a rules-based governance system. Among these, the new **Partnership with Africa** ranks high in the EU's priority list. Such partnership will complement the action of the current **EU-Africa R&I Partnership on Food and Nutrition Security and Sustainable Agriculture** by putting forward new agreements to tackle common issues such as the fight against climate change; digital transformation; sustainable growth and jobs; peace and governance; and migration and mobility (African Union and European Commission, 2020). These and other efforts show an understanding that involving key actors in finding shared solutions to global issues is both ethically responsible and geopolitically necessary.

This in-depth analysis of 10 pathway areas is one of the first European reports to include a discussion of the potential impacts of the Covid-19 pandemic – and the measures EU Member States have taken to contain it – on food systems. While the Covid-19 event is too recent to predict its full impact and produce tailored R&I recommendations to exploit its potential to accelerate the food systems transformation, the analysis produced in this report takes the current context into account. Whenever possible and appropriate, the most recent scientific evidence has been used to substantiate the arguments made in the areas researched.

In light of the ongoing policy developments and historical events that will shape the future of EU food systems in the next future, this report has the ambition to provide policy-makers at the European and Member States level with a comprehensive outlook on the most pressing issues and relevant levers to enable the sustainable transition to the EU food systems of tomorrow. The analysis carried out in this report is geared towards providing solid insights to support the action of the soon-to-be-established Horizon Europe Partnership on Safe and Sustainable Food Systems, as well as the enactment of the European Commission FOOD2030 policy framework.



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## Positioning of the report within the FIT4FOOD2030 project

The analysis of 10 pathway areas contained in this report occupies a strategic position in the FIT4FOOD2030 project ecosystem. It takes into account the catalogue of showcases previously identified in Work Package 3 (deliverable 3.2b) to build its own selection of cases for each pathway area. In terms of project structure, it is a bridge between the trends, barriers & enablers for food system transformation identified in Work Package 2 and the potential social, economic and technological potential R&I breakthroughs identified in Work Package 4. In terms of project lifecycle, this report builds its analysis on the experience of policy alignment process emerging from **Policy Labs** and the research findings delivered by **EU Think Tank Policy Briefs** (Work Package 5), as well as the mapping of social and educational needs, barriers and enablers emerging from the educational modules implemented by the seven **City Labs** and seven **Food Labs** (Work Package 6).

## Methodology

This report is divided into 10 analytical chapters, mirroring the division into 10 pathway areas identified by the European Commission Directorate-General for Research and Innovation Unit on "Bioeconomy and Food Systems" through a public consultation and a workshop held on 4 March 2020. The "Pathways for Action" that are being developed under the Food 2030 initiative were used in the workshop to focus the discussion on those R&I needs that have the potential to deliver real impact. These pathways provide an evidence-based logic to future-proof food systems through R&I action and investment (European Commission, 2020).

The 10 pathway areas are:

- Governance & Systems Change;
- Urban Food System Transformation;
- Food from the Oceans & Freshwater Resources;
- Alternative Proteins & Dietary Shift;
- Food Waste & Resource Efficiency;
- The Microbiome World;
- Healthy, Sustainable & Personalised Nutrition;
- Food Safety Systems of the Future;
- Food Systems Africa;
- Food Systems & Data.



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The FIT4FOOD2030 research team committed to the production of this deliverable included Task Leader EIT Food, which led and coordinated the process; ILSI Europe; Food4Life; the Austrian Institute of Technology (AIT); the Joint Programming Initiative Healthy Diet for a Healthy Life (JPI HDHL); Vrije Universiteit Amsterdam (VU); JPI Healthy and Productive Seas and Oceans (JPI Oceans); and Wageningen University & Research (WUR). Over the course of six months from April through October 2020, partners met virtually 7 times to reflect on the findings of the workshop, develop an analytical framework for the deliverable, allocate tasks, and discuss progress. Responsibilities for research were allocated according to the highly specialized expertise available. Partners carried out research and writing tasks autonomously or in small groups, mobilizing the support and scientific expertise available in their own networks. The deliverable undertook two rounds of review at the FIT4FOOD2030 level: a first round of internal peer-review, where authors commented on the chapters drafted by each other; and a second round where Consortium members not involved in the writing of this report carried out a thorough review of overall consistency of the deliverable.

Each chapter presents the same structure and is divided in six sections. In the **first section**, a **pathway area** is described with reference to the related **social, economic and environmental issues impacting food systems**. The analysis provided builds on the description of trends and megatrends identified by Work Package 2 and goes beyond by framing issues in terms of "needs" for the food systems, and the analysis provided is geared towards exposing the costs of non-action in addressing the problems.

The **second section analyses potential social and economic breakthroughs** towards food systems transformation building on the identification of breakthroughs carried out in WP4. Breakthroughs are here understood as concrete, innovative actions that have not yet established as mainstream tools for transformation, and yet show transformational potential.

The **third section** addresses the **R&I action required in each pathway area**, as well as the social, technological, financial and political barriers & enablers to be taken into account. The actions highlighted in this section are less specific but more comprehensive than the isolated initiatives described in the section on the breakthroughs.

The **fourth section** describes the **potential impact and co-benefits associated with R&I effective action** in a pathway area. Impact and co-benefits are assessed against the 4 dimensions of the EU FOOD2030 policy framework (e.g. Nutrition, Climate, Circularity and Innovation), as well as the UN Sustainable Development Goals (SDGs). This section is conceptually specular to the first section on needs. While the analysis in the first section was framed in terms of costs of non-action, section four frames it in terms of gains associated with action.



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The **fifth section** looks at the **policy alignment of potential R&I action** on a pathway area with existing frameworks at the EU or international level. A review of relevant policy documents, important provisions in specific agreements and most recent political events in the evolving landscape is carried out for each pathway area.

In the sixth section, two **selected cases** are provided for each pathway area. The catalogue previously produced in Work Package 3 described 'showcases' as R&I initiatives with the potential to accelerate food systems transformation based on the principles of novelty, systems thinking and use of a Responsible Research of Innovation characterized by inclusiveness of actors and co-creation of processes (FIF4FOOD2030, 2020). In this report, the research team decided to move away from the concept of showcases to embrace that of 'selected cases'. The change reflects a methodological shift in the criterion used for the selection of cases, as well as for the analysis carried out on each case. Here, emphasis is put on the kind **of impact that selected cases have or can have on food systems**; on a honest **assessment of selected cases' short-comings against the FOOD 2030 analytical framework** (FIT4FOOD2030, 2018); and on an **evaluation of selected cases' prospects for establishment as breakthroughs**. Selected cases are diverse in kind, as they include private initiatives, social awareness campaigns, digital technologies applied to participatory processes and EU R&I projects.

## Positioning of the report in relation to the European Commission 'FOOD2030 Pathways for Action' Report

The European Commission published on World Food Day, Friday 16 October 2020 its own report on the 10 pathways for food systems transformation (European Commission, 2020f), providing its internal assessment of the systemic challenges; co-benefits; barriers and lock-ins; enablers of change; R&I needs; and showcases. While the FIT4FOOD2030 report and the Commission's report address the same questions, the analyses they provide show a high level of complementarity. The FIT4FOOD2030 report aims at reflecting on and expanding the internal assessment of pathway areas provided by the European Commission by making use of its distinctive assets: (1) while the European Commission's report has been developed within the Unit C2 – Bioeconomy and Food Systems of DG Research and Innovation, **the FIT4FOOD2030 research team is composed by independent analysists** representing scientific research centres, Higher Education Institutions, Public-Private Partnerships, public authorities, and industry actors, thus providing a truly diverse, inclusive and comprehensive assessment of the most pressing issues defining each pathway area, in accordance with the principles of the food systems approach to R&I (Gill et al., 2018); (2) while the European Commission's



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publication provides a timely and concise overview of the main elements shaping each pathway, the FIT4FOOD2030 report offers an **in-depth exploration of the 10 research areas**, based on the most recent, **cutting-edge scientific evidence available** and on fresh insights from **selected case studies from the business sector and the EU agri-food tech start-up ecosystem**; (3) the FIT4FOOD2030 report has paid particular attention to the **assessment of the policy alignment** of the action foreseen in each pathway area with initiatives and legal frameworks existing at the European and international level, with the goal to highlight the consistence of the FOOD2030 framework with the evolving political landscape, and promote the establishment of enabling regulatory environments co-designed by all relevant actors across the food value chain and agreed at the international level.

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# Governance & Systems Change


**In order to steer transformation towards sustainable and healthy food systems, there is a need to adopt novel and systemic governance approaches as well as research and innovation approaches that are supportive of such arrangements. The many interlinked challenges in food systems require cross-sectoral governance interventions that are able to mitigate trade-offs, foster synergies and co-benefits, while taking into account the multiplicity of knowledge, values and perspectives involved. This requires multi-level interventions, policy experimentation and the creation of transformative spaces where policy makers, researchers and societal stakeholders can co-create and co-evaluate knowledge, innovations and policies needed for systemic change. Supporting such governance efforts also requires policy innovations such as the programming of more transdisciplinary and systemic R&I efforts that engage the wider society through Responsible Research and Innovation (RRI).**



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## Societal, economic & environmental needs

Currently, a number of interlinked societal challenges face food systems in Europe. These include health-related challenges such as the double burden of malnutrition, the rise of Non-Communicable Deceases (NCDs) and rising antimicrobial resistance (AMR); ethical challenges related to inequities in food systems; animal welfare concerns; and broader societal challenges related to the accessibility, affordability and availability of healthy and sustainable food in the EU. For instance**, childhood obesity is as prevalent as 30% in EU countries** (WHO, 2017) while **adult obesity has a prevalence of 25%** (WHO, 2018). Additionally, **AMR** is a major challenge as it **accounts for approximately 33.000 deaths per year in the EU** and is estimated to cost the **EU 1.5 billion euros per year in productivity losses and healthcare costs** (EC, 2019). These problems are amplified by long-term drivers of change, such as climate change, urbanisation, population growth, and consumerism (Haddad, et al., 2016). Responding to these intertwined dynamics is critical to achieve the United Nation's Sustainable Development Goals (SDGs) and the targets of the Paris Climate Agreement (Caron et al., 2018) and points to the need to combine all possible levers to foster transformation (Editorial, 2019).

European food systems' societal needs are strongly entangled with their economic needs. Economic challenges include health care costs due to poor diets, the cost of food waste and uncertain prospects for growth. **The health costs of addressing the double burden of malnutrition** in the EU are estimated to be **120 billion euros per year** (Shrimpton & Rokx, 2012). An estimated **100 million tons of food is wasted every year in the EU** (EEEA, 2016). In Europe, food waste is generated across the supply chain with the predominant concentration at household level, where it is estimated to be 46% (EEEA, 2016). Little is known about food waste generation at farm level, although it is viable – thus, there is a need to investigate and stimulate transformation across multi-levels of the supply chain in an effort to address food waste. Across different parts of Europe, **people with lower socio-economic status (SES)** reportedly consume fewer fruits and vegetables than those with higher SES and **are less likely to eat regular and healthy meals** (European Commission, 2020a). Furthermore, **moderate food insecurity also affects over 100 million people** across Europe (and Central Asia) (FAO, 2019). Structural changes are needed to address these economic challenges and to reduce inequalities, for instance through channeling more public investments into rural and agricultural areas and improving the quality of spending (FAO, 2019). Additionally, sustainable food systems need to economic benefits for all stakeholders involved, for instance through increasing workers' wages, enterprise profits and food supply improvements for consumers (FAO, 2018). This includes inclusive economic growth as well as green growth (FAO, 2018). Research as well as transformation efforts thus need to focus on developing an economy that prioritizes sharing and resource protection, such as stimulating



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consumers becoming co-producers of goods and services like in urban farming concepts (Gill et al., 2019).

Finally, European food systems are facing increasingly problematic **environmental challenges such as biodiversity losses**, negative impacts from agriculture and fishing on soil health, marine health and animal welfare, water and air pollution, increased carbon and nitrogen emissions as well as deforestation and land degradation (EESC, 2016). In particular, **16.5% of vertebrates and pollinators are threatened with extinction** (FAO, 2019), **agriculture is responsible for around 66% of the renewable freshwater use** (EEA, 2018), 25% of EU agricultural land is suffering from soil erosion (IPBES, 2018) and **pesticide residuals are found in 83% of EU soils** (Silva et al., 2018). Importantly, while food systems contribute to greenhouse gas emissions – **food systems use about 26% of the EU's energy consumption** (EEA, 2016) – they are also heavily affected by the consequences of climate change, threatening the (future) availability of natural resources which in turn could lead to substantial changes in conditions for (industrial) food production (EESC, 2016).

In order to build resilience against crises like climate change, natural disasters and health crises like the current COVID-19 pandemic, it is necessary to address challenges in managing biodiversity across agri-food systems, as biodiversity is vital to maintaining existing resources and ecosystems as well as to improving agricultural and food production. To do so, Europe should embrace biodiversity's full potential in order to enhance its food and agriculture production, as well as re-connect agriculture with ecosystem services (FAO, 2020). In order to address this, strong collaborative efforts are required between agriculture, health and environment sectors in order to make key policy decisions (Parsons and Hawkes, 2018).

### R&I action required

In order to ascertain the promotion of such transformation, Research and Innovation (R&I) strategies, processes and policies should address the complex and systemic nature of European food systems, which involves understanding and acting upon many interdependencies, trade-offs, synergies and other non-linear dynamics (Den Boer et al., 2020). Therefore, it is necessary to better understand the technological, political, economic and social dynamics that shape the food system and to identify the leverage points where intervention will be most effective (Kok et al., 2019). Identifying and acting upon these points necessitates a **systemic approach in which multiple actors, governance levels and policy fields are taken into account** (EEA, 2017; EC FOOD 2030 Expert Group, 2018).



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Though there are many definitions of what "governance" means, it is understood to refer to the *"ensemble of rules, processes, and instruments that structure the interactions between public and/or private entities to realise collective goals"* (Termeer et al., 2011, p. 161). Governance thus moves beyond 'formal arrangements by governments', but *"includes the collaborative efforts of networks of government agencies, societal stakeholders and private entities at and across (local, regional, national, supranational) governance levels"* (Den Boer et al., 2020: 2). Systemic and multi-level governance might help to **develop integrated food policies that take into account the complex non-linear dynamics of food systems, including trade-offs, co-benefits and feedback loops** (Moragues-Faus et al., 2017; Parsons & Hawkes, 2018; Zhang et al., 2018). Multi-level governance efforts should also take socio-cultural factors into consideration, as to ensure equity in distribution of the economic values, considering and engaging vulnerable and marginalized groups, and contributing to the development and advancement of socio-cultural outcomes like labor conditions, nutrition and health (FAO, 2018).

Such systemic approaches in the governance of R&I include for instance transition management approaches; transformative innovation policies; policy mixes for sustainable development; multi-level governance interventions; and transdisciplinary R&I efforts (Loorbach, 2007; Schot & Steinmueller, 2018; Kern et al., 2019; Fazey et al., 2018). Involving stakeholders from the entire food system in both the governance and R&I processes is important to ensure a wide variety of perspectives, values and knowledges to be taken in to account (Fazey et al., 2018; Hoes et al., 2019; Kok et al., 2019). **Embracing collaborative approaches such as Responsible Research and Innovation (RRI) could also lead to more desirable transformations**, as it allows for better anticipation of undesired and unexpected side-effects of (technological) interventions in different areas of the food system and to ensure the design of cohesive and fortifying R&I (Gill et al., 2018).

Furthermore, R&I approaches should shift their focus towards the political economy of food systems as to better understand the factors that drive food systems undesirable resilience and hampers radical transformation. One of the key R&I needs to foster transitions is **to better understand and steer power dynamics and the role of vested interests in transformation processes as well as to empower marginalized actors and communities in sustainable transformative efforts** (Gill et al., Köhler et al., 2019). To increase EUs food security, systemic R&I as well as governance efforts also need to address those systemic elements that reproduce inequality and tackle the underlying causes of vulnerability (Moragues-Faus, Sonnino & Marsden, 2017). In addition, that requires **addressing power imbalances and low institutional capacities, managing cross-scale dynamics, creating congruent values and interpretations of food security, and decreasing geopolitical and sectorial interdependencies** (Moragues-Faus, Sonnino & Marsden, 2017). In order to do so, food systems governance needs to



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address issues related to persistent inequalities in food rights and entitlements in the food system linked to marginalization and poverty. This entails reflexivity across both vertical and horizontal scales, such as governance, and within different communities of stakeholders involved in combating food insecurity. By doing so, a more integrated, reflexive and democratic food security governance approach becomes more likely (Moragues-Faus, Sonnino & Marsden, 2017).

It is **imperative for incumbent R&I systems to examine their own role in the generation of inequalities** and undesirable incumbency in food systems and thus to form part of the response to such challenges (Schot & Steinmueller, 2018). Yet, it is argued that current R&I systems do not fully serve as catalysts for food system transformation (Den Boer et al., 2020). In order to live up to their full potential, R&I action should be carried out differently, and that requires **governance interventions that aim to trigger a double systems transformation: of both food systems and their R&I system**s (Kok et al., 2019).

During the FOOD 2030 Pathway workshop organised on March 4, 2020 by DG RTD on "Future Research & Innovation Needs in view of the transition to sustainable, healthy, safe and inclusive food systems", several R&I actions that are relevant for the pathway on Governance and Systems Change were discussed. They are further substantiated below.

- **Mapping and monitoring of food systems, markets and behavior (actors across the food system, including consumers).** It is important to develop tools and methods for mapping, monitoring and evaluating the cross-scale dynamics from micro-levels (citizens, consumers) to macro-levels (systemic behavior of e.g. markets) and to identify R&I strategies to steer those dynamics to more sustainable equilibria (see also e.g. Gill et al., 2019). Such as take points to the need to better understand the role of and relation between consumer behavior, dietary patterns and food environments in current food system dynamics, as well as the need to develop policy interventions to engage consumers and other actors across the food system to become drivers of food system transformation.

- **New knowledge, insights, data models and methods to support policy development and decision-making.** R&I efforts are needed to develop more integrated quantitative data-driven as well as qualitative knowledge and models to better grasp and link the dynamic nature of food systems activities and outcomes, and their reciprocal relationship with land use practices, health and nutrition, socio-economic challenges, climate change and nature conservation efforts. In particular, decision support tools (such as the SUSFANS modeling tools, see Achterbosch et al., 2019) can be further developed in order to provide policy makers



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with the tools to design interventions in food systems, to enhance sustainable and healthy diets and foster transformation towards climate resilience (see for instance the EAT-Lancet report, Willett et al., 2019).

- **Engaging society for the future of food systems.** To ensure a wide diversity of socially robust knowledge production, to build societal support for transformation, as well as to further democratise science and technology, it is of utter importance to include a wide range of societal stakeholders in transformative R&I processes. This is in line with the increasing emphasis within EU academic and policy environments RRI (see von Schomberg, 2013). Doing RRI means including the non-traditional stakeholders such as citizens, farmers, NGOs and CSOs in R&I, in addition to researchers, innovators and policy makers. Their involvement is crucial to stimulate the transformative capacity and uptake of R&I frameworks, to inform decision makers, and to align diverse visions and perspectives (Gill et al., 2018). Importantly, society should not only be included in research implementation, but also in research agenda setting and evaluation (FEC, 2018; EC FOOD 2030 Expert Group, 2018)

- **Boosting demonstration and testing of solutions to systemic problems.** There is a need for wide-scale experimentation and subsequent scaling of transition initiatives as learning spaces for developing innovative solutions to the systemic problems in food systems. This requires innovation in technical, organizational, managerial, societal, environmental, economic and policy domains. It also involves setting up transformative multi-stakeholder networks that engage in vicarious learning and reflexivity. These networks can build transformative and adaptive capacities in for instance transition experiments, living labs for transformation, innovation networks or protected niches where these networks can co-create and test solutions in local contexts. It also requires the development of impact assessment tools, that are able to capture the non-linearity of transformative change as well as allow for experimentation spaces to find their 'own path' in finding the right solutions to match the local needs.

- **Supporting and investing in innovation deployment.** In order to foster the taking-up and scaling-up of sustainable (social) innovations, it is important to invest in deployment capacities, especially in more vulnerable countries and regions. This also resonates with calls for R&I capacity development in food and nutrition R&I (Gurinovic et al., 2016). It also calls for a better understanding of where and how particular innovations should be scaled-up in order to effectively contribute to desired food systems transformation. This requires fostering and further supporting innovation communities and platforms, such as EIT FOOD, a



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Knowledge and Innovation Community (KIC) established by the European Institute for Innovation & Technology (EIT), an independent EU body set up in 2008 to drive innovation and entrepreneurship across Europe.

- **Improve capacity building to support transitions.** In order to effectively engage in food system transformation, skills and competences beyond the formal 'stakeholder roles' are needed (Fazey et al., 2018; Den Boer et al., 2020). There is a strong need for capacity building in all involved actors on issues as systems thinking, reflexivity and multi-stakeholder collaboration. This would better equip researchers, policy makers, students and other actors to adopt new transformative roles in R&I efforts such as the role of change agent, reflexive monitor and knowledge broker (Fazey et al., 2018; Wittmayer & Schäpke, 2014). The FIT4FOOD2030 City and Food Labs are examples of transformative spaces that develop and/or test educational modules that aim to train a diverse range of stakeholders to develop these transformative capacities, with 18 different modules currently developed.

- **Developing R&I strategies and aligning R&I policies.** There is also the need to better develop new – and align incumbent – R&I strategies and policies so that they are equipped to foster transitions towards sustainable food systems. That is a multi-level exercise which includes aligning programmes and frameworks at the EC-level as well as in and between Member States, regions and municipalities. It also entails bringing together policy makers from different sectoral or thematic domains, in order to align inter-sectoral policies, for instance to identify and foster co-benefits in R&I commissioned within agricultural, health and economic policy domains. Experimenting with and mainstreaming of new policy innovations requires processes such as visioning, scenario building, developing policy pathways, as well as collective learning and reflexivity. At the policy-level, such alignment furthermore needs to be realised on policy (1) objectives, (2) strategies and mechanisms, and (3) outcomes (Forster and Stokke, 1999). It is increasingly acknowledged that fostering transformation requires the deployment of policy mixes (Kern and Rogge, 2017) and transformative innovation policies (Schot and Steinmueller, 2018). The 11 FIT4FOOD2030 Policy Labs are experimenting with designing and aligning national R&I strategies, visions and policy experiments of novel R&I funding or programmes, in order to further develop the transformative innovation policies within the Member States.



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*Barriers to systemic change*

There are many barriers that hamper the uptake of systemic governance and R&I strategies. With regard to systemic and transformative governance, barriers include a **lack of institutional and policy alignment in R&I as well as across sectors and disciplines**. This accounts for different governance levels, from the European Commission level to the Member State level down to the local and regional levels (Gill et al., 2018; Parsons and Hawkes, 2018). Furthermore, **dominant (policy) regimes often favor incumbent power dynamics** that stabilise current (non-transformative) systemic configurations (Avelino and Rotmans, 2009; Grin et al., 2010). This also points to the need to understand what systemic elements contribute to locked-in power dynamics, and to develop transformative agency throughout the system (Kok et al., *forthcoming*). In a mapping exercise of over 450 policies related to food systems in the EU and its Member States carried out in the framework of the FIT4FOOD2030 project, Biondi et al. (2019) show that when considering FOOD 2030 priorities, policies associated with 'nutrition and health' are by far most prevalent, while policies enhancing 'circularity and resource efficiency', 'climate and sustainability' or 'innovation and communities' are still relatively modest. Furthermore, **there are large differences between which target groups (consumers, industry, fisheries, agriculture, R&I) are addressed by which type of policy (regulations, fiscal policy, information measure, etc.) and at which level (EU or Member State)** these policies are adopted. Such complex and fragmented policy landscape across the EU and the Member States, points to institutional barriers for adopting and aligning systemic and transformative governance approaches.

With regard to transforming R&I systems so that they better support holistic and transdisciplinary efforts, Kok et al. (2019) identify **seven systemic and interlinked barriers**.

1. **Knowledge production** has (historically) been **organised in silos**, which limits the experimentation space for cross-sectoral, cross-disciplinary R&I efforts;
2. While the call for systemic and transformative R&I is emerging, most **funding structures** still favor and support **traditional linear R&I efforts**, thereby mostly funding R&D in agricultural production and food security which leads to an underrepresentation of other food system areas in R&I, as well as a lack of funding mechanisms for cross-sectoral R&I;
3. **Academic incentive structures do not promote** the uptake of (time-consuming) **transdisciplinary research**, which allows the disciplinary silos to prevail;
4. **Research cultures** across the globe **do not yet sufficiently value** (the outcomes of) **transdisciplinary R&I processes**, as they are still often considered less legitimate or 'scientific';



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5. As transformative and transdisciplinary sustainability sciences are still evolving as academic fields, there are **severe challenges within doing transdisciplinary R&I**, with a lack of coherent methods and concepts, while knowledge integration in such processes remains challenging;
6. There are still **major challenges in involving stakeholders in systemic approaches to R&I**, not only due to lack of time and resources, but also due to power imbalances, emerging distrust, institutional barriers and the challenge of finding agreement on processes, methods, concepts, problem-framings, and interests;
7. **Researchers and innovators lack competences** to fully engage in transdisciplinary efforts, which requires them to adopt new roles and develop new capacities to contribute more effectively to food system transformation.

*Enablers for transformation*

There are also many enablers that are emerging to support transformative food systems governance and the uptake of systemic R&I efforts. For instance, there is an increasing uptake of the food systems approach at local levels, but also for instance at the EU level (as the term is adopted within the 2020 EU Farm to Fork strategy). Below we elaborate on some technological, social, policy and economic enablers.

**Technological enablers**, such as rapidly developing data-driven tools and metrics, allow to further develop methods to assess the complex dynamics of food systems. Furthermore, they allow for foresight exercises which in turn might help to design more effective decision support tools that can lead to the implementation of more effective policy interventions.

**Social enablers**, such as increasing social entrepreneurship and high levels of citizen engagement, are also promising. Such engagement is reported in for instance the FIT4FOOD2030 Labs, but is also reflected in the many social and community-driven innovations that are rapidly developing across the food systems, from cooperatives that stimulate community engagement in agricultural production to create more local food chains, to citizen initiatives to reduce food waste or foster circularity. In particular, it seems promising that different sets of actors (citizens, entrepreneurs, farmers, policy makers, researchers) are willing – though not always fully succeeding yet – to engage in networks to foster collaboration and transformation of their (local) food systems, for instance in Food Policy Councils (FPCs).

Large-scale **policy enablers** are emerging, as the policy landscape is shifting in favor of transformative policies to address the pressing issues in the world's food systems. Examples are the EU Farm to Fork



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Strategy and the Green Deal, the Paris Agreement, but also the UN Agenda for Development and the UNFCC.

In addition, there are **several economic enablers**, such as the increasing markets for sustainable food initiatives and the relatively high power of public authorities in Europe, to influence markets through green public procurements and audits.

And finally, though the COVID-19 pandemic has revealed the vulnerabilities of our food systems, it has also led to an opportunity for shortening supply chains and as such, enables the political landscape to further enhance local and resilient food systems.

### Potential for sustainable social and economic breakthroughs

R&I should serve as a catalyst for food system transformation (Den Boer et al., 2020) and contribute to addressing the persistent challenges that confront current food systems. In particular, there is vital potential in R&I to inform new policies and to link RRI to food systems thinking (e.g. through mission-oriented innovation systems). This potential relates to supporting policy challenges such as: (1) constructing a resonating policy frame, (2) formulating policy goals, (3) involving relevant sectors and levels, (4) the question of what constitutes optimal policy integration, and (5) designing a consistent mix of policy instruments. Formulating answers to these challenges will enable policymakers and stakeholders to envision the next steps in concretising integrated food policy (Candel and Pereira, 2017).

In order to contribute to more effective governance of R&I, and utilise R&I's potential to contribute to systems change, there is a need for doing and organising R&I differently. Including systems thinking as well as multi-stakeholder engagement in to R&I requires different R&I funding programmes and has implications for R&I practice (Den Boer, 2020). In short: it requires the transformation of R&I systems as a whole so that they are better equipped to facilitate food systems transformation (Kok et al., 2019). Breakthroughs (encompassing social, economic and technical dimensions) could contribute to R&I systems' transformation across different domains. In this section, several potential breakthroughs that could lead to different R&I systems are discussed.

*Social breakthroughs*

**Co-creation and social innovation in Living labs**. Living Labs can be seen as transformative innovation networks that facilitate processes of co-creation in real-life contexts and the inclusion of diverse actors in these processes (Almirall et al., 2008; Leminen, 2015). Local, (peri)urban or regional labs (such as



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the FIT4FOOD2030 City and Food Labs), may be the appropriate tool for engaging citizens as well as industry, local public authorities and NGOs (Bulkeley et al., 2016). Thereby Living Labs contribute to engaged citizens to communicate and shape "their" desired future of food systems. Furthermore, Policy Labs for instance bear the potential to transform the development of policy-making. The FIT4FOOD2030 Policy Labs operate on a national level, where policy makers from different ministries experiment to make R&I policy more transformative (Wagner, 2019; Kok et al., 2019). They co-design for instance novel R&I policy approaches or policy mixes, R&I funding mechanisms or project calls, R&I visions and (cross-sectoral) R&I alignment.

**Applying RRI.** The principles of RRI imply that societal actors (researchers, citizens, policy makers, business, third sector organisations, etc.) work together during the whole research and innovation process in order to better align both the process and its outcomes with the values, needs and expectations of society (von Schomberg, 2013). RRI aims to guide R&I actors (policy, society, industry) in anticipating the implications of their work, including relevant stakeholders upstream, and reflecting and responding to those stakeholders' concerns and expectations. In this way, co-design and co-responsibility for the outcomes of research and innovation can be facilitated, increasing societal uptake and acceptability of research and innovation (see e.g. Owen et al., 2012). This is not a straightforward endeavour, as implementation of RRI and its integration in policy faces many challenges in practice (Fraaije and Flipse, 2020; Novitzky et al., 2020)

**Regional aspects of food system.** The role of citizen participation in food system policy making as a key driver is a recognition that solutions to complex challenges in the food system need the active participation of citizens to drive positive change. To achieve this, it is crucial to give citizens the agency in processes of designing policy interventions. Examples of such participatory approaches are local food (policy) councils or citizen assemblies (Doherty et al., 2020). Local and regional innovations in food system governance include food (policy) councils or partnerships—also called local food policy groups (Santo, 2019). This also calls for further exploration of place-based approaches in R&I efforts and policy instruments such as the Green Deal and the Farm to Fork Strategy (Sonnino et al., 2019; 2020). There is a widely recognised need to increase the alignment between research and innovation policies at the European, national, regional and local levels. For wider impact, additional alignment challenges need to be addressed within the realm of R&I policy (i.e. multiple sectoral and transversal R&I policies), between (multiple) R&I policies and (multiple) sector policies, and between R&I policy & society (i.e. multiple stakeholder values and expectations).

**New models for education and knowledge co-creation**. The raise of personalised education models and interactive learning experiences accounts for the variety of actors interested in learning about



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food systems. Multi-stakeholder platforms including Higher Education Institutions, research & training centres and food companies are increasingly offering cross-disciplinary webinars, MOOCs, Summer Schools and dedicated study programmes. Consumers are thus able to make more informed food choices, while students and professionals can bridge fragmented skills and knowledge of food systems and future entrepreneurs learn how to investigate relevant case studies, initiate plans for joint business ventures, supply chain innovation and commercialisation. For instance, such transformative skills and knowledge for students and professionals are also developed in the educational modules that are co-created in multi-stakeholder workshops in the FIT4FOOD2030 City Labs.

*Economic breakthroughs*

**Green public procurement**. Public authorities are major consumers of agricultural and food products, thus largely participating to and influencing market practices and norms in the food systems. Green public procurement – focusing on the provision of nutritious and sustainable meals for schools, hospitals, elderly people residences and public administrations' canteens – can help stimulate a critical mass of demand for more sustainable goods and services which otherwise would be difficult to get onto the market (see e.g. Lundberg and Marklund, 2018).

**Social entrepreneurship**. Many entrepreneurs are adapting their business models to the changing policy landscape and consumers' preferences to reflect an increasing concern for health, social and environmental considerations. Social enterprises focus on food as a public good, instead of solely considering profit, thus incorporating issues such as fair trade, reduction of waste and fair treatment of laborers into their models. Being able to effectively 'do social entrepreneurship' in the context of complex systems transformation, also requires building capacities of different actor groups in order to facilitate such efforts (Den Boer et al., 2020). This in turn requires interventions in research and policy domains, to co-create educational programmes that support entrepreneurial and systemic thinking among students and professionals.

**Guidance to Start Ups and SMEs, new models of collaboration and impact**. New developments in education allow agri-food start-ups to benefit from business accelerators and innovation initiatives. Effective instruments are mentoring programmes held in partnership with established companies and matching exercises with businesses offering complementary services. Targeted training on innovation capabilities can help SMEs to overcome existing skill gaps and thus unlock untapped market opportunities. For example, the EIT Food Accelerator Network (FAN) is an accelerator programme delivered across Europe, supporting high impact agri-food start-ups to maximise their success. Over a four-month acceleration period, selected start-ups have access to a buffet of tools, connections,



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mentors and expertise to help them succeed in the market (European Innovation and Technology Institute - EIT, 2020).

**Short food value chains**. In shorter value chains the products are identified by and traceable to a farmer, the number of intermediaries between farmer and consumer should be minimal. This can mean face-to-face business, when consumers buy a product directly from the producer/processor (e.g. on farm sales, farmer markets); sales in proximity, when products are produced and retailed in the region of production (e.g. food cooperatives, specialist retailers, food public procurement, catering, supermarkets); sales at distance, when products are produced outside of the region of purchase (e.g. PDO, PGI, internet sales, food box schemes).

**New ways of financing innovation**. Different ways of financing entrepreneurs such as microcredits and microfinance would allow people to obtain small loans at reasonable interest rates, receive remittances from relatives working abroad, safeguard their savings and set up small businesses. Crowdfunding aims to pool rather small amounts of capital from a large number of people resources, primarily through fundraising platforms, and has grown in importance as a financing tool. Importantly, both public and private funders can fund transdisciplinary R&I projects and programmes through novel processes and mechanisms such as sandpit calls, match-making events, phasing of funding acquisition.

### Impacts & Co-benefits

There are many interlinked impacts and co-benefits that could be attributed to the pathway of governance and systems change. In particular, **systemic governance of R&I can support food systems in the delivery of nutritious foods using environmentally sustainable production methods creating health and economic and environmental benefits for farmers, businesses, and consumers**. Such efforts require a reorientation of the entire system where health, environmental and economic goals are met in synergy.

In a recent policy brief, Parsons and Hawkes (2018) elaborate on six impactful areas of opportunity, where co-benefits can be created if governance and R&I efforts embrace a food systems approach. In each area of opportunity, they illustrate how co-benefits emerge for economic, environmental and health domains. For instance, co-benefits could be realised in a wide variety of 'places' in the food system such as (1) school fruit and vegetable schemes; (2) investment in SMEs to deliver healthy and sustainable foods into deprived neighborhoods; (3) the Common Agricultural Policy (CAP); (4) (green) public procurement; (5) short supply chains and finally; and (6) building skills in food systems actors.



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Furthermore, in addition to these areas of opportunity, it is important to acknowledge the role of a wide variety of policy goals embedded across the entire EC (Parsons and Hawkes, 2018). This accounts for the more traditional 'food' related DGs such as AGRI, RTD, SANTE, ENVI, MARE, but also includes DGs such as GROW, EAC, FIN, GROW and EMPL. Ensuring these impacts and co-benefits would require cross-governmental and cross-sectoral collaboration supported through food systems policy audits, linking governance mechanisms across and within Member States and setting up food systems roundtables identifying specific steps for adaption or change.

Furthermore, transforming R&I systems so that they are better able to foster food systems transformation, has **large impact on how research and innovation processes are funded, designed, implemented, conducted and evaluated**. Such transformation would entail changes in R&I cultures, structures and practices. Governance efforts that stimulate the systemic reorientation of food systems R&I would thus pave the way for more inter- and transdisciplinary research, RRI, transformative action-research, citizen science and engagement, transition studies approaches, (free from interest) Public Private Partnerships (PPPs) and other forms of transformative (social) innovation.

The R&I actions and breakthroughs suggested in this chapter could in particular contribute to the **transformative capacity of researchers and innovators, through building competences to engage in transdisciplinary and systemic collaboration**. This has impacts beyond food systems as well, as researchers and innovators often work beyond the scope of single systems. As such, transforming R&I for food systems might facilitate the broader transformations to sustainability and contribute to **multi-systemic sustainability transitions**. This in particular can be relevant for systems that are directly coupled to (food) R&I systems, such as energy, health care, education, rural development, nature conservation and water management systems. Finally, the R&I actions and breakthroughs will further contribute to raising awareness across a broad range of societal actors on the urgent need to steer towards radical food systems transformation.

## Policy alignment

*Alignment with EU policy frameworks*

Within the EU several important policy frameworks and networks relate to the governance and systemic science of food system transformation, including the Farm to Fork Strategy, the EU Green Deal, the EU Common Agricultural Policy (CAP) and the EU Common Fisheries Policy (CFP) as well as for instance the EU Biodiversity Strategy and R&I frameworks and funding programmes such as Horizon Europe.



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**The CAP policy objectives propose a number of multi-level and multi-stakeholder approaches to R&I,** as well as transdisciplinary research. These include supporting EU farmers in securing higher incomes, as farm income and resilience is significantly below the average income of the economy (FAO, 2020). Such support requires a combination of measures and structural adjustments, like helping farmers secure investments while also ensuring equity in income distribution like capping. Increasing competitiveness and agricultural productivity in a sustainable way also requires these approaches as stagnation in agricultural productivity is linked to a number of interdependent factors, such as climate change, loss of biodiversity and food prices (FAO, 2020). Addressing these challenges requires diverse policy tools and drivers like R&I programs, new technologies, continuous training for farm managers and efficient advisory systems (European Commission, 2018). A more specific example is the introduction of **Rural Development Programs**, which provide support for supply chain organisation, for investment, training and advice and on-site innovation, as well as the development of new business models (European Commission, 2018).

**Implementing the Farm To Fork Strategy also requires a systemic and multi-level governance approach** (Sonnino et al., 2020; European Commission, 2020b). The strategy itself proposes multi-level and multi-stakeholder governance involving partnerships with EU countries, foundations, the private sector and additional stakeholders to ensure sustainable strategic cooperation between actors that cover diverse and critical areas like health, biodiversity and circularity (European Commission, 2020b). **In the 2021-2027 EU R&I framework programme, Horizon Europe, relevant stakeholders will include institutions like the European Research Council, Marie Sklodowska-Curie actions, the European Innovation Council and the European Institute of Innovation and Technology – Food (EIT Food)** (European Commission, 2020c) as well as many public and private research institutes, policy makers across various governance levels, industry and other private sector actors, NGOs and CSOs. It also requires addressing interdependent challenges in clusters like the culture, creativity and inclusive society cluster; digital, industry and space cluster; as well as food, bioeconomy, natural resources, agriculture and environment cluster (European Commission, 2020c). Each cluster involves tackling diverse challenges that require inter-stakeholder collaboration and systemic change, such as in addressing the coronavirus pandemic. For example, the role of R&I in addressing the challenges of the COVID-19 pandemic requires designing strategies that facilitate transitions and provide strong (economic) incentives for preserving biodiversity and ecosystem restoration and sustainable food systems. Doing so requires intergovernmental and stakeholder collaboration and for the EU to promote trust and transparency and to lead the global response (European Commission, 2020d).



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A final important development concerns the establishment of **new European Partnerships under the Horizon Europe programme**. These Partnerships will serve as multi-stakeholder platforms for accelerating R&I developments within the EU in order to more effectively achieve the objectives of Horizon Europe. Regarding governance of systemic change, the Food Systems Partnership in particular has enormous potential to accelerate R&I efforts on topics such as (1) dietary shift, (2) food safety, (3) circularity and resource efficiency, (4) urban food systems, (5) consumer behavior, and (6) policy coherence (SCAR, 2019).

*Alignment with international policy frameworks*

The UN Agenda for Change includes a number of Sustainable Development Goals (SDGs) relevant to addressing (governance) challenges facing sustainable food systems transformation, such as zero hunger (SDG 2), good health and well-being (SDG 3), industry, innovation and infrastructure (SDG 9), sustainable cities and communities (SDG 11), responsible consumption and production (SDG 12), climate action (SGD 13), life below water (SDG 14) and life on land (SDG 15). The goals require collaboration between all UN Member States as well as between all sectors of society on three levels, namely global, local and individual action. Global action requires securing more resources, greater leadership and smarter solutions for SDGs, while local action needs to embed the transitions in budgets, policies, institutions and regulatory frameworks of governments, cities and local authorities; and people action (including the private sector, youth and civil society) is required to generate traction for the transformations (United Nations, 2020). Strong leadership and governance are needed to align different levels of change with the SDGs.

**Governance, in combination with systems thinking, is intrinsically necessary in addressing each SDG.** For example, ensuring zero hunger (SDG 2) requires aiding humanitarian relief to regions at risk alongside transforming the global food and agricultural system by increasing sustainable food production and agricultural productivity. Improving global health and well-being (SDG 3) necessitates multi-level and multi-sectoral collaboration and systemic transformation as health is extremely diverse and impacted by multiple factors such as poor sanitation and hygiene, access to physicians, poor health system funding, and low levels of countries' abilities to cope with crises like COVID-19 (United Nations, 2020).



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**FIT4FOOD 2030 POLICY LABS**


The FIT4FOOD2030 project has established 11 Policy Labs in EU Member States. These Policy Labs are working within their national context on aligning and innovating R&I systems to better facilitate food system transformation. This policy experimentation is done in multi-stakeholder setting and through a series of interactive workshops and events.

Policy Labs are located in Austria, Basque Country (Spain), Estonia, Flanders (Belgium), Hungary, Ireland, Italy, Lithuania, the Netherlands, Norway and Romania.

For more information: www.fit4food2030.eu.

## FIT4FOOD2030 POLICY LABS

*Co-creation and social innovation*

### Assessment of added value

The Policy Labs of the FIT4FOOD2030 project have engaged in policy experimentation with a wide variety of stakeholders. They are working within their national context on aligning and innovating R&I policies, instruments, visions and/or funding mechanisms in order for their national R&I systems to better be able to contribute to food system transformation. Though the project is still ongoing, there are many added values to be identified. For instance, they have developed policy experiments as outcomes, influenced research agendas, linked many existing actors and networks, influenced the policy landscape, enhanced the uptake of food systems approaches in their national R&I systems, built strong networks of multi-stakeholder and multi-sectoral collaboration and through those impacts advanced transformative change towards sustainable food systems.

### Assessment of challenges

Policy processes are long-term processes, which means that a main challenge lies in identifying all the areas of impact already within the project's timeframe. Especially as such impacts often become visible only in retrospective. Furthermore, it remains challenging to involve specific but relevant stakeholder groups, to change institutional structures and find funding and commitment for continuation of the experiments. An interesting opportunity to further enhance co-benefits would be to align the work on the national level to policy development on the local, regional or international levels.

### Prospects for future development

The Policy Labs of FIT4FOOD2030 continue their work under the FIT4FOOD2030-umbrella until the end of 2020. After that, some of the developments and activities set in motion by the Labs will continue. The Labs are currently looking into the possibilities of how to further strengthen and sustain their activities, outputs, networks and/or even the entire Policy Lab.



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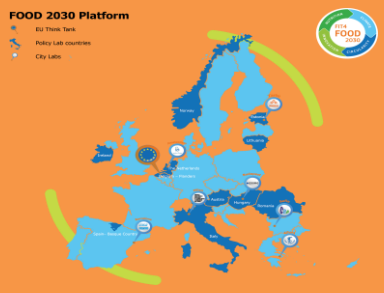
**FIT4FOOD 2030 CITY & FOOD LABS**




The FIT4FOOD2030 project has established 7 City Labs and 7 Food Labs across Europe, hosted by universities, Science Shops and Science Museums.

These City and Food Labs are developing and/or testing educational modules that are co-created in multi-stakeholder settings and aim to train students, professionals or other food system stakeholders to develop competences needed for food system transformation. The Labs are located in: Aarhus, Amsterdam, Athens, Azores, Barcelona, Birmingham, Budapest, Dublin, Graz, Milan, Sofia, Tartu, Trentino and Vilnius.

For more information: www.fit4food2030.eu.

## FIT2030 CITY & FOOD LABS

*Competence building for civil society actors*

### Assessment of added value

The City and Food Labs of the FIT4FOOD2030 have engaged in co-creation processes with a wide variety of stakeholders. They are working within their local context developing and/or testing educational modules that are co-created in multi-stakeholder settings and aim to train students, professionals or other food system stakeholders to develop competences needed for food system transformation. In addition, the local networks of the City and Food Labs catalyse food system transformation efforts on the local level and can impact the local policies. The modules they are implementing directly influence over 1000+ participants and they have engaged over 1200+ people in their multi-stakeholder workshops to strengthen local R&I initiatives. They have developed vibrant networks of engaged actors, influenced local policy agendas and stimulated capacity building for local transformations.

### Assessment of challenges

The City and Food Labs have the specific aim of developing and/or testing educational modules, thereby aiding the much needed effort to build capacities. However, that does not always align with developments in the local context, nor with the desire of their networks to influence policy agendas and act upon more direct mechanisms for transformation. In addition, reaching specific important stakeholder groups remains a challenging endeavor, as well as balancing divergent views, power and interests within Lab activities.

### Prospects for future development

The City and Food Labs of FIT4FOOD2030 continue their work under the FIT4FOOD2030-umbrella until the end of 2020. After that, many developments and activities set in motion by the Labs will continue thanks to the agreements for sustainability alreached or in course of negotiation with local authorities. The Labs are currently looking into the possibilities of how to further strengthen and sustain their activities, outputs and networks.



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## Conclusion

European food systems face many interlinked challenges which lead to a wide variety of societal, economic and environmental needs that should be addressed. In order to facilitate transformation towards sustainable and healthy food systems, there is a **need to adopt novel and systemic governance approaches as well as R&I approaches that are supportive of such arrangements**. The many interlinked challenges in food systems require cross-sectoral governance **interventions that are able to mitigate trade-offs, foster synergies and co-benefits, while taking into account the multiplicity of knowledge, values and perspectives involved**. Successfully implementing such efforts necessitates multi-level interventions, policy experimentation and the creation of transformative spaces where policy makers, researchers and societal stakeholders can co-create and evaluate knowledge, innovations and policies needed for systemic change.

**Supporting such governance efforts requires the programming of more transdisciplinary and systemic R&I efforts** that engage the wider society through Responsible Research and Innovation (RRI). However, for R&I to effectively contribute to food system transformation through systemic and transdisciplinary R&I, the underlying R&I systems should support such endeavors. Currently, R&I systems are not fit to serve as catalysts for food system transformation (Den Boer et al., 2020), as they do not sufficiently stimulate transdisciplinary and transformative approaches. As such, there is a need for a double transformation: transforming R&I systems so that they can better support food system transformation (Kok et al., 2019).

There are many interlinked barriers that hinder the uptake of transformative R&I efforts, both within the R&I practices, cultures and structures as well as in the broader policy environment that aims to govern R&I efforts. Despite the difficulties, **enabling factors** that enhance the potential for transformation are emerging. These factors include, notably, the many emerging (bottom-up and multi-stakeholder) innovation initiatives that are emerging across the EU, the emergence of multi-stakeholder policy initiatives in **Living Labs and Food Policy Councils**, the uptake of transdisciplinary research efforts, and **many opportunities for aligning with recent policy developments**, both within the EU and internationally.

Facilitating the double transformation requires strong governance interventions, R&I actions and the facilitation of potential breakthroughs in the realm of R&I itself. In particular, the following specific R&I actions could be further designed and implemented:



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- Mapping and monitoring of food systems, markets and behavior (actors across the food system, including consumers;
- New knowledge, insights, data models and methods to support policy development and support decision making;
- Engaging society for the future of food systems;
- Boosting demonstration and testing of solutions to systemic problems;
- Supporting and investing in innovation deployment;
- Improve capacity building to support transitions;
- Developing R&I strategies and aligning R&I policies.

Successful implementation of these R&I actions can contribute to the transformation of R&I systems that support food systems transformation. **Transforming R&I systems so that they are better able to foster food systems transformation, thus has large impact on how research and innovation processes are funded, designed, implemented, conducted and evaluated**. Such transformation would entail large-scale changes in R&I cultures, structures and practices. Governance efforts that stimulate the systemic reorientation of food systems R&I would thus pave the way for more inter- and transdisciplinary research, RRI, transformative action-research, citizen science and engagement, transition studies approaches, (free from interest) Public Private Partnerships (PPPs) and other forms of transformative (social) innovation.

Governing the transformation of European R&I systems towards R&I systems that better enable systemic and transdisciplinary R&I is not just an opportunity. Rather, it is a necessity that helps to further identify, understand and act upon systemic synergies and co-benefits that will ultimately lead to the delivery of social, environmental and economic sustainability of healthy, inclusive, and resilient European food systems.

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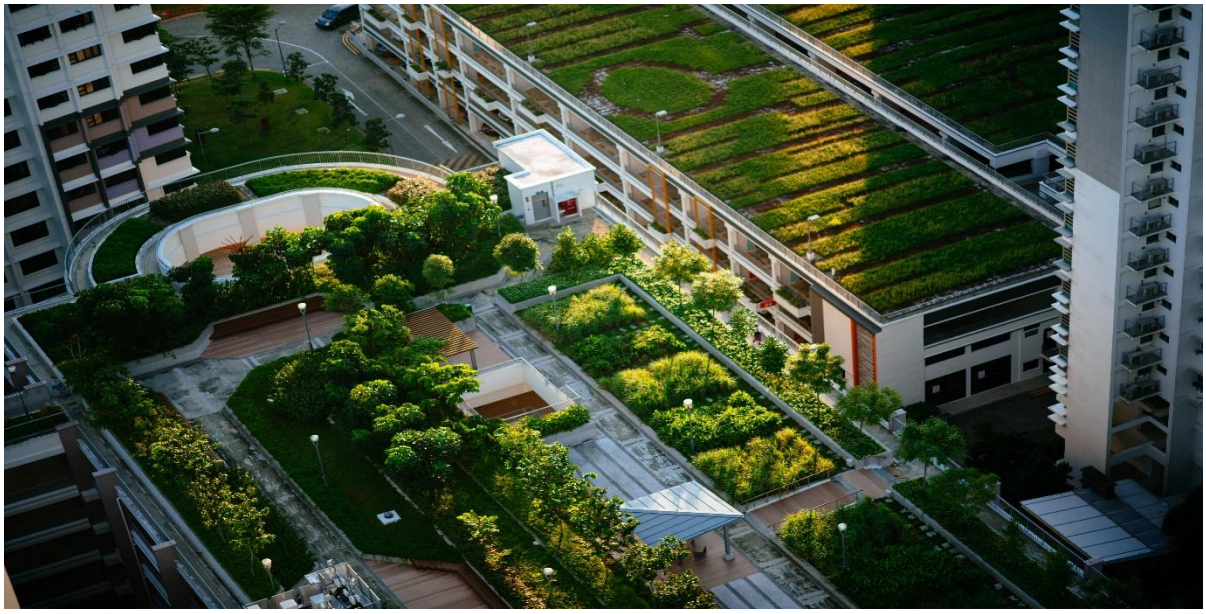
# Urban Food Systems Transformation



**Food systems in most of European cities generate deep social and economic inequalities, over-exploit natural resources and jeopardise the already fragile nutrition and health of vulnerable groups of citizens. As cities are not equipped to produce the food needed to sustain their own population, they are forced to rely on imports of processed goods and commodities from afar. Dependence on external markets increases the susceptibility to supply chain disruptions, including those caused by climate-related events and global shocks such as the COVID-19 pandemic. Immediate action is needed to reverse the current situation and scale up efforts to ensure that emerging innovative practices and technologies receive the necessary support to enable EU urban food systems to become environmentally sustainable, socially inclusive, as well as spatially and economically connected with their rural surroundings.**



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## Societal, economic & environmental needs

Starting from the 1950s, Europe has witnessed **unprecedented urbanisation and urban growth**. This process has long been interpreted by focusing solely on the criticalities linked to cities' uncontrolled expansion: **environmentally unsustainable production and transport models, political instability, disease outbreaks, social and economic injustice, forced migration flows, concentration of resources and wealth, supply chain disruption**, etc. (Sonnino, 2016). Failure to factor in and address the negative externalities linked to the urbanisation mega-trend has been quoted as a main factor leading to the crystallization of current urban food systems, which fail to feed adequately all urban dwellers while putting a disproportionate strain on the environment (Marsden, 2013).

However, starting from the late 1980s, there has been a shift in the way urban food systems are understood by part of the EU scientific community, policy-makers as well as the public opinion. There is now a **growing recognition of the interrelatedness of the food value chain and of the role of cities in the development of sustainable food systems**, due to the potential an urban food systems transformation bears to address challenges such as climate change, public health, poverty and social equity.

**In Europe, more than 74% of the population lives in urban areas**, a number that is likely to increase in the forthcoming years (World Bank, 2019). It is estimated that **80% of all food will be destined to cities by 2050** (Ellen MacArthur Foundation, 2019). Yet, until recently, food policy was considered to fall beyond the sphere of competence of cities, mainly because food was produced outside the city limits, and the issues related to its production, processing and distribution were not considered as a regulatory priority by city governments (Potukuchi and Kaufman, 2000). The absence of targeted planning or adaptation measures to the process of urbanisation has produced remarkable consequences on food and nutrition security, as well as negative climate and environmental impacts and broader economic consequences on European societies. World food systems generate up to 37% of global GHG emissions (IPCC, 2019) with **EU agriculture-related emissions, especially those coming from the animal sector, heavily contributing to this sizeable environmental and climate footprint** (European Commission, 2020). Meanwhile, **excessive amounts of packaging and volumes of food are wasted at every stage of the food value chain**, including a considerable amount spoiled in transit (Lipinska et al., 2019**), with food and green waste comprising more than 50% of all municipal waste** (FAO, 2019). The environmental sustainability of cities faces numerous challenges related to the transformation of urban food systems, including **increasing health risks associated to the contamination of air, water and livestock, loss of biodiversity, degradation of natural resources and water shortages.**



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**Changing urban lifestyles**, including increasing working hours and the decline of time spent at home, **have contributed to significant shifts in food consumption habits and a rise in the demand for convenience and processed foods** amid nutrition and public health concerns. Cheap foods high in salt and sugar and low in nutritional value are particularly popular in EU cities also thanks to the **heavy marketing** they are subject to, thus contributing to disproportionately **high incidences of obesity and diet-related diseases** (Hawkes et al., 2017). Excessive energy consumption, coupled with limited physical activity, leads to rising problems in many cities, thus putting an **unsustainable strain on EU Member States' healthcare systems**. Currently, seven of eight major risk factors for premature death in Europe are linked to poor nutrition choices and limited exercise (European Commission FOOD 2030 Expert Group, 2018). Such issues are **especially affecting the less affluent sectors of European societies**, where it is not uncommon to find overweight and obese adults living with underweight children, amid widespread micronutrient deficiencies (FAO, 2011). The uneven expansion of the European cities has also given rise to the concerning phenomenon of '**food deserts'**, e.g. low-income, peri-urban neighborhoods with scarce availability of markets and fresh produce and high concentrations of fast-foods and wholesalers, leading to additional nutrition challenges and increased costs in time and transport to access quality food. The issue of food security in EU cities has therefore a clear dimension of social justice: **while about 45 million of Europeans cannot afford a quality meal every second day** (European Commission Food 2030 Expert Group, 2018), **about 173 kilos of food per capita are wasted every year** (FUSIONS EU, 2016).

Cities are dependent on outside food sources and their needs usually exceed the capacity of surrounding agricultural regions, whose soils and ecosystems end up over-exploited and degraded (EllenMacArthur, 2019). **As cities grow, urban food demand also has a huge impact on rural areas and agricultural supply chains**. A sharp urban-rural divide marks the unidirectional flows of people, skills, products and wealth from the countryside to the city. **Pay and livelihood for primary producers and, more in general, workers in the food sector are** often low, as agri-food jobs — from abattoirs to factory production lines, to fast food restaurants and school canteens — **are considered as low-skilled labour, and workers have few opportunities for training or professional advancement** (Freudenberg et al., 2016).

The **COVID-19 pandemic** has produced a significant impact on urban food systems, exposing its fragilities while at the same time spurring innovations that may lead to durable transformation. In particular, European citizens have come to experience first-hand the **importance of urban-rural**



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**linkages to maintain their food security**, as those cities highly dependent on imports from far regions have suffered from the **vulnerability of long supply chains to the pandemic's external shock.** On the opposite, **cities with a functional connection to their rural hinterlands have managed to increase the consumption of food locally grown** and thus better adjust to the evolving context (FAO, 2020).

**Overall, the pandemic has indeed aggravated the issue of food nutrition and security for EU citizens,** as loss of jobs, income, and the lockdown measures have impacted disproportionately vulnerable groups such as elderly people, individuals with disabilities, rough sleepers or asylum-seekers, who are reported to suffer from increased macro-nutrient deficiencies and difficulties in access to food (FAO, 2020). To respond to the emergency and, more generally, to fix unsustainable urban food chains, **EU cities urgently need to invest in strengthening their resilience including through enhancing local food production**, as it has been recognised by the EU Commissioner for Agriculture Janusz Wojciechowski (POLITICO, 2020).

### R&I action required

- **Device urban food strategies for trusted, inclusive, safe and resilient food systems**. In Europe, issues related to urban food systems have long been addressed through sectorial food policies, often decided upon at the national level. While such an approach has delivered on the overall provision of sufficient and affordable food to cities, urban food systems are failing nonetheless as a narrow focus on food availability is not enough to solve the many interlinked issues affecting urban food systems. For this reason, EU cities are increasingly taking action to address the scale and the complexity of the challenges through integrated strategies. System thinking should inform the development of such strategies, as an inclusive and participatory process of all relevant actors of the food chain is crucial to ensure institutionalisation and take-up, regardless of whether the origins of urban food strategies in different cities are top-down (e.g. public-private action on waste reduction) or bottom-up (e.g. grassroots mobilisation to expand city community gardens). A comprehensive food systems approach will be key to the rethinking of urban food environments, e.g. the physical, social, economic, cultural, and political factors that impact the accessibility, availability, and adequacy of food in cities. Currently, food environments in low-income neighbourhoods lack access to healthy dietary choices and feature high rates of obesity and overweight (Black, Moon and Baird, 2014). Potential R&I actions to improve urban food environments include retail interventions to promote healthy corners in supermarkets; labelling or highlighting heathier options on restaurant menus; and adopting healthy food procurement policies to increase availability



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and affordability of healthier foods in the city. The openness and inclusivity of urban food strategies will also increase the trust of vulnerable actors such as primary producers and consumers in the system, thus also contributing to increase their acceptance of new technologies with tranformational potential for the protection of the environment, as well as for the safety and transparency of urban food systems (European Commission FOOD2030 Expert Group, 2018).

- **Targeted initiatives for changing dietary habits towards a healthier and sustainable nutrition**. Changing dietary habits and increasing physical activity could address major risk factors and reduce rates of obesity and non-communicable diseases in Europe by 50% (European Commission FOOD2030 Expert Group, 2018). Successful nutrition and lifestyle strategies will enable European citizens to live healthier lives in a more sustainable environment, decreasing the costs of health systems. In order to achieve such objectives, a combination of actions is needed, including enabling policies by public authorities; commitment and responsible innovations by food companies; awareness and education campaigns by public and non-governmental actors; and behavioural changes by urban dwellers (Gil et al., 2019). City authorities, in cooperation with the relevant state departments, can influence citizen diets by promoting healthy choices, for example by mainstreaming organic and plant-based foods during public events and fairs, or by setting up 'green' procurement tenders to supply public canteens in schools, hospitals, and city offices. City authorities have a role to play in the city spatial planning, which has an important impact on dietary choices. For example, local authorities can avoid the proliferation of 'food deserts' by regulating the concentration of fast food outlets across the city, or they can decide to regulate the circulation of vehicles in specific areas as to allow for fresh fruit and vegetable markets to take place on weekends. The private sector needs to support the transition by adjusting to the increasing demand for sustainable food. Food products should be designed not only to be healthy from a nutritional standpoint, but also with respect to how they are produced. This means that food designers and processors need to create and prioritise products with ingredients sourced regeneratively and, where possible, locally and seasonally. Food processors should abide by the circular economy model in the creation of foods whose by-products are safe to use as inputs for new cycles, for example by avoiding additives that prevent food to return to soil as organic fertiliser (Ellen MacArthur, 2019). Distributors and retailers should market and position such products so that they become an easier, more accessible choice for people on a daily basis. Tech start-ups, on their side, can facilitate the



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transition towards healthier and sustainable diets by developing enabling technology, including apps focusing on personalised nutrition, waste reduction, food tracking and food delivery, as well as 3D food printing for people with swallowing difficulties and other conditions putting their nutrition security in jeopardy (European Commission FOOD2030 Expert Group, 2018). Awareness and education initiatives will be instrumental to produce dietary shifts. Potential initiatives include the inclusion of food and nutrition education in school curricula and grassroots sensibilisation campaigns targeting adult citizens and public representatives to make public opinion aware of unsustainable food practices currently encroached in urban food systems. For instance, EIT Food – a European Knowledge and Innovation Community (KIC) funded by the EU to make food systems more sustainable, healthy and trusted – offers several education courses aimed at empowering citizens to lead the transformation of EU food systems, including a Massive Open Onlince Course (MOOC) on Circular Business Models for Sustainable Urban Food Systems (EIT Food, 2020). The FIT4FOOD2030 project has designed and delivered a set of transformative hands-on future oriented trainings on food systems R&I for students and professionals, with the aim of fostering a strong multi-stakeholder engagement, critical thinking, collaborative learning skills and transdisciplinary approaches to food systems learning. “City Labs” and “Food Labs” have been used as a prototype in order to produce a kit of tools for transformation and methodologies that can be used in different settings (FIT4FOOD 2030 D.6.1, 2018). Consumers will need to play their part to make the shift towards healthy and sustainable diets happen. This should entail an increase in the consumption of plant-based foods and alternatives to animal proteins; a drastic reduction in household food waste through improved purchasing, storing, consumption and waste disposal practices; and a change in social norms currently validating unhealthy and unsustainable behaviours.

- **Increase urban-rural linkages for shorter, fairer and more sustainable urban food chains**. The effort to make food chains more ‘visible’ to consumers in EU cities implies the need to highlight and make the most of the relation between cities and their surrounding rural environments. Since EU cities absorb a large share of all food demand in Europe, they have a great potential to influence the way in which food is grown. EU cities can use their public and private demand power to motivate a shift towards healthy and sustainable consumption. While practices such as urban farming show potential to increase city’s reliance to food shortages and external shocks, cities should especially invest in shifting from a consumption model where a core percentage of the supply is imported from far regions to one based on



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sourcing from their peri-urban surroundings – where 40% of the world's cropland already exists (Ellen MacArthur Foundation, 2019). By increasing purchase and consumption of food sourced locally, EU cities would establish shorter and more resilient food value chains, while also maintaining a percentage of products imported globally to retain dietary diversity. Improving urban-rural linkages would have a number of other benefits beside the positive impacts on urban diets: it would support the diversification of crops by promoting varieties best fitting local conditions, thus improving soil resilience; it would help reconnect citizens with their environments, thus promoting a circular consumption model that entails more waste reduction efforts and a more efficient return of nutrients to peri-urban farms; it would improve the livelihood of peri-urban farmers and rural livelihoods while increasing access to markets and employment, thus promoting economic growth and reducing rural to urban migration (European Commission Food2030 Expert Group, 2018).

*Barriers to systemic change*

**Technological/administrative barriers.** Lack of comparable data represents a main issue for EU cities when attempting to carry out food systems analyses towards the establishment of urban food strategies. This exposes the need for an assessment of urban-specific food issues and policy gaps through in-depth research that would provide local decision-makers with the tools they need to understand and map where their food comes from. Such an assessment should include a consideration of the specificities of different urban food environments, infrastructures and the extent to which these promote a healthy and sustainable access to food. Missing data is also a barrier to the creation of monitoring frameworks for the overall understanding of food systems, food flows, and the impact of local food policies (European Commission, 2017). A relevant administrative barrier is represented by the lack of jurisdiction in food policies by EU city authorities, as competences are often held at the regional or national level. Delineation of responsibility and authority may be absent, weak or limited to one department and not integrated across administrations in municipal governments, such as the departments for planning, health, sanitation, economic or social development, etc. There may be gaps or conflicts between legal mandates and jurisdictions, not only within local governments but also between neighbouring governments engaged in the same territorial food system (Food Links, 2018).

**Social barriers**. In many cases, EU cities still suffer from a lack of awareness or participation – and therefore engagement and support – of key actors in the food system within and outside local government. Mechanisms for inclusion of critical actors such as industry representatives from all the



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supply chain and civil society organisations are rarely adequate to meet the opportunities for more effective, broad-based and participatory outcomes, while civil servants' capacities in city administrations are often lacking or are under-developed (Food Links, 2018).

**Political barriers**. Among the most relevant barriers to the establishment of coherent urban food policies is the dependence of political initiative on electoral cycles and, therefore, on the political mindset of the officials in charge at a given time. As urban food strategies are relatively recent and may not yet be fully institutionalised across Europe, the alternance of city administrations attributing different levels of priority to the transformation of urban food systems may compromise the process (IPES-Food, 2017). In a similar way, different ideologies can promote conflict and policy fragmentation between departments, actors and jurisdiction (Milan Urban Food Policy Pact, 2018) both in terms of horizontal governance – e.g. potential clash between city council officials in charge of public health cracking down on sugar consumption and the officials in charge of spatial planning promoting the construction of shopping malls with pizza and candy parlours – and vertical governance – e.g. potential divergence between a national government supporting foreign investments of big food companies to ease pressure on the economy and a local administration trying to shift to short supply chains and locally sourced-food.

**Economic/Financial barriers**. A recurring obstacle for city administrations is represented by the scarce availability of resources to influence urban food systems transformation, e.g. small budgets for staff training and green public procurement (Jégou and Carey, 2015). To overcome this issue, local authorities should elaborate effective strategies to negotiate more funding with regional and national governments, as well as establish coherent strategies to gather private investments and philanthropic donations, by making explicit what it in for them. Explaining the benefits of agenda alignment for investments, for instance, is an effective way to catalyse and concentrate funding on a selected set of strategic lever actions for transformation. It is however very important to make sure that public authorities retain control over how private funding is used, as often financial support from private actors comes with strings attached that may distort the overall objective to establish healthy and sustainable food chains (IPES-Food, 2017).

*Enablers for transformation*

**Technological/administrative enablers.** EU cities can benefit by learning from the solutions other cities have put in place and to regularly review the effectiveness of approaches taken. Implementing projects dedicated to the exchange of best practices has been found to have a strong impact in EU cities, as food is a relatively new area of city governance (European Commission, 2017). Establishing



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clear indicators is also crucial to ensuring that new data are collected, and that progress and outcomes can be monitored on a regular and continuous basis throughout implementation. A key mechanism in this respect could be the establishment of international platforms that support the exchange of knowledge and competences and, longer-term, can provide the basis for the development of a global repository of good practices about urban food policies, programs and initiatives (European Commission, 2017).

**Social enablers**. In order to overcome the lack of participation or commitment of important stakeholders, cities need to identify entry points suitable to make urban food system transformation surge as a political priority in the public agenda. Some EU cities have used the 2008 economic crisis and the ensuing food price spikes to sensibilise their agri-food actors and citizens on the transformative action needed. Other cities engage the food system as an element of broader strategies being designed to confront the impacts of climate change, to combat food poverty and malnutrition, or to mitigate rural to urban migration (Food Links, 2018). One specific type of experimental intervention that has gotten increasing attention recently are urban living labs (ULL) allowing urban stakeholders to design, test and learn from socio-technical innovations in real time (von Wirth et al., 2018). The urban arena is thereby considered to be of particular importance as cities face some of the most pressing sustainability challenges regarding food production, distribution and consumption, and have started to design and deploy localized responses to address these transformative pressures. Furthermore, the issue of limited financial and human resources notwithstanding, urban areas contain the necessary spaces and interconnectedness of various sectors and actors to enable meaningful innovation. In the framework of the FIT4FOOD2030 project, 7 City Labs and 7 Food Labs have been established to bring together policy makers, researchers, educators and citizens to work on their visions of the EU food systems of the future and consider concrete actions on how to get there (FIT4FOOD2030 D.6.2, 2019).

**Political enablers**. An essential condition is to ensure strong and continued political commitment towards urban food system transformation. To this extent, it is necessary to find incentives to include city representatives and other relevant actors active in the food system, like citizens' associations and private companies, in devising urban food strategies with assigned resources and responsibilities. It is necessary to make a strong case for the relevance of urban food policies to different stakeholders' agenda, drawing on research and providing training in order to break down prejudices and enact transformative innovation policies such those devices by collaborative Food Policy Councils. Often it may be helpful to find small ways to cooperate initially, then expand to larger partnerships once common benefits are established (IPES-Food, 2017).



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**Economic/Financial enablers**. New and inclusive approaches are needed to food systems finance, combining public sector budgets with third party donors. EIT Food, for instance, has created the Rising Food Stars network, which provides privileged contacts between innovative strat-ups and potential investors, and offers structured market development for start-up services and products (EIT Food, 2020b). Investments in food start-up enterprises are important, but so is financial support to be provided to innovative food governance practices, including the development of new partnerships and alliances between sectors, actors and different levels of government. While core funding from city government and, where necessary, from other public sources is key to enable a minimum of implementation, additional funding from other sources is often essential. To make optimum use of money, streamlining with other city programmes avoids duplicate spending, and close continual monitoring of outcomes ensures no funds are wasted on ineffective actions (IPES-Food, 2017).

### Potential for sustainable social and economic breakthroughs

*Social breakthroughs*

**Food Policy Councils**. EU cities increasingly establish these networks of stakeholders with different interests from civil society, the private sector and the city administration, with the mandate to analyse the fallacies of a specific urban food system and advice on how to improve it. The configuration of a Food Policy Council is different according to the specificities of different cities. Some may enjoy a strong lead from public representatives and close linkages with the city council, as it is the case for the Food Lab in Bruges (France). In other cases, such as in the city of Lubjiana (Slovenia), Food Policy Councils are predominately grassroots efforts consulted on selected issues by public authorities with the objective to educate officials and the public (European Commission, 2017).

**Urban agriculture**. During the last few decades, new forms of gardening and farming practices using high levels of social innovation, environmental friendly lifestyles and mixed bottom-up or top-down approaches have been emerging. Examples include Community-Supported Agriculture (CSA), community composting and gardening, guerrilla gardening and squat farming, urban food strategies, support of small entrepreneurs, local food chains, including market gardens and farmers' markets, the Slow Food initiative, including a revival of local food production and farm shops and markets (Interreg, 2017). Urban agriculture can tackle issues such as urban poverty alleviation and promotes social inclusion, urban food security and nutrition, and urban environmental challenges. Given the important role that urban agriculture can play from a livelihoods and social cohesion perspective, in the last decade an increasing number of EU national and local authorities have included urban agriculture as



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a precise strategy in city planning that can be used to enhance the resilience and sustainability of urban areas and populations.

**Trans-localism**. As evidence shows that positive food systems innovations in one city lead to diffusion of learning and reproduction of best practices in other cities (Sonnino, 2016), trans-local networks that aim to enhance knowledge exchange and cooperation between urban areas, cross-scale collaboration among EU cities are emerging as useful tools to promote and formalise exchanges of knowledge and increase the benefits of action through collective efforts. Several networks with a specific focus on urban and regional food policy have been established in Europe, including the Milan Urban Food Policy Pact, signed by 140 EU and non-EU cities committed to work towards inclusive, resilient, safe and diverse food systems; the C40 Cities Food Systems Network; that supports the efforts of 80 global cities to develop and implement measures to reduce carbon emissions and increase resilience in food systems; and the EUROCITIES' food working group, an innovation hub designed for sharing information, ideas and best practice on urban food between members of the network of elected local governments in 130 European cities (IPES-Food, 2017).

**Food Banks**. Food banks play a major role in the urban food aid sector by distributing donated and purchased groceries directly to vulnerable individuals in local communities. The public health implications of food insecurity for cities are significant, particularly as food insecurity has a higher prevalence among certain population groups. New social practices based around food are emerging due to uncertainties within the current industrial food system. Changes in economic and environmental conditions over the last few years have challenged the security of the world's food supplies. situations where systemic shocks hit cities and public assistance fails to meet community needs, food aid services, such as food banks, community kitchens, soup vans, and subsidised community markets have been established to bridge the food security gap (Bazerghi et al, 2016). These services, often termed 'emergency food aid', are typically intended as short-term solutions for the unprivileged. However, as socio-economic inequalities have become endemic features of European societies, some emergency food aid providers have morphed into permanent redistributors of food, ranging from a large organisations donating rescued products to smaller charities providing cooked food or grocery shopping services to vulnerable users (European Food Banks Federation, 2020). Since the establishment in the late 80s, food banks have expanded the scope of their mission to include new dimensions of food security beside nutrition: health; education and technical assistance; farming; economic and workforce development; business enterprises; and community empowerment and advocacy. Within each of these categories, food banks are adopting a variety of



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approaches to achieve both the short- and long-term goals of feeding the hungry and permanently ending food insecurity.

*Economic breakthroughs*

**Smart traceability in the food supply chain**. New digital tools assuring traceability, safety and authenticity of foods are being developed to meet consumer expectations and build trust in the urban food chain. Furthermore, traceability enables more effective identification of vulnerabilities along the food chain, including determining and measuring food loss and waste occurring at different stages, thus making value chains more efficient and better equipped to meet the growing demand from urban food systems. Researchers are increasingly focusing on the blockchain and Internet of Things technology to design a trusted, self-organized, open and ecological food traceability system which involves inputs from all parties of the food chain (Lin et al., 2018).

**E-commerce and new delivery systems**. The Covid-19 pandemic has exposed the need to make sure that all citizens retain their right to access to food in spite of external constraints, such as short shopping hours, long queues and limited availability of products on the shelves. However, vulnerable people such as the elderly, those with disabilities, as well as single parents working long office hours have long being familiar with the burden associated to concrete action to go food shopping in terms of time, energy and resources. The Covid-19 epidemic has seen the raise of food e-commerce and delivery services, including in the case of small grocery stores and farmers who joined forces with IT companies to harness the economic benefits of new market opportunities. While the agri-food business has historically been slow in moving sale online (Just Food, 2020), digital services have the potential to overcome several challenges of urban food systems. They can contribute to fix the issue of 'food deserts', by providing delivery of fresh and nutritious foods to neighbourhoods lacking physical stores; help reduce food waste, by connecting suppliers with surpluses with potential buyers; and solve the mobility issues of citizens unable to go to markers or carry heavy weights.

## Impacts & Co-benefits

Moving towards a circular, short food chain model would contribute significantly towards the **EU ambition to achieve 100 climate neutral cities by 2030** (European Comm, 2020b), in particular by allowing for net zero carbon dioxide emissions, as well as lower levels of methane and nitrous oxide. Furthermore, urban food systems transformation would allow for a drastic 51% overall reduction in GHG before 2050 with **dietary change as the intervention with the greatest potential for emissions reductions (-60%), and action on household food waste (-10%) and supply chain food waste (-5%)** as additional enablers (C40 Cities, 2019). Urban food system transformation will also directly



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contribute to the transition towards a circular and regenerative production to consumption model, thus **reducing nutrient dispersion and increasing soil and land productivity**. A study on the city of Brussels has showed that transitioning towards a short-supply chain systems where 30% of food is sourced from the peri-urban surroundings by 2030 would allow for yearly savings as high as 9.2 million EUR from avoided soil degradation and over 21 million m3 in water savings, equivalent to half of the city's residential consumption of drinking water (Ellen MacArthur, 2019).

EU cities represent an ideal hub for experimentation in the application of food system thinking to system and policy change, due to their relatively small size and uniform governance model as compared to EU Member States. In particular, moving towards a circular model and short supply chains will have a **positive impact on EU cities' social cohesion by reconnecting urban citizens with nature** and catalysing the attention of (local and national) policy-makers, thereby facilitating a shift away from sectoral actions and towards more systemic approaches to food governance. The involvement of many relevant stakeholders in the decision-making process will allow for the **production of evidence-based strategies leading to balanced, comprehensive policy decisions**. Urban food system transformation will also require and, at the same time, spur technological innovations, thus **supporting job creation and economic growth and ultimately contributing to social inclusion and equity along both urban and peri-urban dwellers** (EU Committee of Regions, 2018).

EU cities will benefit from a 73% deduction in deaths associated with obesity, coronary heart disease, stroke, cancer and type-2 diabetes if a shift towards a drastic reduction of meat consumption and an increase intake of fruit and vegetables is achieved (C40 Cities, 2020). Furthermore, providing personalised nutrition to elderly people and other vulnerable citizens, as well as improving urban-rural linkages will **positively contribute to enhance life expectancy and improve the life quality** of peri-urban residents (EC FOOD2030 Expert Group, 2018).

## Policy alignment

*Alignment with EU policy frameworks*

Overall, food-related challenges and potential solutions are still addressed through a sectorial approach, with **relevant policies spread over a wide array of EU legislative documents and competence areas**. In particular, EU frameworks directly relating with local and regional governance, such as the **Partnership on Circular Economy within the EU Urban Agenda** and the **Urban Innovative Actions within EU Cohesion Policy** touch only incidentally upon the steps needed to achieve a urban food system transformation (Urban Agenda for the EU, 2020). Furthermore, the 2020 Farm to Fork Strategy - the EU communication meant to apply a comprehensive food systems approach to the



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transformation of EU food systems - only mentions the word 'cities' twice , thus revealing a relatively **low degree of thematic priority in the political agenda of DGs AGRI, MARE and SANTE** responsible for the strategy development (European Commission, 2020). The situation seems to be different as regards to DG Research and Innovation (RTD), as cities are identified as new actors that can make a difference in food-system transformation (European Commission, 2019), while EU cities are proposed as innovative partners for Europe in defining a multi-objective and multi-actor drive for responsible innovation across the food system (European Commission FOOD2030 Expert Group, 2018). **DG RTD** has also actively **supported the creation of the 2015 Milan Urban Food Policy Pact (MUFPP)**, a global platform based on signatory mayors' commitment to develop sustainable food systems, grant healthy and accessible food to all, protect biodiversity and fight against food waste. Building on the creation of MUFPP, the European Commission has promoted the **creation of a working group on food within the EUROCITIES network**, aimed at establishing a creative hub for sharing information, ideas, best practices and experimenting innovative solutions related to urban food among the **140 European partner cities** (EUROCITIES, 2020).

*Alignment with international policy frameworks*

At the international level, urban food system transformation has been recognised as an imperative by the **New Urban Agenda (NUA) adopted by the UN Habitat III conference** in October 2016 to **guide the urbanization process over the next 20 years**. NUA builds on the 2015 UN Sustainable Development Agenda to provide more guidance to national and local governments the food-city nexus and the intersection between SDG 2 (e.g. end hunger, achieve food security and improved nutrition, and promote sustainable agriculture) and SDG 11 (e.g. make cities and human settlements inclusive, safe, resilient and sustainable). The NUA also makes explicit commitments to strengthening food systems planning, working across urban-rural divides and coordinating food policies with energy, water, health, transport and waste (UN, 2017). More recently, FAO published, in the framework of the ongoing work of its programme "Food for the Cities", a comprehensive **Framework for the Urban Food Agenda to support NUA and identify strategic actions** to support system transformation (FAO, 2019).

Several networks of cities have food as a thematic priority, or have established proactive working groups and put forward urban food strategies. The already mentioned **MUFPP**, established after the 2015 Milan Universal Expo, **reunites 210 international cities around 37 actions to improve urban food policies**, ranging from requiring school canteens to serve healthy meals to encouraging markets for nearby farmers to sell their goods. All the initiatives are designed to strengthen rural-urban links and build ties between producers and consumers (MFUPP and Barilla Foundation, 2017). The



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**CITYFOOD network** on resilient city-region food systems and urban agriculture was launched by the **Local Governments for Sustainability – ICLEI** and **Resource Centre for Urban Agriculture and Forestry -RUAF** in 2013 as a platform for information, training, technical and policy advice between cities, and to help them access financial assistance (ICLEI CITYFOOD, 2020). Finally, the **C40 Food Systems Network, in partnership with EAT Initiative,** convenes city officials to work together to achieve solutions to their most pressing food systems challenges. Building on the findings of the 2019 Lancet breakthrough report on food, planet and health, the C40 Cities Food System Network commits partner cities to work together with their urban residents to achieve urban food systems respectful of the 'planetary healthy diet' by aligning the signatory cities' procurement policies; supporting a shift in consumption towards healthy, plant-based foods; reducing food loss and waste by 50%; working with city stakeholders to develop a joint strategy for implementing these measures; and incorporating the strategies into their climate action plans (C40 Cities, 2020).



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**C40 Cities**

C40 Cities connects more than 90 of the world's leading cities to take bold climate action and build a healthier and more sustainable future. Representing 700+ million citizens and one quarter of the global economy, mayors of C40 cities are committed to delivering on the most ambitious goals of the Paris Agreement at the local level, as well as to cleaning the air we breathe.

For more information: https://www.c40.org/.

## C40 GOOD CITIES DECLARATION

*Applying Responsible Research & Innovation*

### Assessment of added value

The declaration, signed at the C40 World Mayors Summit in October 2019 by 6 EU cities (Milan, Copenhagen, Barcelona, Paris, Stockholm and London) and 10 global cities, commits the parties to: 1) Align food procurement policies to the Planetary Health Diet promoted in the Lancet 2019 report "Food in the Anthropocene", ideally sourced from organic agriculture; 2) support an overall increase of plant-based food consumption in by shifting away from unsustainable, unhealthy diets; 3) Reduce food loss and waste (FLW) by 50% from 2015 figures; 4) Work with citizens, businesses, public institutions and other organizations to develop a joint strategy for implementing these measures and achieving these goals inclusively and equitably, and incorporating this strategy into the city's Climate Action Plan. By doing so, the Declaration puts forwards a sustainable, inclusive and circular roadmap for the achievement of the FOOD2030 priorities, and serve as a model for other EU cities to take transformative action.

### Assessment of challenges

The Declaration establishes few precise targets to measure progress towards the achievement of its objectives. Apart for the commitment number 2, which sets FLW reduction goals more ambitious than those established by the EU Farm to Fork Strategy, the other commitments leave a significant space for interpretation to city governments, thus potentially watering down the potential of the initiative. Furthermore, EU cities taking part to the Declaration had already relatively developed urban food strategies before the 2019 World Mayors Summit. Therefore, it is to be ascertain how the commitments underpinning the Declaration can be scaled up from a few cities to the totality of EU urban food systems.

### Prospects for future development

The success of the initiative will depend on the political capital invested by city governments to achieve the objectives, as well as on the support of all stakeholders to the roadmap implementation. Should the 14 signatories start harnessing the benefits of the action – including positive electoral returns – many more cities could follow suit.



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**Infarm**

Infarm reflects the growing desire for highly nutritious locally grown food free of herbicides and pesticides. INFARM relies on vertically stacked layers under carefully controlled conditions, using hydroponics and light-emitting diodes (LEDs) that mimic sunlight to grow fresh produce. INFARM takes the concept a step further by employing its smart modular farming units directly where people live and eat. Its modular farms are placed in grocery stores, restaurants, shopping malls, and schools, enabling the end-customer to actually pick the produce themselves.

For more information: https://www.infarm.com/ .

## INFARM

*Vertical farming*

### Assessment of added value

Developed since 2013 as a urban farming network in Berlin with the ultimate goal of increasing the city' self-sufficiency, Infarm has expanded its action across Europe and around the world. As the produce is grown in the heart of the city, often directly at points-of-sale, Infarm contributes to shorten the length of the fruit and vegetables supply chains. This also has a positive impact on nutrition, as freshly picked produce retains more nutritional qualities. Besides consumers, the main beneficiaries of Infarm services are small retailers – who are at comparative disadvantage with big wholesalers as regards the sale of imported fresh produce that rapidly deteriorates. More broadly, the whole urban food system can potentially benefit from vertical farming, as its potential positive effects include a reduction of produce waste, less GHG emissions associated to land use and distribution, and increased resilience of urban food resilience to external shocks.

### Assessment of challenges

The technology behind Infarm type of urban farming is complex and expensive, requiring substantial investments. In its early stages (2016), Infarm received two EU Horizon2020 grants which allowed the start-up to develop its products and move to the proof of concept stage. While the Infarm business model, based on small vertical modular units, is potentially scalable as long as space allows, there is a concern that, should the company establishes as a leader in the fresh vegetable production worldwide, rural producers in peri-urban areas could be crowded out of the market, with obvious negative consequences on their livelihoods and food security.

### Prospects for development

COVID-19 represents a challenging testing bed for the future of Infarm. While the pandemics' pressure on supply chains has opened up new opportunities for its services provided locally, it has also fragilized small and medium businesses that make up a significant portion of Infarm's customers. Should the company overcome the current difficulties, it may be able to establish as a solid reality on EU food market and affirm its innovative concept together with its brand.



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## Conclusion

As urban dwellers will continue to represent a vast majority among EU residents, and EU cities will require an increasing quantity of food to feed them, the currently unsustainable urban food systems will need to change. At present, **EU urban food systems deliver on sufficient and affordable food, but fail to ensure all citizens have access to a healthy, nutritious and sustainably produced alimentation**. Hidden hunger, obesity and non-communicable diseases linked to poor diets are the direct consequences of food systems that are contributing to a public health crisis and high healthcare costs for citizens and Member States. Furthermore, the current model of production, distribution and consumption that serves EU cities is responsible for **significant GHG emissions that are projected to dramatically increase by 2050** if relevant action is taken swiftly and decisively**.**

However, there is growing awareness that urban systems also have the potential to revert the process by **making healthy and sustainbly produced foods affordable, available, and attractive for all citizens**, thus mitigating health risks while cutting down on the social and economic costs of malnutrition, and collectively improving the climate and the environment. EU cities are becoming increasingly important agents of change, through the development of urban food strategies including vast networks of stakeholders and addressing transversal issues through cross-cutting actions. **The choices that city authorities make on procurement, managing systems for food loss and waste, and designing and regulating the urban food environment** all represent great opportunities for system change. Their power can shape markets and influence private sector responses to the growing demand for sustainable and healthy food. **Competence-building and skill-transfer** will be needed so as to empower urban actors and help them **grow into change-makers** and multipliers of results. However, urban food transformation cannot materialise as a top-down process only**.** Start-ups and agri-food companies' creativity will be needed to design breakthrough innovations accelerating the pace of the transition and so as to meet the UN Sustainable Goals. Private investments will be required to support technologies and social processes that may take time to produce economic returns. EU urban citizens, as well, will need to play a major role for the sake of their communities, by switching to healthier and sustainable diets and changing norms and behaviours regarding consumption and waste.

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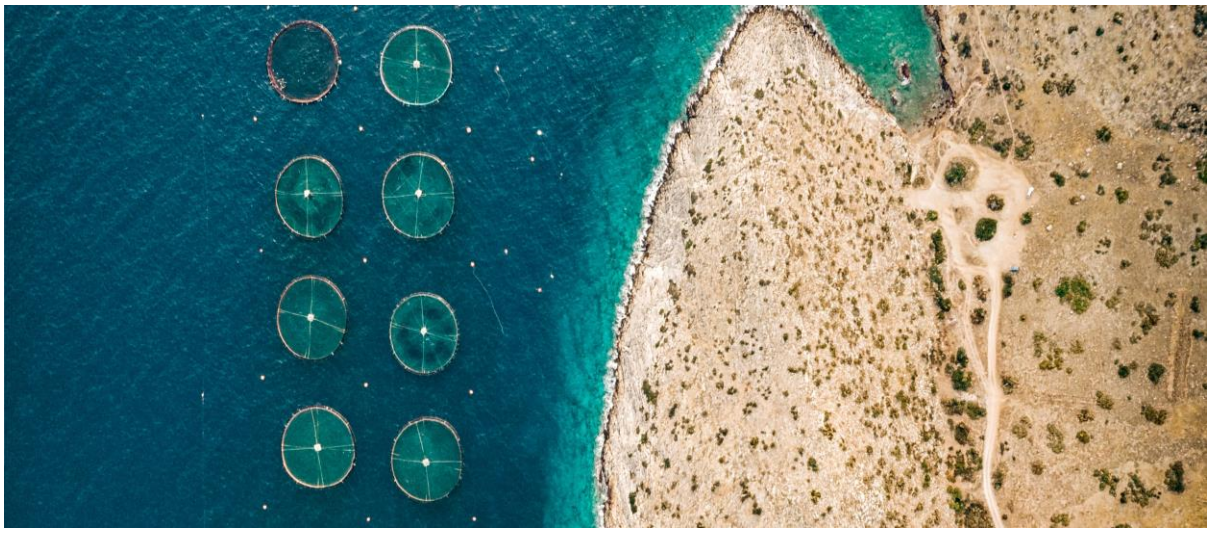
# Food from the Oceans & Freshwater Resources



**Food from the oceans has the possibility to satiate 12-25% of the protein demand of the estimated 9.8 billion people of 2050 (Costello et al., 2020). Together with sustainably increased freshwater and land-based aquaculture, there is potential to feed an even more significant portion of the world's population by 2050. Multiple significant challenges stand in the way of meeting this ambition, yet current and future improvements in food production processes and techniques can act as enablers and catalysers.**

**As only 65.8% of global fish stocks are within biologically sustainable levels, fisheries and aquaculture management policies must improve. There are many potential technological streams for sustainably increasing food and feed production from the oceans and freshwater resources, from utilising the ocean microbiome, harvesting new or underutilised species, reducing waste and increasing circularity. The largest potential lies however in promoting a shift in EU consumers' dietary habits from the over-consumption of meat proteins to healthy, energy-efficient and environmentally friendly foods from the oceans and freshwater resources.**



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## Societal, economic & environmental needs

Both the ocean and freshwater resources are central to our lives, they provide jobs, transport, recreation, energy, food and ecosystem services. More than half of Europeans live in a coastal region, while 75% of Europe's external trade and 37% of internal trade is seaborne. In 2016, the EU Blue Economy directly employed close to 5 million people and generated around €750 billion in turnover (OECD, 1016). **Fisheries and aquaculture play an increasingly important role in providing food, nutrition and employment, but innovative solutions are needed to produce more food in a sustainable manner**. It is important to mention that in the European context of food from the ocean and freshwater resources, there is a significant difference between Europe and the EU. Three non-EU countries (Russia, Norway and Iceland) accounted for almost 60% of total European production in 2017 (EUMOFA 2017). **The EU is a net importer in fisheries and aquaculture, and is only self-sufficient in species like mussel, herring, mackerel and sardines** (EUMOFA, 2017).

The world needs 60% more food by 2050 and the global 7,5% per year growth of aquaculture since 1970 shows that aquatic food has the capacity for contributing to food security, while capture fisheries have remained stable since the 1980s (FAO, 2020) (Figure 1). As SAPEA (Science Advice for Policy by European Academies) states in the "Food from the oceans" report: "Increased food production from the ocean could release some of the pressure that has been put on agriculture, as well as supporting a range of livelihoods and activities associated with the fishing and mariculture industries" (SAPEA, 2017). Modern agriculture is very successful but is currently using 70% of freshwater resources and 50% of habitable land. **At present, only 2% of the food in the world is produced in the ocean, even though 17% of protein consumed is from the ocean**. With a growing population and declining environment, the only way to produce more nutritious food is by producing food that needs no additional fresh water and land, and that can withstand climate change. This food should come from the oceans and freshwater resources.

There are multiple hurdles to reaching the goal of feeding the world from the oceans and freshwater resources, and substantial work has already been done to identify these challenges and opportunities to find sustainable solutions. The body of work is mainly divided along marine/freshwater lines, but the challenges are overlapping, and a comprehensive approach is needed.



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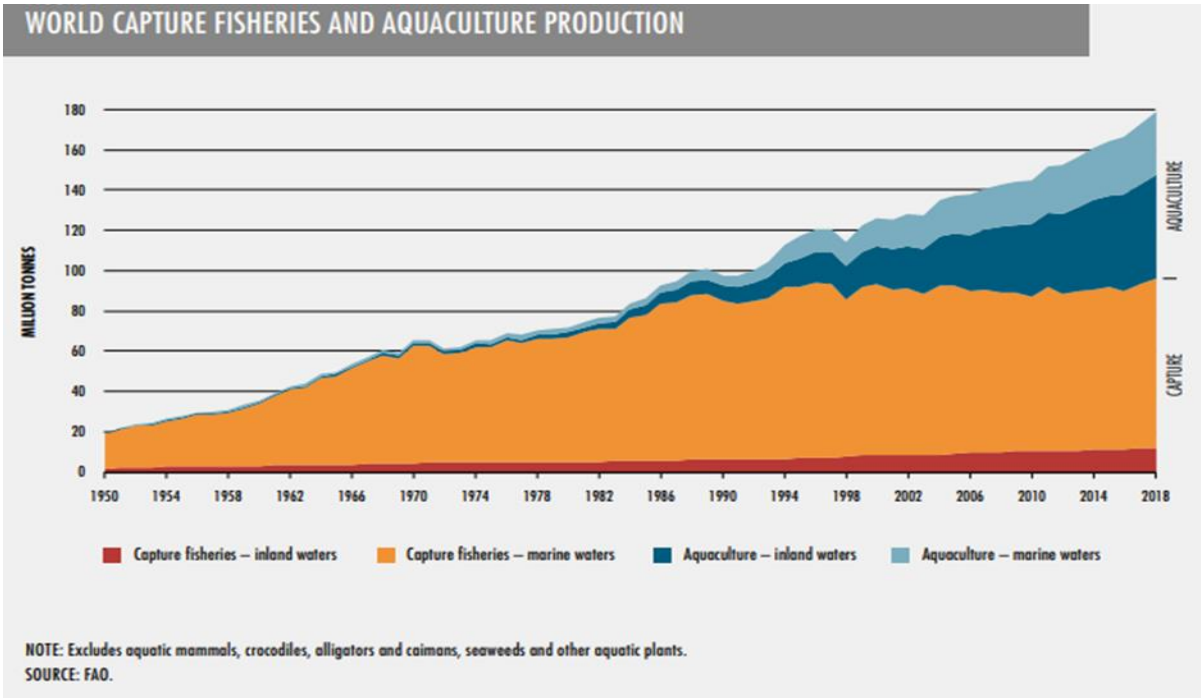


Figure 1: World capture fisheries and aquaculture production. Source: FAO (2020). State of the world fisheries and aquaculture 2020.

Both Costello et al. (2020) and the Blue Bioeconomy Forum roadmap state that increases in all three main marine food producing sectors – wild fisheries, finfish mariculture and bivalve mariculture – are likely. However, **whether production potentials are realized in a sustainable way depends on policy reform, technological innovation and shifts in demand**. Edible food from the sea could increase by 21-44 million tonnes by 2050, a 36-74% increase compared to current yields, which represents 12-25% of the estimated increase in all meat needed to feed 9.8 billion people by 2050. Shifting demand affects the quantity supplied from all three production sectors (Costello et al., 2020).

Consumer engagement is a challenge and a trend at the same time. Consumers do not only demand what is supplied, but are actors who pursue their own interests, thus information that is trusted by consumers is vital when needing to change dietary preferences in consumers (FIT4FOOD2030, 2018). In order to shift demand for the future food production, it is essential that **trustworthy consumer information and new approaches to social responsibility** are provided (SAPEA, 2017). Additionally, it is crucial to involve citizens and other relevant stakeholders in planning processes and awarding social licenses to operate.

From an economic perspective, fishery management has one of the more direct links between lack of innovative action and the costs and damages connected with it, reflected in the lack of self-sufficiency in fisheries and aquaculture in the EU. There is a need for **coordinated fishery management to allow**



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**overexploited fish stocks to rebuild and to increase long-term food production from wild fisheries**, especially in EU waters like the Mediterranean (Costello et al. 2020; FAO 2020).

The UN SDG12 states that **per capita global food waste should be halved by 2030 in fisheries and aquaculture**. It is estimated that 35 percent of the global harvest is either lost or wasted every year (FAO, 2020) while industrial processing of fish and shellfish may result in as much as 70 percent by-products (Olsen et al., 2014). Reducing food waste is essential across all sectors of the food value chain, including fisheries and aquaculture (Common fisheries policy, 2013). However, the lack of a broadly agreed definition of food loss and waste is particularly problematic for food from the oceans and freshwater. One common definition of food waste refers to the edible parts of plants and animals that are produced or harvested for human consumption, that are ultimately not consumed by people (World Resources Institute, 2019). A weakness in this definition is what exactly is meant by "for human consumption". **What kind of food is eaten from the oceans and freshwater resources varies significantly across the globe and has changed over time**; seaweed e.g. is a staple food in Japan, but not in Europe, and fish heads and bones have been eatable parts of the fish in Europe previously, but not anymore (Zheng et al., 2018). There is a need to increasingly use by-products from fisheries and aquaculture. Stevens et al (2018) show that for Scottish aquaculture food production, value and sustainability can be increased by strategic management of by-products, resulting in over 60% increase in food production from fish farming.

**Discarding is the practice of returning unwanted catches, the so-called bycatch, to the sea**. In 2013, a landing obligation was added to the Common Fisheries Policy (CFP) to gradually eliminate the wasteful practice of discarding, to improve fishing behaviour through improvements in selectivity. The landing obligation requires all catches of regulated commercial species on-board to be landed and counted against quota and recorded in the logbook. These are species under Total Allowance Catch/quotas (TACs) or, in the Mediterranean, species which have a Minimum Landing Size (MLS). Ensuring monitoring of discards in fisheries is an area where research and innovation is much needed.

To accommodate the required 60% increase in food production, **feed composition must be moved away from marine products and scaled up**, and alternative aquaculture species must be introduced, while also assuring sustainability (Turchini et al., 2009). After shifting demand, managing wild fisheries and reforming mariculture policy, an area with true challenges and where R&I is extremely useful and active, is advancing feed technologies for fed mariculture and freshwater aquaculture (Standing Committee on Agriculture Research, 2020). 75% of mariculture production requires some feed input, but terrestrial plant- and animal-based proteins, seafood processing waste, microbial ingredients, insects, algae and genetically modified plants are also being developed for feed (Costello et al, 2020).



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**Salmonid feed has changed dramatically in raw material composition from 80% marine products in 1995 to <30**% in 2016 (Döring 2019; Aas et al 2016). To ensure human and animal health, the EU's From Farm to Fork strategy has included in its 2030 targets that the sale of antimicrobials for aquaculture will be reduced by 50% (European Commission, 2020c). The 2018 European Medicines Agency report on **sales on veterinary antimicrobial agents states that there already is an overall decline in sales of 34.6%** in 25 of 31 countries, with larger reductions in highest-selling countries, reflecting also the large difference in sales between countries (European Medicines Agency, 2018). There are also relevant examples from Norway, where aquaculture antimicrobial use was reduced by 99% between 1987 and 2013 (Norwegian Ministries, 2015), while reducing the use of veterinary medicines in freshwater aquaculture is identified as a research topic of the highest priority in the Evaluation of the freshwater aquaculture research needs in Europe by SCAR-FISH (Standing Committee on Agriculture Research, 2020).

Luckily, **50% of the aquaculture produced in EU are molluscs and crustaceans**, which are largely unfed (filter feeders), while 27% are marine fish and 23% freshwater fish. About 57% of aquaculture consumed in the EU is produced outside the EU, with Norway as the EU's principal supplier of aquaculture products. The two most consumed aquaculture species in the EU are salmon and mussels (European Commission, 2015). **Continued development of feed should be centred on species with a high feed conversion ratio (FCR**), e.g. weight of feed administered over the lifetime of an animal divided by weight gained. Using FCR, aquaculture and chickens are similarly efficient at converting feed into animal biomass. FCR does not account for differences in feed content, edible portion of an animal or nutritional quality of the final product, but Fry et al. (2018) identified 'nutrient retention', which can be used to compare protein and calories in feed (inputs) and edible portions of animals (outputs). Following the calculations, chickens are the more efficient, followed by Atlantic salmon (Fry et al, 2018, Figure 2).



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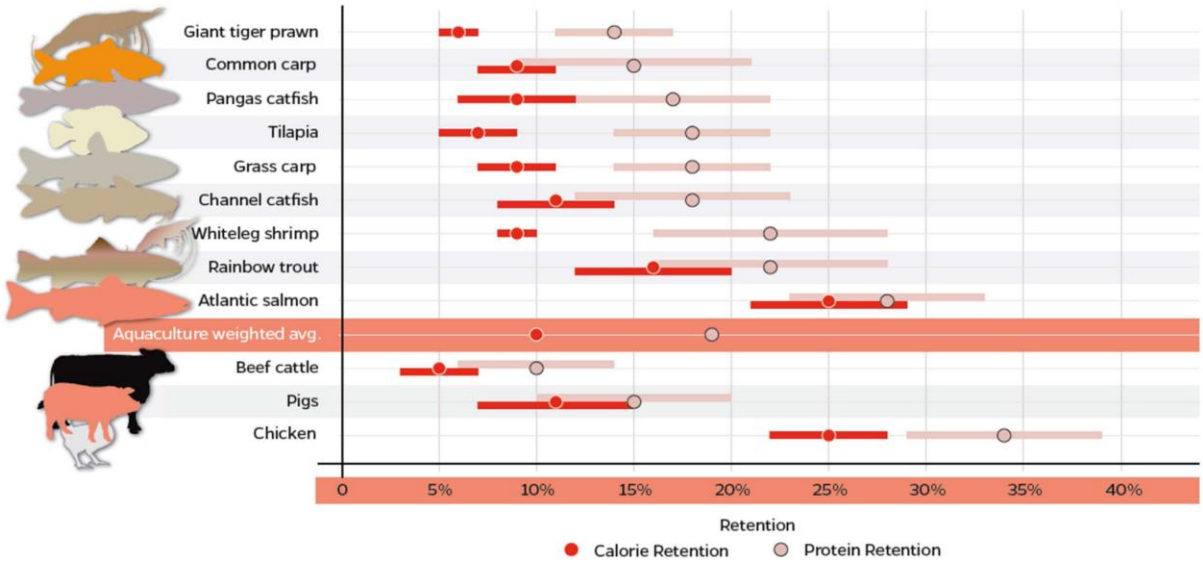


Figure 2. Feed conversion efficiency and energy retention in aquaculture and agriculture species. Source: Fry et al. (2018).

In aquaculture and fisheries, both in marine and freshwater habitats, harvesting animal species at lower trophic levels (lower in the food chain) than is common at present, utilising species which are either not exploited at all, or only marginally exploited, or utilising techniques like integrated multi-trophic aquaculture (Greenwave, 2020) to harvest more sustainably can fulfil animal protein needs for the future.

The technical paper 'Impacts of climate change on fisheries and aquaculture' (FAO, 2018) states that **short-term climate change impacts on aquaculture can include losses of production and infrastructure arising from extreme events such as floods and increased risks of diseases**, parasites and harmful algal blooms. Long-term impacts can include reduced availability of wild seed as well as reduced precipitation consequently leading to increasing competition for freshwater. In relation to inland fisheries, the technical paper additionally highlights that in the **competition for scarce water resources, the valuable contributions of inland fisheries are frequently not recognized or undervalued.** The remarkable human contribution to climate change is also evident in the water bodies: climate change is making the oceans more acidic, warmer and the sea level is increasing (Climate Science Special Report, 2017). Additionally, decreased water quality is threatening food resources from marine and freshwater habitats (United Nation Environmental Programme, 2010).

In light of the implications of Covid-19 on the fisheries and aquaculture sector, Dr Manuel Barage, director of Fisheries and Aquaculture Policy and Resources, said at the Nor-Fishing conference 2020 (20.8.20): "Aquaculture and fisheries will be crucial in ensuring that the health crisis will not be a food crisis", and: "We must re-activate the supply chains, to keep jobs and food production" (FAO, 2020). The outbreak of the **Covid-19 pandemic has put the EU's fisheries and aquaculture sectors under**



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**substantial pressure**, especially because of a **high dependency on trade and on out-of-home consumption**. Fishers, producers and processors have been forced to suspend or severely reduce their activities and the closure of sales venues, markets, outlets, and distribution channels has seen a substantial **drop in prices and volumes by 20-100**% (Pita, 2020). Fisheries and aquaculture are industries that employ relatively few people in Europe (265000 in 2017) (European Commission, 2017), compared to the production output, but are central in local communities (FAO, 2018). The European Commission has taken action to protect the fisheries and aquaculture sectors from severe Covid-19 shocks by introducing specific measures, including amendments to the European Maritime and Fisheries Fund (EMFF), for member states to use their unused EMFF budget to support their fisheries, aquaculture and processing sectors (European Commission, 2020d).

### R&I action required

- **Improve fish stock management.** Stock management practices need to be improved on account of current high levels of overfishing, which is an environmental and financial burden. Fishing new species that are only marginally exploited today can alleviate the pressures of the more overharvested populations and species and might allow for increased harvest. Aquaculture policy (marine and freshwater) needs to be reformed, and licences and permits must be simplified, to help expand production and ensure a systemic and sustainable approach to governing the land and the sea. If we consider the recommendations from the SAPEA report Food from the ocean (SAPEA, 2017) and Costello et al. (2020), we see that they both identify improvement in management of wild and traditional capture fisheries, and improvement of mariculture, whether in selection of species, management or feed technology. SAPEA also recommends fishing species that are marginally exploited today, while Costello et al. suggested shifting demand. These recommendations most certainly require research and innovation; on feed technology and farmed fish, on net pens and recirculating aquaculture systems (RAS), but most importantly fundamental work is needed in management and governance, changing public awareness on the safety and transparency of aquaculture products.

To improve management and governance, and to ensure strategically relevant research and innovation, multiple entities in the European landscape have produced relevant reports: The Strategic Research Agenda for Oceans and Human Health (OHH) in Europe (2020), developed by the Seas, Oceans and Public Health in Europe programme (SOPHIE), recommends OHH research in order to answer fundamental questions, provide evidence to policy, and increase OHH literacy in Europe and



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beyond; European Fisheries and Aquaculture Research Organisations' (EFARO) recommendations on research and innovation gaps and needs beyond Horizon 2020 (2019); European Aquaculture Technology and Innovation Platform (EATiP) Vision and Strategic Research and Innovation Agenda (2012) (SRIA) and Review of the SRIA (2017), identifying gaps and topics of importance for European aquaculture; Strategic Research Agenda for Fisheries, Aquaculture and seafood Processing by the COFASP ERA-NET (2016).

In line with RRI and the FOOD 2030 policy framework, we highlight two major recommendations from the JPI Oceans SRIA (2015), which at the time were endorsed by 21 European countries and that have the most promising potential:

- **Promote technological developments in aquaculture production** including research on innovative feeds, and research-based DNA sequencing brood stock, new species and stock baselines adapted to climate change impacts.
- **Foster engagement between marine fisheries, aquaculture and land-based food production** to maximise sustainable food production and sound governance.

*Barriers to systemic change*

Change in consumer behaviour and dietary habits is required to successfully change our food systems. The average EU citizen consumed 24.35 kg fish and seafood in 2017 (EUMOFA, 2019), but the number hides large variations between Member States. Per capita consumption of fisheries and aquaculture products in 2017 varies from 56.8 kg live weight per year (Portugal) to 5.6 kg (Hungary) (EUMOFA, 2019). A survey commissioned by the European Commission on EU consumer habits regarding fishery and aquaculture products determined that **consumers in land-locked countries are shown to eat fish and seafood less frequently** than those in countries with coastlines (European Commission, 2018). Consumers who prefer sea products tend to eat and buy fish and seafood more frequently, while wild/farmed preference is not relevant. As consumers buy mostly from supermarkets (77%), a stable supply of farmed fish and seafood to supermarkets will encourage consumption in the next decade (European Commission, 2014b). **Appearance and cost are key determinants for consumers**, along with places of origin, as consumers show preference for local and EU fish and seafood products. A general preference for wild products emerges from the survey, although the most important determinants of purchase seem to be price and quality, rather than the production method. These are all highly relevant to the role of food from the oceans and freshwater resources in the necessary food system transformation.



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A relevant barrier to increase fish consumption is the **resistance to its taste, smell, and appearance of seafood** – with the challenge being even bigger for farmed products (FIT4FOOD2030, 2018). This evidence is consistent with the overall agri-food trend that people prefer food with specific aesthetic features corresponding to the standards set by the advertisement industry and social media.

Barriers in pond aquaculture are also related to management of environmental factors and to the social and demographic structure of rural fishery communities (Halasi-Kovács, 2019). A **better understanding of socio-economic consequences and mechanisms of subsidies for production is required** to improve freshwater aquaculture. Urszula Budzich (TABOR, FARNET) listed community acceptance (66%) and legislation/ licensing (57%) as key challenges identified by freshwater aquaculture producers, because they inhibit new companies from establishing and reduce possible profits (Budzich, 2019). Citizen participation is crucial for the development of a more sustainable aquaculture industry.

*Enablers for transformation*

Enablers of food from the oceans and freshwater resources are present and needed on global to local sales. The UN conference on trade and development in 2018 stated that "The Blue BioTrade approach involves **working across multiple levels of the value chain to develop sustainable livelihoods**, adopt an **ecosystem-based management approach**, and foster swift adaptation to dynamics markets and changing ecological conditions" (United Nations Conference on Trade and Development, 2018), highlighting that fisheries and aquaculture is one of four priorities in Blue BioTrade.

In its 2018 "Impacts of climate change on fisheries and aquaculture" report FAO lists increased fishers' income and higher levels of and employment from fishing and related activities as very important to certain fishery-dependent towns and coastal villages (FAO, 2018). Providing opportunities for employment is an important enabler for future breakthroughs in the sector.

### Potential for sustainable social and economic breakthroughs

**Dietary shifts to alternative proteins.** Food from the oceans represents a relatively nutritious and environmentally sustainable alternative to meat proteins. The change in dietary habits towards more food from the sea could also produce the secondary effect to help consumers turn to even more sustainable foods from the ocean and freshwater resources like algae, filter feeders and other lower trophic level organisms. Dietary shifts must be tailored to local conditions, both environmental and cultural. Over the last century, we have seen massive changes in diets all over the globe with a



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significant increase in animal meat consumption, and such changes are expected to continue as a larger part of the world experiences wealth increases. Consumers need to trust the product they are paying for, if the objective to increase demand for seafood is to be achieved. On the other side, demand can only be increased if communication is transparent and trustworthy and the consumer is informed. Sustainability certifications (ASC (Aquaculture Stewardship Council, 2020), MSC, CITES, (Convention on International Trade in Endangered Species of Wild Fauna and Flora, 1998)) and validation of seafood species are available to provide consumers with the essential information to change their diets (SCAR 2019; Barendse et al., 2019).

**Reconnection with the oceans**. Being aware of the ocean food system means also knowing the oceans. There are many European initiatives like Campus Mondial de la Mer (2020) and the Ocean Hackathon (2020) which engage youth and foster ocean stewardship, and citizen science initiatives for the oceans like "Dugnad for havet" (Marine Citizen Science, 2020). Online TV series exploring ocean health, the stewardship of the seas and the impact the oceans have on society (Ocean Aware) (Institute of Marine Engineering, Science and Technology, 2020) also highlight the importance of preserving the oceans. Multiple social initiatives related to innovation and oceans are currently being established, like the floating start-up hub The Ocean Opportunity Lab with the Creative Cities Alliance (Ocean Opportunity Lab 2020) or Katapult Ocean (Katapult Ocean, 2018) investing in ocean start-ups having a positive impact on the oceans. So far, they have invested in start-ups dealing with everything from electric service vessels in aquaculture (Evoy, 2020), drones used against illegal fishing (ATLAN Space), tracing and ensuring that fish are caught in a sustainable manner (RemoraXYZ), sustainable fishing (Innomar), producing fabric from algae (Algalife), bio-packaging (Oceanium), aquatic animal health diagnostic tool for aquaculture (Marimetrics), keeping seafood fresh (Tracio), keep-cold chain in Arica (KeepITCool) and sea lice counting (Fiscency). Innovation clusters on seafood are also being established (Seafood Innovation) (Norwegian Centres of Expertise, 2020), as well as initiatives for ocean sustainability through transparency, data-sharing and collaboration (Global Fishing Watch, 2020) using satellite tracking and data analysis, so as to help governments and maritime security agencies to strengthen monitoring and control of fisheries and meet sustainability goals. Making vessel activity publicly trackable is a key first step for countries committed to achieving greater transparency in fisheries.

**Improved fishing methods.** An impressive number of breakthroughs is emerging in the field of improved fishing methods to improve quality, reduce waste and increase earnings (Sogn-Grundvåg et al. 2020). These include capture-based aquaculture, where live whitefish is kept in net pens in the sea



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to extend the fishing season (80% of the fish is caught between January and April); and innovative techniques to improve transport and conditions as to not stress the fish, so that whitefish quality is improved in order to have a steady supply all year. Both initiatives help reduce waste and avoid compromising fish quality (NOFIMA, 2020). Additionally, waste can be reduced by using boats where weak or potentially sick fish are slaughtered on a support boat by the pens (Elax, 2020). Another emerging breakthrough is the on-board processing of fish from fisheries using artificial intelligence (AI), autonomous data collection and decision support, AI algorithms that log the species and size of fish caught (e.g. catch scanner), and robotic sorting of wild fish catch with robotic arms. Location of fish stocks can be predicted with data models indicating where fishers should go, and sensors are used in the net pens to inform decisions (SEALAB Sintef). Better techniques for cooling fish on the boats (OPTI COOL, CFlow) and freezing the fish at lower temperatures (-30 rather than -18) both reduce waste and improve quality. The ultimate goal of such innovations is to develop a fully integrated AI that knows integrates consumer demand and supply shortages, and then inform the fishers, so as to avoid waste.

**Smart farming** is an important technological improvement affecting aquaculture in particular. Smart farming includes automatic and precision feeding, remote sensors and ROVs (remote operated vehicles) and on the one hand reduces feed waste, drug use, and fish escapes through better net inspection; on the other hand, it decreases the stress put on the surrounding environment. It also reduces risk for workers and equipment. Smart farming also has the capacity to make systems adaptable to unpredictable weather and conditions through AI. This will enable food production in the oceans to adapt to climate change and be introduced in new domains or geographic areas. As food from the oceans is not limited to aquaculture, application of smart farming in fisheries might have the potential to reduce by-catch, increase quality through improved catch and storage methods during transport, be more respectful of the environment and more precise in catch size to not exceed fisheries management levels.

**Regenerative and circular initiatives.** Environmental breakthroughs include aquaculture techniques or regenerative ocean farming processes like Integrated Multi Trophic Aquaculture (IMTA) (Greenwave 2020) or repairing the kelp forest by harvesting sea urchins (AquaVitae, 2020). Aquaponics use the excess nutrients in water from aquaculture to achieve more food production and in practice create a whole circular ecosystem, which is especially relevant for freshwater aquaculture. Projects contributing to the circularity objective include AQUABIOPRO-FIT, that is reducing waste and creating nutrient supplements among other things (Aquabiopro-fit, 2020), developing high-quality proteins and bio-actives from European aquaculture, fisheries and agriculture side streams for



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applications as diverse as health integrators, fitness supplements and animal feed. The project BlueNalu is based on cellular aquaculture and is specialising in growing fish protein artificially (in the lab) (Blue Nalu, 2020). There have been great changes in feed composition in salmonid feed production (Döring, 2019) from more than 50% fish meal in addition to almost 30% fish oil in 1995, to less than 30% of the two combined in 2016. The feed producers changed the composition of the feed on the basis of both price, competition, volatility, availability, to not be dependent on a limited resource with huge variability in price and availability, in addition to sustainability, and being a part of a certification (ASC) value chain. More breakthroughs are expected in aquaculture feed, where Hua et al. (2019) state that beyond plant-based ingredients that are increasingly common in feed now, fisheries and aquaculture by-products in addition to insect meals, have the greatest potential to supply the protein required by aquafeeds over the next 10–20 years.

### Impacts & Co-benefits

*Environment*

**Less impact of fishing gears on marine habitats**. Fishing gear can be destructive during fishing, but even more so when lost or forgotten in the water, because fishing gear continue to catch animals well beyond fishers' intentions, a phenomenon known as "ghost fishing." This is particularly wasteful and destructive because the gear can ensnare tons of animals that aren't being harvested or used in any way. Fishing piers can become sites of ghost fishing as lures and lines become wrapped around pilings, where animals swimming by become trapped. Fish are not the only casualties, however, as birds that dive into the water for prey can also get caught in the lines when they enter the water (Matsuoka et al 2005).

**Less impact of fishing on non-target species including on endangered and/or traditional ones**. An estimated 300,000 marine mammals, 160,000 albatross and 3 million sharks are lost to bycatch from fishing practices each year. This high rate of mortality is not sustainable for these animal populations. Animals like albatrosses and sea turtles that are long-lived and slow to reach maturity are particularly impacted by these threats and many populations have declined precipitously over the past few decades (EnvironmentalSciences.org, 2018).

**Less impact of aquaculture on surrounding water quality and integrity of aquatic ecosystems**. Aquaculture uses resources such as water, land, labour, materials for construction and feedstuffs. There are also outputs such as the fish that is being farmed, uneaten food, faeces and other waste products as well as therapeutants and other chemicals entering the environment. Demand for land



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and water resources has caused problems in some areas, leading to competition between aquaculture and other resource users.

**Carbon sequestration by farmed algae**. Algae, when used in conjunction with AI-powered bioreactors, is up to 400 times more efficient than a tree at removing CO2 from the atmosphere. Algae can consume more carbon dioxide than trees because it can cover more surface area, grow faster, and be more easily controlled by bioreactors, given its relative size. Bioreactors can contain large amounts of algae and optimize for its growth (and related sequestration) cycle in a way that is easier than trees and takes the overgrowth of algae, dehydrates it, and ultimately puts it to use as fuel or biomass.

**Bio-remediation of water by filter-feeding farmed mollusks**. Rapid environmental change is linked to increases in aquatic disease heightening the need to develop strategies to manage disease. Filter-feeding species are effective biofilters and can naturally mitigate disease risk to humans and wildlife. Filtration can reduce transmission by removing pathogens from the water column via degradation and release of pathogens in pseudo-faeces.

**Less feed consumption.** Higher conversion rates of ectothermic aquatic animals and farming of low trophic species result in less greenhouse emissions. This combines feed conversion ratio and selecting the most efficient production. Fed aquaculture is similarly efficient at converting feed into animal biomass, and both are more efficient compared to pigs and cattle (Fry et al., 2018). In addition, wider low-trophic species production, including macroalgae, shellfish, echinoderms, shrimp and low trophic finfish will result in lower greenhouse emissions.

*Health*

**Provision of high-quality seafood protein, poly-unsaturated fatty acids, minerals and trace elements.** Seafood is considered to be a low-calorie food when compared to other protein-rich foods such as red meat and poultry. Even the fattier fish like mackerel, herring, and salmon contain approximately 250 calories or less in a 200g cooked serving. Seafood contains high-quality protein that includes all the essential amino acids for human health, making it a complete protein source. Seafood is also considered to be low in both total fat and saturated fat. Even the fattiest fish have a fat content like lean meats, and contain less fat than most ground beef, some processed meats, and the fattiest (skin and dark meat) portions of some poultry products. Finally, there is a significant amount of scientific evidence that suggests that omega-3 fatty acids may play a role in reducing the risk of heart disease, which is the leading cause of death in most Western countries. Seafood is considered the best dietary source of omega-3 fatty acids. All fish and shellfish contain some omega-3's but the amount



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can vary. For these reasons, an increase consumption of seafood will significantly decrease the prevalence of non-communicable diseases.

P**rovision of safe seafood by farming low trophic species that do not accumulate contaminants.** It is established that due to bioaccumulation/biomagnification contaminants increase in concentration towards higher trophic levels. Increased provision of lower trophic species with lower bioaccumulation will provide safer consumption of seafood (Borga et al., 2008).

*Communities*

**Trigger blue growth and job creation in coastal areas and around lakes and rivers** and employment opportunities in Europe's maritime economy. The EU Blue Growth strategy promotes smart, sustainable and inclusive growth (European Commission 2014). Europe's seas, coasts and maritime sectors and regions are drivers for the European economy, with a potential of 5.4 million jobs and a gross added value of just under EUR 500 billion per year. Looking to 2030, many ocean-based industries have the potential to outperform the global economy, both in terms of value added and employment. The output of the global ocean economy is estimated at EUR 1.3 trillion today and this could more than double by 2030 (OECD 2016).

**Increase resilience of communities around lakes, rivers and coasts**. The diversification and integration of economic activities, including agriculture, livestock, fisheries, aquaculture and tourism will increase resiliency in the communities built around lakes, rivers and coastal areas. Especially in catch fisheries, management of fish populations is essential for their continued existence and monitoring of both fish populations and the fishing fleet is the most effective tool. Food from the ocean is an important part of the European culture, and fishing boats and fish markets, seasonal seafood and subsistence and recreational fishing activities are just as part of our culture and of food production. The foreseen changes in modalities and increase in production of food from the oceans and freshwater resources will also influence our societies.

*Circularity*

Better use and valorisation of marine biomass, including fish and shellfish rest raw materials, resulting in less waste: Marine biomass is considered an important substrate for anaerobic digestion to recovery energy i.e. methane. It leads to radical reduction in discarded aquatic biomass. The oceans have the potential to contribute heavily to more diversity in diets. There are still large undiscovered areas of the oceans and seas where potential new protein sources might be present. Potential co-benefits will also arise from fully exploiting the potential of groups like algae, and reducing production



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waste in aquaculture. The most popular aquaculture species still require high quality (marine) feed and R&I actions are needed to reduce the proportion of the feed that is either human food grade or that deplete the ocean.

## Policy alignment

*Alignment with EU policy frameworks*

The **Ecosystem Approach (EAM)** is a management and resource planning procedure that integrates the management of human activities and their institutions with the knowledge of the functioning of ecosystems (Convention on Biological Diversity, 2004). EAM is the underlying principle for environmental management strategies as formulated in the **EU Water Framework Directive (WFD)**, **Marine Strategy Framework Directive (MSFD), Maritime Spatial Planning Directive (MSPD)** and the **Common Fisheries Policy (CFP**). The **JPIs FACCE, HDHL, Oceans** have since 2015 been working on alignment of national agendas for safe and sustainable food systems. Under the umbrella of the three JPIs, a Knowledge Hub was launched in July 2020 to connect science and investigate the impacts of climate change on the nutritional make-up of food and the impacts on diets, in order to develop resilient and sustainable food systems. Besides the joint activities, the interlinkages of various societal challenges connected to food systems are also reflected in the strategic agendas of the JPIs and considered in more targeted research investments. One of the major challenges many have encountered is the need to bring different actors together to work towards a common vision and direction for R&I to contribute with more impact to futureproof food systems, but collaboration across blue-green areas is necessary for a sustainable shift in food systems.

In parallel, **EU Blue Growth** is the long-term strategy to support sustainable growth in the marine and maritime sectors. The strategy aims to develop sectors that have a high potential for sustainable jobs and growth, such as aquaculture and marine biotechnology. The Blue Economy report 2020 addresses the environmental dimension of the blue economy in detail, thereby also contributing to achieving environmental objectives (European Commission, 2020e). With a decrease of 29% of $CO^2$ per unit of gross value added between 2009 and 2017, fisheries and aquaculture growth are firmly decoupled from greenhouse gas production. Moreover, the report stresses the correlation between sustainable fishing and positive economic performance.

EU overall aquaculture output has been more or less constant in volume since 2000 whereas global production, at the same time, has been growing by nearly 7% per year. The European Commission intends to boost the aquaculture sector through the Common Fisheries Policy (CFP) reform, and in



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2013 published Strategic Guidelines presenting common priorities and general objectives at EU level. Four priority areas were identified in consultation with all relevant stakeholders: (1) reducing administrative burdens, (2) improving access to space and water, (3) increasing competitiveness and (4) exploiting competitive advantages due to high quality, health and environmental standards. On the basis of these guidelines, the Commission and EU Member States are collaborating to help increase the sector's production and competitiveness. EU countries have been asked to set up multiannual plans to promote aquaculture. The Commission is helping with the identification of bottlenecks, but also facilitates cooperation, coordination and exchange of best practices between EU countries. The strategic guidelines on aquaculture are currently being revised.

The Blue growth strategy supports policymakers and stakeholders in the quest for a sustainable development of oceans, coastal resources and, most notably support the development and implementation of polices and initiatives under the **European Green Deal** (European Commission, 2019b). The **Farm to Fork Strategy** is a key component of the European Green Deal. The goal of the strategy is to change the way the EU produces and consumes, without compromising the safety, quality and affordability of healthy food, while being produced with minimum impact on nature. Oceans and freshwater resources are key to food production and consumption in Europe and EU's Farm to Fork Strategy sets ambitious targets to increase seafood consumption and to make seafood production ecologically sustainable and a source of low-carbon food. The Common Fisheries Policy will remain a key tool to support these efforts while ensuring a decent living for fishers and their families. Around 30% of the overall **Maritime Fisheries Fund** budget is set to contribute to climate action.

Another key action from the EU Green Deal is the **EU Biodiversity strategy** for 2030, aiming at putting Europe's biodiversity on the path to recovery by 2030, for the benefit of people, climate and the planet. The new EU-wide Biodiversity Strategy will establish protected areas for at least 30% of sea in Europe. It will also restore the good environmental status of marine ecosystems (European Commission 2020f). Future measures will be introduced to limit the use of fishing gear most harmful to biodiversity, including to the seabed. It will also look at how to reconcile the use of bottom-contacting fishing gear with biodiversity goals.

The **Standing Committee on Agricultural Research (SCAR)** plays an important role in coupling research and innovation and in removing barriers to innovation, and aims to make it easier for public-public and public-private sectors to work together in delivering innovation that tackles the challenges faced in the bioeconomy area. SCAR-FISH, on fisheries and aquaculture research, reviews current



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programmes, coordinates data collection and facilitates discussions on longer-term themes like innovation and governance (Standing Committee on Agriculture Research, 2020).

The coordination, alignment and leveraging of European and national policies and efforts is essential for tackling the challenges associated with safe and sustainable aquatic food systems. There are multiple EU policy frameworks that already support the necessary transformation of food systems related to oceans and freshwater resources. The EU Common Fisheries Policy was introduced in the 1970s, aimed at both managing and keeping European fish stocks sustainable. Recently, the EU has developed the marine strategy framework directive (MSFD), which was adopted in 2008 with the ambition to achieve a good environmental status (GES) in European seas, especially with sustainability in mind. Effective fisheries management has been found to be instrumental in improving fish stock status around the world (Hilborn et al., 2020). The **EU Sustainable Fisheries Partnership Agreements (SFPA)** highlight the need for a transparent, coherent and mutually beneficial tool to enhance fisheries governance for sustainable exploitation, fish supply and development of the fisheries sector. SFPAs establishes minimum standards for sustainable resource management by stating, among other things, fishing opportunities, fishing access of vessels, electronic catch reporting system (ERS), observers, vessel monitoring system (VMS) and control and enforcement. Scientific management and social empowerment with a focus on environmental sustainability, local growth, human rights and shared accountability is essential especially in Europe, where The state of world fisheries and aquaculture 2020 (FAO 2020, figure 20) show that the Mediterranean and Black Seas have the fish stock that is the least biologically sustainable in the world, with less than 40% of the stocks fished at sustainable levels. Integrated ocean management (IOM) is suggested as the key overarching approach for achieving a sustainable ocean economy (Winther et al. 2020) and harvesting fish stocks at sustainable levels.

In Europe, the marine environment and its ecosystems are subject to multiple pressures and impacts from human activities, such as fishing, Illegal, Unreported and Unregulated (IUU) fishing, seabed disturbance, pollution and global warming. As a response, the EU designed the **Marine Strategy Framework Directive (MSFD)** as a holistic policy to protect the marine environment of the seas around Europe while enabling the sustainable use of marine goods and services (European Commission 2008). However, the MSFD is not meant to regulate specific activities and needs to be complemented by more specific legislation when the current national, regional or EU legal framework has gaps.

Fishery management includes the fight against Illegal, Unreported and Unregulated (IUU) fishing, and is an important aspect of increasing the sustainability of European food production. IUU fishing depletes fish stocks, destroys marine habitats, distorts competition and weakens coastal communities. The EU Regulation to prevent, deter and eliminate illegal, unreported and unregulated



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fishing (IUU) entered into force on 1 January 2010 (European Commission, 2010). Only marine fisheries products validated as legal by the competent flag state or exporting state can be imported to or exported from the EU. There is an IUU vessel list, based on IUU vessels identified by Regional Fisheries Management Organisations. EU operators who fish illegally anywhere in the world, under any flag, face substantial. In May 2019 the European Commission launched **CATCH**, an IT-system that aims to digitalise the currently paper-based EU catch certification scheme to improve efficiency and transparency (European Commission, 2019). The use of IT-systems in connection with governance is important to ensure lasting change and improvement.

In the EU, the new R&I **Horizon Europe Framework Programme** will run from 2021 until 2027, with an expected total budget of around €75.9 billion. Food and nutrition security is a targeted area through multiple proposed partnerships to be established from 2022-2023. The proposed European **Partnership on Safe and Sustainable Food Systems** will provide an overarching platform and process to underpin the needed transition to sustainable food systems, provide solutions to the Farm to Fork strategy by connecting national, regional and European research and innovation programmes and food systems actors, to deliver co-benefits for nutrition, climate, circularity and communities and food from the oceans and freshwater resources must be a part of this work (EIT Food, 2020). In this multi-actor framework, the blue aspects of food systems need to be an integral part.

In addition to partnerships, five mission areas have been identified, and each mission will be provided with a dedicated mission board, and assembly, and budget to achieve its clear targets. Two of the five mission areas underline the importance both of oceans and freshwater resources (**Mission area: Healthy oceans, seas, coastal and inland waters**) and food production (**Mission area: Soil health and food**). The report 'Regenerating our ocean and waters by 2030' (European Commission, 2020f) suggests these targets to be chieved by 2030 with the contribution of Horizon Europe missions: 1) cleaning marine and fresh waters, 2) restoring degraded ecosystems and habitats and 3) decarbonising the blue economy in order to sustainably harness the essential goods and services they provide (European Commission, 2020g). The targets will be highly relevant to food production in oceans and freshwater, both to supply a sustainable "template" and to manage the industries.

*Alignment with international frameworks*

On a global scale, 5 of the 17 UN Sustainable Development Goals have a direct relation with food from the oceans and from freshwater resources.

**SDG 2: Zero hunger**. Oceans, inland fisheries and aquaculture bear the highest potential to serve the world's growing population by providing highly nutritious and safe food with a low ecological impact.



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**SDG 8: Economic growth**. This goal aims at promoting sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all. It is estimated that worldwide, 40 million jobs are linked fisheries – half of them are linked to aquaculture. **SDG 12: Responsible consumption and production**. This goal aims at ensuring sustainable consumption and production patterns, including sustainable management and efficient use of natural resources (e.g. allow fish stock to replenish), reduce waste generation through prevention, reduction, recycling and reuse (including reducing by-catch and reducing fish biomass waste). **SDG 13: Climate change**. The oceans play an important role in mitigating climate change. The microscopic organisms present in the oceans act as primary producers of roughly half the earth's carbon and 70% of our atmospheric oxygen. The oceans also play an important role in absorbing carbon emissions. For instance, photosynthetic phytoplankton reduces the amount of atmospheric carbon by sequestrating carbon $CO_2$ to build their shells. Haptophyte algae remove half of the $CO_2$ that results from the burning of fossil fuels and produces secondary compounds that aid in light scattering and cooling. **SDG 14: Life below water**. This goal aims to conserve and sustainably use the oceans, seas and marine resources for sustainable development. It requires the protection of aquatic ecosystems by preventing overfishing, reducing marine pollution, addressing ocean acidification, and conserving marine and coastal areas. The World Trade Organisation is working to prohibit certain forms of fisheries subsidies which contribute to overstocking and overfishing. The goal also prioritizes the ocean's impact on human lives, with targets to increase economic benefits to small island developing States and least developed countries from the sustainable use of marine resources, and to provide access for small-scale fishers to marine resources and markets.

The Food and Agriculture Organisation of the United Nations (FAO) members adopted the **Code of Conduct for Responsible Fisheries (CCRF)** in 1995. This sets international standards of behaviour for responsible practices to ensure the effective conservation, management and development of living aquatic resources, with due respect for the ecosystem and biodiversity (FAO 1995). As commitment to the guidelines established by the Code is on a voluntary basis, these standards may be implemented, as appropriate, at the national, regional and sub-regional levels. However, the non-binding nature of the agreement could be considered as a shortcoming in the establishment of a solid set of enforceable rules. The overarching goal is the achievement of long-term sustainable outcomes.

In 2013, FAO launched the **Blue Growth Initiative (BGI),** which builds on the CCRF and focuses on fisheries, aquaculture, ecosystem services, trade and social protection (FAO 2018b). It advocates ways to balance economic growth, social development, food security, and sustainable use of aquatic living resources. The aim is to safeguard food security from wild fish stocks; as well as exploring alternative



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sources of food security such as aquaculture. The BGI explores ways for economic diversification in the fisheries and aquaculture sectors, particularly through synergies with growing sectors, such as tourism. Moreover, BGI increases system and energy efficiencies while adding value along the fisheries and aquaculture value chains.



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**CLIMEFISH**

ClimeFish was an EU-funded (Horizon 2020) project (2016 - 2020). The overall goal of ClimeFish was to help ensure that the increase in seafood production comes in areas and for species where there is a potential for sustainable growth, given the expected developments in climate. ClimeFish thus contributed to establishing fisheries and aquaculture management plans that include climate adaptation measures, in co-creation with the operators and other stakeholders.

For more information: https://climefish.eu/.

## CLIMEFISH

*New governance models*

### Assessment of added value

ClimeFish investigated the effects of climate change on fisheries and aquaculture at European and regional scale. The project team developed novel forecasting models to simulate and analyse changes in distribution and production in the fisheries and aquaculture sectors, and identify risks and opportunities based on analysis of market and non-market costs and benefits of affected ecosystem services and proposed potential mitigation strategies. In co-creation with stakeholders, ClimeFish developed case-specific Climate Adaptation Plans (CAPs) that mitigate risks and utilize opportunities associated with anticipated effects of climate change on aquatic production. In addition, ClimeFish developed guidelines, good practice recommendations and a voluntary European standard outlining how to develop CAPs. Importantly, together with multiple stakeholders, the project developed the ClimeFish Decision Support Framework (DSF) that contains the ClimeFish Decision Support System (DSS) and other decision support resources, such as models, datasets, sample runs and guidelines.

### Assessment of challenges

ClimeFish explored how the most important and the less resilient exploited European fish stocks and the most productive established aquaculture species respond to the different climate scenarios. The project results are based on 15 case studies across 3 production sectors: marine fisheries, freshwater lakes and ponds and marine aquaculture. The outcomes of the projects need to be scaled up across Europe and across different species. To ensure scalability, a multi stakeholder (all actors in food system) partnership must be put in place.

### Prospects for future development

ClimeFish scientists and stakeholders now have the means to promote climate action for industry and policy makers. The project has expanded its impact beyond Europe through cooperation with FAO, training in Vietnam and Chile, and the 2020 International Forum. Some of their exploitable outcomes have been implemented in Member States. They also have shared experiences with a sister EU-funded project CERES and other scientists and stakeholders across the world, and will further build on this network beyond the project lifetime.



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**BlueNalu**

BlueNalu is a company that aims at providing consumers with great tasting, healthy, safe and trusted cell-based seafood products that support the sustainability and diversity of our ocean. BlueNalu uses sustainable food technology such as cellular aquaculture whereby living cells are isolated from fish tissue, placed into culture media proliferation and then assembled into fresh and frozen seafood products. Therefore, BlueNalu is offering an alternative that is healthy for people, humane for animals, and sustainable for the planet.

For more information:
https://www.bluenalu.com/.

## BLUE NALU

*Cellular Aquaculture*

### Assessment of added value

BlueNalu is committed to generating seafood products locally, to reduce seafood imports and limit the carbon footprint from shipping fish around the world. Since only consumable parts of fish are produced, feed conversion will be maximised and will result in zero fish waste. BlueNalu is also committed to working with the seafood industry to supplement current supply, and special focus is dedicated to species that are over-fished, primarily imported, or difficult to farm-raise. As a result, BlueNalu aims at reducing pressure on wild fisheries, decrease the need for imports, create local jobs, enhance food security and promote increased consumption of healthy seafood options globally.

### Assessment of challenges

Scalability will be a great challenge for cellular aquaculture. With the increase in world's population, it remains to be shown whether lab grown fish protein could meet the ever-growing demands. Consumer's acceptance will most probably be the greatest hurdle to overcome and ensure great development and success. To ensure consumers' acceptance, food safety and nutritious aspects will have to be thoroughly investigating. The transition should be coordinated with action at system level by contributing to a transition multi-stakeholder ecosystem. In addition, it must be demonstrated that producing fish protein using cellular aquaculture is more sustainable than traditional fisheries and aquaculture.

### Prospects for development

BlueNalu has great opportunities for expansion. The work at BlueNalu comes at a time of fast-paced growth within the cultured lab-grown meat space which has attracted interest from a variety of key investors and innovation from all over the world in recent years. Lab-grown meat is making waves among some of the world's biggest investors tipping the innovation to be the future of protein-packed food.



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## Conclusion

Aquatic food production bears a high potential to contribute to EU food systems transformation**. The food needed to feed a growing EU population can be produced in the oceans**, given that it is technically possible to produce feed without putting further stress on ecosystems. In coastal areas and in less developed countries fish is a major food source, but it is under strong competition from industrialised fishing industry with lower prices. **An ecosystem-based approach is needed to protect the oceans and the people around them** (EEA report, 2019). By managing wild fisheries, implementing policy reform in mariculture, advancing feed technology and shifting demand, large challenges can be solved. As Costello et al. (2020) state "fed mariculture alone is capable of generating at least the benchmark 177 Mt of additional meat, but realizing these gains would require enormous shifts in [market] demand". **Only 2% of the food produced today comes from the oceans, demonstrating high potential for a radical increase** of production of food from the oceans and freshwater resources, is only possible insofar market conditions allow for it. The dietary and societal changes needed to achieve a significant shift in dietary preferences might be the largest challenge associated with aquatic food. **Substantial growth in consumption of food from aquaculture will rely on public perception, which is highly variable by region and context**.

In general, there is great potential in the oceans, especially in aquaculture, for **establishing circular economy business models and restorative practice**s where food production stewards ecosystems and cleans the water without any additional feed. Aquaculture is an environmentally friendly practice, as it produces a low aesthetical degradation of the landscape, but **popular opinion is still often against aquaculture for reasons associated to the appearance and smell of food**. Aquaculture demands less land space than agriculture, especially as it uses the whole water column (vertical space between the surface of the water and the bottom).

**Public policies** are crucial in this regard as they determine the conditions which either permit or forbid certain ocean-based activities. They also shape the market and incentive conditions needed to enable the harvesting of such species to account for a significant rather than marginal proportion of food for human consumption.

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# Alternative Protein & Dietary Shift

**“If we want to have a nutritious diet, we need proteins, vitamins, fats and calories, and in balanced amounts. These nutrients can be supplied by plants, and this requires less land than if these nutrients are derived from animal sources. If instead, we want to distract these nutrients from animal sources, we then first need to grow feed for these animals with a typically low efficiency of converting their feed into human food. On top of that, animal husbandry contributes majorly to polluting greenhouse gas emissions. In other words, not only do they produce proteins inefficiently, they also contribute significantly to global warming.” – Tim Benton, University of Leeds (CommBeBiz, 2017).**

**This pathway aims at driving consumers’ behaviour towards sustainable and healthy diets by increasing the intake of alternative to complement animal-based proteins. This will support the provision of sufficient, nutritious, safe, healthy, accessible and affordable food to a fast-growing world population while also addressing the increasing pressures from climate change and natural resource scarcity.**



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### Societal, economic & environmental needs

To achieve more sustainable food systems in the EU, there is a need for **changing dietary habits, including reducing EU citizens' overall protein intake and meat protein intake in particular**. Achieving such a dietary shift is complicated, as habits and values related to current eating patterns are difficult to change and acceptance of alternatives by consumers tends to be rather low whenever novelty is introduced. Amino acids forming proteins are the basic building blocks in all living organisms. An adequate protein intake is required all over the lifetime of an individual to provide nitrogen and indispensable amino acid to the organism. Most amino acids are provided via the diet. The World Health Organization has set **the required level of protein intake at 0.66 g per kilogram per day for adults**, which is expected to meet the protein needs of 97.5 per cent of the world's healthy adult population (WHO, FAO and UNU, 2007). Needs are different at different ages – as growth requires increased amounts of proteins (1.5 g per kilogram per day for infants from q-12 months old, and 0.86 g per kilogram per day for 1-3 years old). Besides quantity, **the quality of the proteins introduced in the human organism is a critical aspect**. Indeed, proteins must provide an adequate content of each of the 9 indispensable amino acids not synthesized in the body. In addition, amino acids must be transformed in a bioavailable form after digestion and absorption (the digestibility of proteins). **A large part of the EU population consumes more proteins than necessary** (PBL Netherlands Environmental Assessment Agency, 2019). Currently, in most of European diets, Animal Source Foods (ASF) such as meat, eggs, milk and fish products deliver the bulk of protein intake. For consumers in the high-income countries, the intake of ASF is on average above recommended levels. **Red and (particularly) processed meats are high in cholesterol and saturated and solid fatty acids**, which raises public health concerns as it contributes to a higher prevalence of cardiovascular diseases, increasing the burden on Europe's health services and infrastructures (Godfray et al., 2018). There is also strong evidence that **consuming red and processed meat increases the risk of colorectal cancer** (World Cancer Research Fund International, American Institute for Cancer Research, 2018). Therefore, moderate ASF consumption is consistently advocated (WHO, 2013 & 2014) in strategies to prevent major diet-related diseases (Non-Communicable Diseases – NCDs) and is also included in recent EU strategies to meet the objectives of health for all and reduce health inequalities (SUSFANS, 2017). Consumption of alternative proteins could reduce the intake of cholesterol and fatty acids, thus reducing the incidence of cardiovascular diseases.

Awareness campaigns that promote alternative protein consumption while maintaining adequate intake are important. Examples include stimulating/increasing the consumption of traditional plant-based proteins such as pulses or raising consumers' acquaintance with recipes and international



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cuisines rich in plant-based and low in animal-based proteins. For instance, in the traditional cuisine of several Indian states dishes are often served in combinations of different nutrients in one single service, as opposed to most of the European cuisines where dishes are usually divided in 3-5 separate services of carbohydrates, meat proteins, plant proteins, etc. Research shows that diets combining nutrients in one single service could be more suitable to encourage a shift towards plant-based diets, as meat is easier to take out from the menu (Dagevos et al., 2012; Kamsma, 2020; Onwezen et al., forthcoming). However, **the world-wide production of agricultural commodities such as maize, rice, wheat and soy – the key sources of plant-based dietary protein – will also need to increase to meet global demands if more people shift to plant-based diets** (FIT4FOOD2030, 2018).

Meat and dairy production contribute for around 6% of the EU GDP. The per capita total animal protein consumption in the EU remained relatively stable from 2000-2013. However, the consumption of animal protein product types changed significantly. The consumption of proteins from cheese and poultry increased with about 15%, while the consumption of bovine meat decreased with nearly 14% (Joint Research Centre, 2010). A study on the consumption of meat in the Netherlands did not show a reduction in the overall meat consumption (Dagevos et al, 2019). However, certain population groups did lower their meat intake in recent years (Onwezen et al., forthcoming). Although the trend is stable, the world population is expected to reach 9 billion people by 2050. It is therefore estimated that the **global protein consumption could reach 944 million metric tons (MMT) by 2054.** As the demand for proteins grows more rapidly than conventional meat sources can supply, there is an **urgent need to supply non-meat-based proteins while also decreasing the (growth in) demand of meat proteins.** It is estimated that the market for alternative protein sources could grow up to 9% yearly in the coming 40 years (FIT4FOOD2030, 2018). Also, the need for alternative proteins ought to lead to trigger innovation for new products, markets and business models (European Commission, 2020). Yet, from a food systems perspective, technological innovations alone will not solve all problems. Attention should also be focused on social innovation aspects and on promoting **a shift in the behaviour of producers, consumers and the other agri-food actors towards healthy, environmentally sustainable, safe and nutritious protein intake**. Technological innovations in novel foods require consumer acceptance. Hence, it is crucial to take into account consumers tastes and preferences when designing new food products.

The current production and consumption of meat proteins is associated with high greenhouse gas emissions (GHG), water use and land use. Research indicates that **halving the meat and dairy consumption would lead to 25-40% lower GHG emissions, 40% lower nitrogen emissions and 23% per capita less use of cropland for food production**. This, in parallel, will reduce the current rate of



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biodiversity loss, since livestock production is the single largest driver of habitat loss affecting the conservation of terrestrial ecosystems and biological diversity (Westhoek et al, 2014; Machovina et al., 2018). Water use will also be reduced since **it currently takes more than 15,000 litres of water to produce just 1 kg of meat compared to 800 litres used for growing 1 kg of wheat** (UNESCO, 2010). Meat and dairy products contribute for around 24% to the negative environmental impacts caused by the total food consumption in the EU, based on a life-cycle assessment method (Weidema et al., 2008). However, with projected increases in the global population numbers causing increased demands for animal-based products, there is also increased environmental pressure. Thus, a reduction in the demand for animal-based food products (meat, dairy, eggs, fish and seafood) and a shift to other sources of protein have the potential to reduce the EU's environmental footprint while delivering health benefits (EuroHealthNet, 2018).

### R&I action required

During the workshop on FOOD 2030 pathways for food systems transformation, organised by the European Commission on March 4th 2020, 10 food systems R&I actions were identified in the pathway Alternative Proteins and Dietary Shift (European Commission, 2020). Below, three of those actions are selected and expanded, based on their potential for greatest impact:

- **Shifting norms and behaviours regarding proteins.** A substantial shift from meat proteins to plant-based proteins is necessary across the whole EU agri-food systems. There is a specific need to find and understand both the drivers and barriers to production, processing, retail, & manufacture, consumption of (alternative) proteins and potential levers to enable more sustainable choices. To this end, the potential of tools and instruments such as policy measures and new business models should be analysed. A 'demand pull' is needed to create a 'new normal' in production and consumption patterns, which should be fair for the primary producers and maintain vibrant rural areas. Elements to be considered include cross-cultural, place-based contextual differences as opposed to cross-country approaches; social inequalities; links with dietary guidelines; and uneven level of awareness across the EU. Behavioural change of consumers towards alternative protein consumption should have priority in further developments. Currently, non-animal-based proteins rank low in EU consumers' preferences for protein sources, with meat products or non-meat animal based protein sources (cheese, eggs, fish) ranking highest (Verain et al., 2015; Bouwman et al., 2016; Onwezen et al., forthcoming). It is important to promote a norm shift related to expectations and standards regarding what should compose a good meal. For instance, meat dishes are



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dominant in restaurants in many parts of the EU, with only limited vegetarian options (de Vaan et al., 2019). The chapter on 'Transition towards healthy, sustainable and personalised nutrition' of this report digs deeper in the analysis of consumption patterns and the transition towards healthier diets. The two leverage areas on alternative proteins and healthy lifestyles are interconnected, in particular in relation to empowering and engaging consumers, developing new technologies to support consumers in getting more insight in their own dietary behaviour and promoting personalised nutrition.

- **Filling knowledge gaps on nutritional, safety, allergenicity and environmental aspects of alternative proteins**. Several types of alternative proteins should be further investigating to better map their potential, including crops, sea-based algae, mussels, etc. Data and best practices exchange should be stimulated. A EU central database on alternative proteins should be created to allow for cost-benefit analyses including the calculation of environmental footprints and other comparative analyses of the impact of conventional/alternative proteins, including through the use of new PEF-based categories (Product Environmental Footprint). The comparative impact of meat and alternative protein sources on health and food safety, including on the microbiome and the proliferation of NCDs due to nano-plastics, contaminants, disqualifying nutrients, salt and statured fat present in associated food products, should be duly measured. Potential impacts and trade-offs of a EU shift to alternative proteins should be considered, including the environmental, trade and competition impacts at the international level; and the impact of genomic engineering on health and the environment through the production of alternative protein crops.

- **Improving and diversifying food environments**. Important actions required to facilitate the transition towards alternative protein acceptance include new analyses of positive and negative impacts of (new) marketing approaches; promotion of different varieties of proteins; innovation in processing methods; careful consideration of preserving product taste, protecting natural resources and maintaining affordability. For instance, while legumes and algae are already sold on the market as alternative proteins, further insights are needed to allow for more product developments and increase the nutritional potential. Marketing and communication campaigns are key to increase consumption (WHO, 2014). In particular, more efforts are needed with regard to the communication of the nutritional value of algae, and new business and marketing models should be developed to increase product placement and ensure consumption (FIT4FOOD2030, 2018b). Furthermore, training of agri-food workers in



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the middle streams of EU food systems - from chefs and caterers to restaurant service staff – is important. Famous chefs and food influencers could be empowered so as to influence what consumers cook at home, teach new techniques and recipes, and inform about different tastes. Restaurants could also become the place to eat something different – including alternative proteins- thus prompting a potential spill-over effect on what consumers eat at home. In addition, actors in the food service industry could also make vegetarian dishes the standard option, so that choosing meat meal would become the exceptional choice. would only be consumed for special occasions. Specific knowledge topics needing further research to improve and diversify EU food environments include the impacts of pricing policies and incentives exposing the 'true cost' of food, impacts on taste of new processing methods for plant proteins; and genetic research to close the economic productivity gap of protein crops.

*Barriers to systemic change*

The greatest barrier for alternative protein production is incumbent institutional framework regulating current land-use and producing lock-ins across the EU food value-chain. Overcoming the barriers of the current regime is one of the most difficult challenges to achieve the transition to safe, healthy and sustainable food systems.

**Technological/administrative barriers.** Allergenicity is one major concern for all novel foods and particularly those containing proteins (EFSA, 2019). Although the levels of tolerance to certain types of nutrients could be due to genes - e.g. high levels of lactose intolerance/deficiency among specific social groups - additional research is needed to understand what the potential risks are for specific target groups (e.g. with high protein needs). In addition, there is a current lack of understanding of the long-term health consequences of the dietary shift from animal-based to plant-based proteins (FIT4FOOD2030, 2018). As the current regime is dominated by the consumption of animal proteins, knowledge and information available on alternative proteins is limited. This lack of knowledge/information greatly contributes to the current low levels of consumer acceptance of new products containing alternative proteins. Further research is needed to demonstrate that alternative proteins are indeed safe and nutritious and also have a lower environmental footprint compared to animal protein production. This is particularly important when considering the need to feed the vast majority of the population with alternative proteins, as up-scaling and mass production of alternative proteins are important factors yet to be fully investigated (FIT4FOOD2030, 2018c). Finally, there is a need for more research acknowledging different tastes and cultural preferences, so as to enable optimal mixes of different protein sources for balanced diets. For instance, animal proteins are unlikely to be fully replaced by plant-based proteins. However, the possibility to include insects in



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certain types of diets for certain population groups who are open to that kind of alternative protein should be explored.

**Social barriers**. The main barrier is to the uptake of alternative proteins is represented by current dietary preferences. Indeed, the cultural norm associating a satisfying meal with the consumption of meat hinders the necessary shift to alternative proteins in the EU. Other social and religious values also have an impact on the acceptability of alternative sources consumption, especially with regard to insects (Onwezen et al., 2015). To shift from animal-based to other kind of alternative proteins, there is a need to secure EU consumers acceptance first.

**Political barriers**. Different social and power dynamics are at play with an overall negative impact innovation process. In particular, it can be observed across Europe a remarkable contradiction between the slow development of the legislative process and political discussion around alternative proteins versus the fast-technological development already happening. Food safety assessments are often missing, partly because statistical evidence is itself lacking. New procedures, guidelines and protocols need to be developed, as well as labelling legislation, which is either missing or is evolving too slowly in response to novel products (FIT4FOOD2030, 2018). The demand for nutritious animal protein such as fish and other seafood products is expected to increase as replacement for meat consumption. However, fully replacing meat with fish and seafood products is not compatible with the expected shift to alternative proteins (FIT4FOOD2030, 2018c).

**Economic/Financial barriers**. From a macro-economic perspective, economic barriers to the transition of alternative proteins include considerations of job security for people working in the meat industry, market, and perceived risks for the industry /large producers to invest in uncertain novel proteins. The current EU Common Agricultural Policy (CAP) is designed to support the incumbent regime based on the production and consumption of animal protein, while alternative protein sources are barely considered. Current EU legislation allows little room for experimentation, flexibility and learning, which hinders the development of non-meat protein sources. Consumer acceptance can also be influenced by pricing. As the current regime favours meat productions through subsidies, it is difficult for alternative proteins to penetrate the market due to a competitive disadvantage (FIT4FOOD2030, 2018).

*Enablers for transformation*

**Technological/administrative enablers.** Increased knowledge and education on new technologies will empower consumers to make more sustainable food choices, including (more) alternative proteins. On the production side, increased knowledge on consumer behaviours will enable food producers to



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better cater for consumers' needs. Increasingly, vegetarian and vegan options are already changing the protein market. New technologies unlocking the potential of crops or insects with a high protein will also increase the protein yield during extraction processes. New technologies can contribute to the development of new product formulations, allowing the incorporation of alternative proteins into current or new products (FIT4FOOD2030, 2018).

**Social enablers.** There is a need to bridge the information gap between all actors, especially between consumers and food producers on the benefits of alternative protein consumption. More space should be created for education, learning and knowledge sharing. Universities and research institutes, schools and educators, governments (at all levels), consumer organisations and philanthropic organisations, as well as influencers and online communities will play a critical role in enabling new social trends and moving away from current unsustainable dietary patterns. Consumers should be made more aware that alternative protein sources have less negative environmental impacts than meat on average. Research indicates that a change of dietary habits could be achieved communicating better the positive health benefits of a higher diet diversity, especially a higher consumption of proteins from non-meat sources. Consuming more alternative proteins will allow for a healthier population (with lower prevalence of NCDs and healthier ageing) and have lower environmental impact of the food consumed (WHO, 2013 & 2014). It is also important to highlight the benefits of the alternative protein uptake for animal welfare, as this is a topic that is dear to EU citizens.

**Political enablers**. Lowering subsidies currently awarded to meat production would promote the production and consumption of alternative proteins, although the trade-offs and negative economic impacts on the EU food value chain should be carefully examined through dedicated impact assessments. New EU legislation will allow for a wider diffusion of innovative products, including the use of new technological solutions such as cultured/lab meat, and a faster and larger implementation of new solutions derived from an academic research (FIT4FOOD2030, 2018c).

### Potential for sustainable social and economic breakthroughs

**Entomophagy.** Insect consumption could become a good alternative for animal-based protein consumption, since it is less polluting for the environment than livestock production, and over 2,000 types of insects have already been marked as edible. However, one of the most important barriers to overcome is the reluctance of EU consumers to eat insects (FIT4FOOD2030, 2018). Onwezen et al. (2015) showed in a study on five protein sources (fish, pulses, insects, in vitro meat and seaweed) that consumers' level of acceptance for insects is the lowest (2.11 on a 7-point scale). Furthermore, the study showed that the perception of food safety risks is higher for insects than it is for other plant-



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based novel foods such as seaweed. Another study on different forms of insect products by Onwezen et al. (2019), shows low levels of consumer acceptance for raw insects, processed insects and meat from animals that were fed with insects. Promising pathways to increase EU consumers' aacceptance of insect protein include its (relatively) low price, an increasing availability of products and types including different tastes and food textures, targeted marketing and stressing the environmental advantages of insect consumption over meat consumption (WHO, 2013).

**Imitation meat/fish and cultured meat/fish**. Available technology allows for production methods that copy the meat/fish molecular structure but do not require livestock, fishery nor aquaculture. Imitation meat is constructed of plant-based protein sources (e.g. soy) and often imitates the texture, flavour and form of meet containing a high level of proteins (WHO, 2013). Cultured meat is produced by culturing animal stem cells in a medium that contains nutrients and energy sources required for the division and differentiation of the cells into muscle cells. Latest technological developments include improvements in the efficiency of machinery used to produce cultured meat for scaling up the current production (FIT4FOOD2030, 2018). Onwezen et al. (2015) showed that consumer acceptance for cultured meat is higher than for insects and seaweed. Additionally, a recent study (Onwezen et al., in forthcoming) shows a trend of raising acceptance for cultured meat.

**Biotechnology**. New technology allows to obtain new sources of nutrients from the microbiota. The further exploitation of microbiota/microbiome knowledge can impact the way food is produced and the nutrients that it provides. The development of biotechnological tools on the knowledge of genome and its sequencing opens the possibility of new applications and implementations. Some examples are the conversion of biomass and residues into a range of new sub-products and ingredients, the use of actual biorefineries to separate protein and energy into protein usable for humans, or the use of microalgae to produce nutraceutical components without impacting food agriculture (FIT4FOOD2030, 2018b).

### Impacts & Co-benefits

In the recently published FOOD 2030 report on Pathways for action, the following co-benefits of alternative proteins are expected (European Commission, 2020c):

1. Nutrition and health: r**educing diet-related mortality and NCDs**, diversification of the supply in proteins and place-based dietary shifts to meet diverse and specific needs;
2. Climate and sustainability: **reducing GHG emissions and biodiversity loss, better air and water quality** and decreasing dependence on imports and less deforestation;



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3. Circulation and resource efficiency: a better consumer footprint and **savings in energy, land and water**;
4. 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 and increasing farmers' resilience and image.

Regarding the market expectations for alternative proteins, it is foreseen that in the coming decade soy-based protein will still be dominant, while protein products derived from pea, rice, flax, canola and lupin will gain a 9% share of the market by 2024. However, a considerable growth of alternative protein products other than soy can be expected due to consumers' concerns about potential health risks deriving from soy over-consumption. In addition, other plant based proteins such as moringa, quinoa or chia are expected to cover 4% of the alternative proteins market by 2024. The market for insects and algae is projected to increase but to stay behind with a 2% market share (FIT4FOOD2030, 2018). Although reducing meat consumption and replacing animal-based proteins with alternatives is expected to have positive effects on both our health and the environment, more R&I is needed to form an evidence basis (FIT4FOOD2030, 2018).

## Policy alignment

*Alignment with EU& international policy frameworks*

Alternative protein sources are indicated as a potential R&I pathway to address the **EU FOOD2030 priorities** related to rising protein demand, malnutrition and hunger, obesity and the rise of NCDs, food safety issues and crises and unhealthy and unsustainable diets. The ever-increasing global demand for protein cannot be sustainably met through conventional farming alone, given its large carbon footprint. This has created an opportunity for the alternative proteins market. R&I support for alternative proteins can help end hunger and ensure all EU citizens have access to safe, nutritious food by 2030, one of the targets of **UN SDG 2 (Zero Hunger)** (European Commission, 2017).

The promotion of alternative protein sources is included in the European Commission **Farm to Fork Strategy** through the realisation of sustainable fisheries and food from the oceans, in the light of climate change and nature-based solutions (European Commission, 2020c). The Farm to Fork Strategy focuses on well-targeted support for the algae industry, as the European Commission considers algae an important source of alternative protein for a sustainable food system and global food security. Furthermore, the Farm to Fork Strategy mentions the upcoming R&I **Horizon Europe framework programme**, where a key R&I area will focus on increasing the availability and source of alternative



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proteins including plant, microbial, marine and insect-based proteins and meat substitutes (European Commission, 2020c).

The EU Communication on the Future of Food and Farming confirms market orientation as a key element of the **Common Agricultural Policy (CAP)**, but also highlights challenges related to environmental sustainability and climate change. Moreover, it places the agricultural sector squarely in the sustainability debate about citizens' concerns, recalling that the most important role for the CAP policy is to help farmers anticipate developments in dietary habits and adjust their production according to market signals and consumers' demands. As the current CAP still features rules that may prevent the necessary shift towards alternative proteins, the ongoing negotiations over the new CAP present an opportunity to make necessary changes to further address citizens' concerns regarding sustainable agriculture production (European Commission, 2018). EU Member States should therefore be allowed to use an additional part of their financial ceiling available for direct payments to grant coupled income support specifically for the promotion of protein crop production in order to reduce EU's deficit in this regard (European Commission, 2018).



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**PROTEIN2FOOD**

PROTEIN2FOOD is an H2020 funded project (2015-2020) that aims to develop innovative, cost-effective and resource-efficient plant proteins –rich food sources with positive impact on human health, the environment and biodiversity. The quality and quantity of protein from selected highly nutritious seed crops (quinoa, amaranth and buckwheat), and legumes (lupin, faba beans, pea, chickpea, lentil) will be significantly enhanced by using a multi-disciplinary approach that will include genetic, agronomic, food process engineering, sensory, socio-economic, and environmental assessment.

For more information: https://www.protein2food.eu.

## PROTEIN2FOOD

*Bio-technology*

### Assessment of added value

Research carried out in the framework of PROTEIN2FOOD is expected to improve the quality of plant-based proteins produced in Europe and of the sustainability of their production and processing. Through a better understanding of the: i) genetic mechanisms driving the protein formation and accumulation in the seed, ii) plant performance towards biotic and a-biotic stresses, and iii) protein interactions with other components in the food matrix and its sensory repercussions in the final food products, this research will lead to the development of adapted plant protein sources with positive impact on human halth, the environment and biodiversity.

### Assessment of challenges

Some of the long-term objectives require a thorough follow-up after the end of the project. For example, the project foresees an increasement in the plant-based to protein production by 25% in the EU corresponding to the uptake of new effective breeding techniques and optimised crop management, that will produce an increase of 10% of Europe's arable land destined to protein-crop production, including marginal soils. In addition, the project foresees an increase in Europe's agro-biodiversity thanks to the introduction of novel high-quality crops and the development of prototypes of new protein-rich foods. The viable market potential for such innovations is still to be demonstrated. Furthermore, the transition towards higher consumtion of these products will need to be explored, and could be facilitated with transition innovation approaches and (based on a multi stakeholder perspectives, transdisciplinary approach and system approach).

### Prospects for future development

A follow up EU-funded project SMART PROTEIN (2020-2023) will be building upon the results from the PROTEIN2FOOD. This new project will future-proof protein supply chains with a positive impact on the bio-economy, environment, biodiversity, food and nutrition security and consumer trust. SMART PROTEIN will test, validate and demonstrate innovative, cost-effective and resource-efficient plant protein products. This new project will increase the market potential of the results obtain in the PROTEIN2FOOD project.



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**NextGenProteins**

The EU-funded NextGenProteins project (2019-2023) has identified microalgae, single cell protein and insects as promising sources of alternative proteins. NextGenProteins makes a case for pairing edible microorganisms with emerging technologies. Proteins can be produced through innovative and environmentally sustainable bioconversion processes using industrial waste streams, causing limited environmental impacts and putting minimum pressure on natural resources. NextGenProteins will work to boost the acceptability and trust of consumers towards alternative proteins and processes. Overall, it will help to strengthen food security, sustainability and self-sufficiency of EU protein production.

For more information: https://nextgenproteins.eu/.

## NEXTGENPROTEINS

*Increasing consumer trust*

### Assessment of added value

Alternative proteins can be produced through innovative and environmentally sustainable bioconversion processes using industrial waste streams. Through collaboration between the industry and DG RTD, the project addresses key barriers that currently prevent or limit the application of the three alternative proteins in food and feed, such as production scalability and optimisation, production costs, value chain risks, safety, regulations and consumer trust and acceptance. The project will demonstrate the suitability and economic viability of the alternative proteins in food and feed value chains and explore their market opportunities with the industry, stakeholders, policy makers and consumers. NextGenProteins will find means to improve the acceptability and trust of consumers towards alternative proteins and processes. By doing so, the project will contribute to strengthening food security, sustainability and self-sufficiency of EU protein production with future-proof supply, as well as long-term reduction of land use, water use, GHG emissions and energy of the EU food sector.

### Assessment of challenges

The economic sustainability and market acceptance for the three kinds of alternative proteins researched will need to be further demonstrated and an assessment cannot be fully carried out in the scope of the project, as there are too many variables to replicate to be able to determine with precision the success of a food product on the market. To facilitate the shift to diets based on alternative proteins promoted by NextGenProteins, EU as well as Member States horizontal policies will need to be adapted to match the requirements and opportunities emerging from the vast production and consumption of these new alternatives proteins. Finally, the consumer adoption of these new proteins would need to be investigated. To facilitate the adoption RRI approaches should be considered.

### Prospects for development

There is great potential in developing novel high-quality food products containing alternative proteins, to pave the way for subsequent commercialisation of the proteins and food products. The project will also establish market potential for food and feed products, containing the alternative proteins identified.



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## Conclusion

It is important to stress that **a dietary shift is a cultural, social and economic phenomenon**. Consumption of fruits and vegetables, pulses, limited amounts of fish and dairy should be encouraged, while high consumption of foods such as red meat, food preparations with salt, saturated sugars and fats is to be discouraged through measures respectful of cultural traditions, social values and the need to keep food affordable for all EU citizens. In the EU in particular**, it is important to focus on lowering the growth in protein demand instead of simply trying to meet the increasing protein demand with alternative protein sources.**

Across the whole food value chain, a distinction on alternative proteins should be made between, on the one side, enhancing traditional crops such as pulses and, on the other side, developing 'new' alternative proteins such as cultured, in-vitro meat and edible insects. **Consumer behaviour and acceptance of non-animal based proteins varies across different social groups, types of alternatives and novel food products.** Currently, EU consumers are less reluctant to use insects as animal feed than as food, and it will take time and continued effort by all actors in the food systems to transform psychological mechanisms and increase acceptance (Onwezen et al., 2019). For a behavioural change of this scale to happen, **public authorities will need to create an enabling environment for consumers, including the correct incentives and motivations; a sufficient variety of products so as to cater for different preferences and tastes; and affordable prices** (Rotschild, 1999).

Currently, EU meat eaters tend to replace meat proteins with other animal-based proteins rather than with plant-based foods when encouraged to do so for health or environmental reasons. However, **the drivers behind personal hierarchies of foods and the mechanisms of food substitution are complex and differ considerably between consumer groups.** This has to be taken into account by policy-makers when designing future R&I action on alternative proteins and dietary shifts. The consumption patterns of vegetarian and heavy flexitarian consumers need more research and has the potential to provide useful insight to promote among the vast EU population. The most promising pathways to achieve the sought dietary shift in the EU seems to be the design of novel foods; the increase in consumption of traditional plant-based protein sources; the uptake and large diffusion of international cuisines and recipes low in animal-based proteins; and an overall reduction in protein consumption. Further research is required on the impacts on the health and environment, consumer acceptance, and comparative differences between traditional plant-based protein sources (e.g. pulses, soy) and new sources (e.g. insects, cultured meat) to be able to fully assess the most effective route to enable dietary shifts in protein consumption.



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# Food Waste & Resource Efficiency

**The amount of food lost and wasted in Europe is as high as 88 million tons, according to 2012 estimations. At a time when 43 million Europeans cannot afford a quality meal every second day, this is a clear indicator that our food systems are not sustainable. Food Loss and Waste (FLW) produces remarkable environmental impacts, as it generates about 8% of global greenhouse gas emissions, accounts for 23% of fertilizer use and consumes one fourth of all water used in agriculture. FLW is also responsible for significant economic loss, as it is estimated that an annual market value as high as €143 billion is lost in the EU due to food that is never consumed.**

**Reducing the current rate of FLW is indispensable to meet the objectives of the UN Sustainable Development Agenda on food security, the Paris Agreement on climate change and the targets included in the recent EU Farm to Fork & Biodiversity strategies.**
**As a global leader in promoting food security and climate protection, Europe must promote new efforts to close knowledge and research gaps in FLW measurements, set clear targets and scale up innovative initiatives to halve and valorise FLW.**



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## Societal, economic & environmental needs

The discussion around food loss and waste (FLW) is also complemented and shaped by the debates on its definition. For purposes of clarity, this chapter adopts the World Resources Institute definition of FLW as "food (and its associated inedible parts) that is intended for human consumption but that leaves the food supply chain somewhere between being ready for harvest or slaughter (herein referred to as the "production" stage of the food supply chain) and being consumed" (WRI, 2019). FWL has been acknowledged as a major challenge over the last decade, having negative impacts on GHG emissions and climate change, resource efficiency, food prices and hence on access to food, health and social justice.

Data on FLW across Europe collected by the EU FUSIONS project and validated by the REFRESH project resulted in an estimate of **88 million tons of food wasted for 2012** (REFRESH, 2019). This equals **173 kilograms of food waste per person in total EU-28**. Compared to 2011, where the total amount of food produced was around 865 kg per person, this means **a waste of around 20% of the total food produced** (Stenmarck, Jensen et al., 2016). However, there is a relatively high uncertainty associated with these data because **the number of underlying studies, as well as the quality of data collected in many countries is limited** (WRI, 2019).


Figure 1: Food waste over the food (supply) chain. Source: Obersteiner, Sacher et al. (2019)

As shown by the REFRESH project, FLW in EU Member States is not distributed equally over the food chain (see Figure 1). **Reliable data of FLW in agriculture, horticulture, aquaculture, fisheries or other primary production activities is widely missing** and there are considerable differences in the definition of FLW within the sectors (Stenmarck, Jensen et al., 2016). However, the situation with regard to FLW measurement is projected to significantly improve, as from 2020 EU Member States will be required to start monitoring their waste levels according to a common methodology agreed at the EU level, in view of submitting detailed yearly reports to the European Commission from 2022-2023 (EU Commission, 2019). **By 31 December 2023, the Commission will examine data on food waste provided by Member States** and consider the establishment of EU food waste reduction targets to be met by 2030.



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**FLW happens all across the food value chain**. Regarding food loss from farm to retail, underlying drivers fall into four generic categories. Technological drivers include the lack of adequate physical infrastructure such as roads and processing facilities, as well as equipment and packaging. Poor management procedures also contribute significantly, including lack of skills and knowledge of food operators and processors, inflexible procurement requirements, poor supply and demand forecasting and wasteful marketing strategies (WRI, 2019). Available data show, however, that **the highest proportion of food** in the EU countries surveyed – over 50 per cent **– is discarded at the household level**, which highlights the role of EU consumers in reducing FLW (Wunder, 2019). Waste increases when consumers do not keep track of stock at home and do not use rational shopping lists when they go shopping. Preparation and serving of excess food, little knowledge of how to deal with leftovers, poor storing techniques, and incorrect interpretation of the 'consume by' or 'best before' indications on front-of-packaging labels all add to FWL in the everyday lives of consumers (Obersteiner, Sacher et al., 2019).

As long food supply chains suffer significant disruptions due to the international shutdowns and other precautionary measures taken to address the Covid-19 pandemic, it is essential to boost the resilience of EU food systems to crises and external shocks, including by focusing on increasing local food production and strengthening urban-rural linkages. However, EU food systems should also prepare for what will happen when the current emergency situation will subside. In times of crises, at once the significance of local supply increases dramatically and local food chains all of a sudden are expected to provide for wider communities. However, maintaining such increased production capacity after the end of a specific crisis may lead to increased levels of FWL, because consumer preferences could turn again to products imported from far regions of the world. At the moment, **we do not know how the current global pandemic will affect the demand for food in the long run**. Furthermore, as the origins of the recent outbreaks of SARS-CoV, MERS, SARS-CoV-2 and other viruses similar to COVID-19 may be traced in zoonotic transmission of viruses to humans (Galanakis, 2020), the increased focus on food safety during **the pandemic may lead to the discard of large amounts of food and the killing of animals as precautionary measures, thus substantially increasing FLW levels.**

**FLW a high economic impact estimated around 143 billion** eur per year in the EU. Included in this figure is un-harvested produce; edible products discarded because they do not adhere to market size and aesthetic standards; products spilt during storage or transport; unsold products in retail; and food wasted at household level (EU Parliament, 2017). In addition to the monetary estimation of the food wasted, there are also **additional costs for collecting, managing and disposing of food waste**.



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**Economic needs vary according to the sections in the EU food chain**. For primary production, produce may be damaged on the fields by pests and diseases, or become defective during transport, processing and storage. Inefficient harvesting and saturated markets for established food products may increase the amount of spoilt food and therefore add to FLW (Obersteiner, Sacher et al., 2019). In the retail sector, the highest amount of food waste results from bread and bakery (28 per cent), followed by fruit and vegetable (22 per cent), dairy products (15 per cent), and meat and fish (14 per cent) (source TESCO, cited in Obersteiner, Sacher et al., 2019). One reason is that bread, bakery, vegetable and fruits are unpackaged foods which may be subject to physical, chemical, microbiological contamination and varying temperatures along the distribution, storage and sale chain. While **unpackaged products** deteriorate easily and contribute massively to FLW**, plastic packaging** is also under much criticism for its impact on the environment, difficult post-use disposal, and for reasons of chemical migration of contaminants from packaging to food (Schweitzer, Gionfra et al., 2018). In the food service sector, studies provide evidence of a high share of FLW resulting from leftovers on the plate in the case of hospitals, whereas hotels show the highest level of FLW from leftovers from the buffet table and preparation loss. Regarding restaurants, FLW is observed to happen due to over-production of meals and during kitchen preparation. In workplace canteens, the main causes of waste are reported to be kitchen leftovers resulting from over-production and plate waste (Obersteiner, Sacher et al., 2019). This points to **different issues and targeted interventions needed to tackle FLW**, such as reducing menu size, good use of edible guarnition for catering services, better communication between food service stakeholders, etc.

**Reducing FLW would lower many negativel impacts of human activity on the environment** by essentially reducing the amount of food produced to adequately feed a growing human population. This includes using fewer natural resources such as water and land, applying less fertilizer, and reducing biodiversity loss. As the production and distribution of food entail energy use, GHG emissions and water use, FLW directly relate to negative impacts on environment and climate change. These negative impacts on environment and climate change characterise every sector of the food supply chain. **4% of EU GHG is associated with food that is actually wasted, corresponding to 186 million tons per year**. The EU FUSION project estimates that GHG emissions in the EU associated with food waste amount to the total level of GHG emissions in the Netherlands (Stenmarck, Jensen et al., 2016). Plastic packaging is often promoted as a means for avoiding food waste, with Europe's total demand for plastic amounting to 49 million tons per year. **40 per cent of total packaging in Europe is used for protecting food**. At the same time, under 30 per cent of plastic waste is collected for recycling in the



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EU, and the average European throws away 30 kg of plastic packaging per year. The prevalent solutions for managing post-use food plastic waste are landfilling and incineration (at 31% and 39%, respectively), however **high rates of littering and environmental leakage of plastics** contribute to raise the environmental food print of foos packaging (Schweitzer, Gionfra et al. 2018).

### R&I action required

**Reducing FLW across the whole agri-food value chain is a particularly complex challenge**, as actions targeting specific actors/sectors risk to produce unforeseen trade-offs in other segments of the value chain due to the **high interconnectedness** of FLW causes. For this reason**,** the successful design, implementation and uptake of innovations designed to reduce FLW require **a truly comprehensive approach** taking due account of the complexities of market practices, business models and consumer behaviours. Therefore, in order to meet the ambitious UN SDG goal 12.3 of halving per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains including post-harvest losses by 2030, priority should be given to three R&I macro-areas bearing the highest potential for impact at the systemic level:

- **Overcome data deficit.** There is an urgent need to deepen knowledge of the food chain to better understand the drivers, barriers and enablers to reduce FLW in all the segments; assess impact of ongoing public and private initiatives; and address behaviour change so as to be able to influence public authorities', businesses' as well as consumers' norms. It is rather telling of the data gaps still persisting in FLW analysis that the most recent estimates of the scale and the nature of FLW in Europe date back to 2012 (FUSION, 2016) and present several inconsistencies due to the scarcity of data sources used, the extrapolation of results from a small number of studies and the disputed accuracy of the figures proposed. Producing more information will provide the evidence base for developing and prioritizing reduction strategies and interventions. Measurement is also necessary if public and private entities are to know whether or not they are on track to realizing their targets. A positive development in this direction is the EU Commission Delegated Decision on the Food Waste Directive (European Commission, 2019). The Delegated Decision lays down a common FLW measurement methodology to support Member States in quantifying FLW at each stage of the food supply chain based on a common FLW definition and an agreed methodology. According to the Delegated Decision, Member States will be required to start collecting consistent data from 2020 in view of the first Europe-wide baseline assessment on food waste at each stage of the food supply chain carried out by the European Commission in 2023. The newly established EU



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Platform on FLW – and especially its sub-group on FLW measurement – will play an important role in supporting Member States beyond the scope of the Delegated Decision, for example by addressing important issues overlooked in the Decision such as the quantification of harvest losses and the ranking of food waste by waste hierarchy destinations (WWF-WRAP, 2020). EU Member States have thus the opportunity to promote the establishment of national binding targets as a replacement for the current aspirational, non-mandatory targets to allow SDG 12.3 to be met by 2030. Measurement by regional and local authorities appears to be much less advanced, although positive examples are starting to emerge in cities like Amsterdam and Milan (Milan Food Policy, 2018). Businesses and households have also marked significant progress in measuring FLW as compared to the past (Flanagan et al., 2019). However, they will require incentives and significant resources to be able to step up their efforts. Companies, in particular, need to scale up FLW measuring and reporting within their own operations and, over time, in their supply chains to enable the identification of success stories, best practices and benchmarking. A review of 1,200 business sites across 700 companies in 17 countries found that nearly every site evaluated achieved a positive financial return for taking action on FLW reduction, with half seeing a 14-fold or greater return on investment. In the UK, findings show that for every £1 invested in efforts to curb avoidable household food waste, households and local authorities saved £250 (Hanson and Mitchell, 2017). Consumers, on the other hand, will benefit from the diffusion of fast and free-of-charge digital tools to carry out household food waste audits. The issue of motivation is best addressed through initiatives based on solid behavioural insights and aimed at engaging grassroot movements, community leaders, as well as families in collectively shifting social norms, so that food wasting becomes as socially inacceptable as littering or smoking in public spaces (Simson, 2015). Europe-wide awareness campaigns have shown some positive results in promoting responsible consumption behaviours. The LIFE-Food.Waste.StandUp project, for instance, involved 20 000 Italian agro-food companies in an anti-food waste awareness campaign which informed 500 000 consumers and 200 000 food and drink enterprises across the EU about best practices and models for managing and donating surplus food between 2016 and 2019 (LIFE-Food.Waste.StandUp, 2019). The European Commission has stepped up its commitment to citizen information by establishing the first International Day of Awareness on FLW on 29 September 2020, which featured the organisation of several Europe-wide events and a social media campaign in various EU languages with advice for citizens on how to avoid food waste at home (European Commission, 2020d).



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- **Scale up innovations promoting circularity and market opportunities**. An essential step to meet FLW reduction objectives in Europe is to move away from the current semi-linear consumption models resulting in traditional disposal of food waste through landfills, to a circular model maintaining the value of food in the economy for as long as possible, as indicated in the Food Recovery Hierarchy (Figure 2).

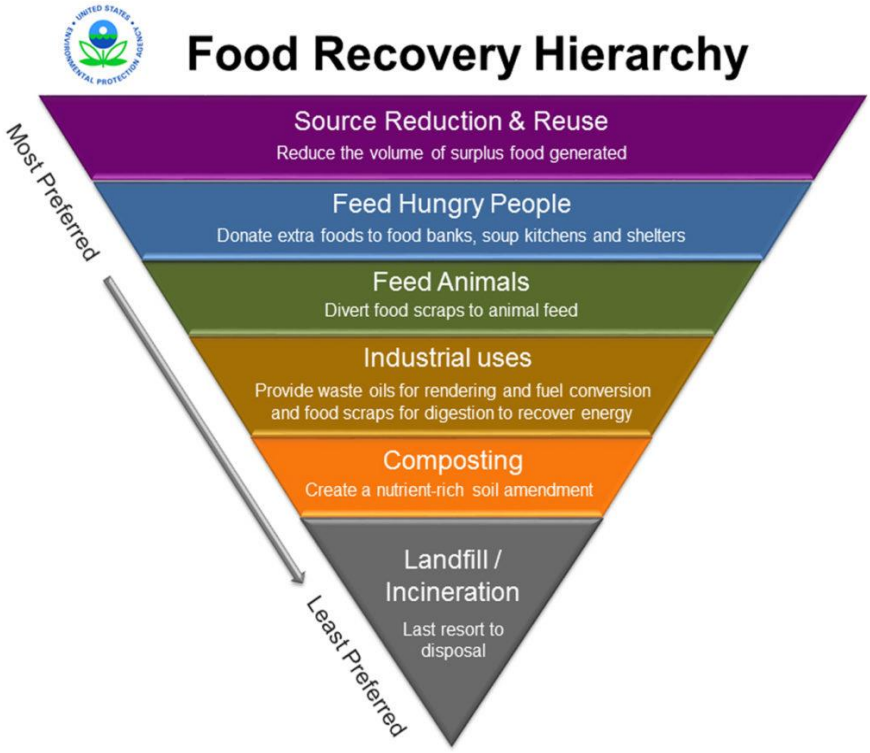


Figure 2: Food Waste Recovery Hierarchy. Source: EPA (2018).

Indeed, the uptake of food waste valorisation opportunities has a significant, albeit unchartered potential due to the scale of agri-food waste streams that are currently being dealt with through traditional disposal routes and that could instead be valorised to create high quality products. Adopting a FLW valorisation approach means taking the active decision to disrupt business as usual. Therefore, it is crucial for EU and Member States regulators to make a business case for waste valorisation, so that companies can benefit from a financial return on their investments to make the green transition without compromising their economic sustainability (Clowes et al, 2019). To this extent, regulators are increasingly promoting initiatives that encourage market implementation and scaling up of innovative action through a system of incubators and accelerators aimed at relevant actions selected according to the priorities highlighted in the Food Waste Recovery Hierarchy. For instance, in 2019 the European Knowledge and Innovation Community EIT Food selected the start-up Kaffe Bueno for its Food Accelerator Network (EIT FAN). Kaffe Bueno upcycles coffee waste



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into active and functional ingredients for cosmetics, nutraceuticals and functional foods . Over a four month acceleration period, EIT Food enabled access to tools, connections, mentors and expertise to help Kaffee Bueno and its innovation potential to succeed (EIT Food, 2019). The issue of communicating valorisation opportunities of FLW is closely associated with the promotion of a business case for FWL reduction and relies on the success of market uptake of innovation opportunities. It is extremely important that decision-makers facilitate the exchange of information, participation and coordination among relevant stakeholders, so that established companies become aware of the potential and technical feasibility of valorisation of waste streams, while start-ups and technical innovators understand the market space for products based on by-streams (WRI, 2019). The most effective way to valorise edible food that has been discarded due to its appearance is to keep it in the production cycle as food. As part of the Circular Economy Action Plan, the Commission has adopted EU food donation guidelines in order to facilitate the recovery and redistribution of safe, edible food to those in need. Developed in consultation with the EU Platform on Food Losses and Food Waste, the EU food donation guidelines seek to facilitate compliance of providers and recipients of surplus food with relevant requirements laid down in the EU regulatory framework (e.g. food safety, food hygiene, traceability, liability, VAT, etc.) and promote common interpretation by regulatory authorities in the EU Member States of EU rules applying to the redistribution of surplus food (European Commission, 2017). Governments are increasingly enacting policies to encourage food surplus donation and redistribution, while new apps are being developed to redistribute food from retailers and restaurants. Transformation of perishable surplus into more durable food is another increasingly popular innovation allowing for optimal use of resources. Bio-based chemicals produced from plants rather than crude oil represent a dynamic area of innovation suitable to stimulate growth, trade, investment and job creation (IEAS Bioenergy, 2020), especially in light of the ambitious target that foresees slashing by 50% the use of chemical pesticides by 2030 set by the EU Farm to Fork Strategy. The creation of animal feed or bio-based packaging from food waste (Arancon et al., 2013) also represents an interesting area for development, as businesses can thus achieve a triple win: meet waste reduction targets, reduce waste recycling and disposal costs, and potentially access new income streams.

- **Promoting Public-Private Partnerships & Voluntary Agreements**. Considering the significance of the challenge posed by FLW and the urgency of acting quickly and effectively towards EU reduction goals, public authorities and the business sector need to collaborate to



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pool available resources, as well as relevant expertise to tackle the issue. Partnerships are essential considering the very systemic nature of FLW and the inability of any single actor to bring about significant change by acting on its own. While the public sector has a critical control on public policies, incentives and infrastructures, private businesses play a major role in FLW proliferation at the production, distribution and sale levels (Flanegan et al., 2019). Therefore, commitment from both sectors is required to catalyse the systemic change needed to achieve large-scale reduction of food loss and waste. Furthermore, Public-Private Partnerships have the potential to provide flexible and efficient alternatives to mandatory regulatory structures, by improving the credibility of both public authorities and business through their commitment to a process of environmental protection. First promoted within the EU project REFRESH in 2017, Voluntary Agreements (VA) are evidence-based frameworks for action, including all major actors in the food chain from national and local agencies to industry, NGOs and research institutions in a specific Member State focussing on the delivery of transformative, long term change (REFRESH, 2019). VAs also constitute inclusive platforms where the issue of financing action can be discussed, for example by involving philanthropic institutions and supporting financing schemes for technologies and start-ups with the potential for sustainable innovations. Currently, the Netherlands, Germany, Hungary and Spain have launched VAs or national partnerships to reduce FLW. In such frameworks, participants jointly design interventions to measure, act on specific hotspots and assess the results of the foreseen initiatives (REFRESH, 2019).

*Barriers to systemic change*

**Technological/administrative barriers**. Technological gaps are present all across the food chain, but are particularly relevant at the level of agri-food harvesting; post-harvest storage solutions, including the issue of electricity supply; in the area of plastic food packaging (Schweitzer, Gionfra, et al., 2018). Complex food labelling also represents a technical barrier, as the "consume by" and "best before" labels often provokes misunderstanding among consumers and results in more waste (ICF, 2019). EU hygiene and safety standards on feed and food, and animal welfare regulations are often criticised for making the recovery or valorisation of wasted food legally or technically complex, while similar valorisation routes are allowed in countries outside the EU (REFRESH, 2018b).

**Social/psychological barriers**. Lack of awareness and engagement by various actors in the food systems can hinder the effectiveness of FLW reduction efforts. Consumers' beliefs and social norms on abundance of food, desired shapes and colours, expected portions and perceptions of acceptable amounts of waste at the household level can prove very resistant to targeted campaigns and



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transformative efforts (do Carmo Stangherlin, 2010). Private companies often display a distinctive lack of commitment to FLW reduction targets if incentives for action are not judged sufficient. In particular, a possible concern with regard to companies participating in VAs is the potential for "free-riding" to harness the benefits without investing resources. Variability in the levels of participation to VAs needs to be monitored carefully, as the long-term success of VAs will ultimately be determined by high levels of participation from all stakeholders involved (Delmas and Montes-Sancho, 2007).

**Political barriers.** EU policies, regulations and subsidies may inadvertently contribute to food leaving the food supply chain. The Common Agriculture Policy (CAP) can have a direct influence on the generation of food waste in production, processing and the retail stages of the food supply chain, through mechanisms such as direct payments, market measures and rural development payments. Such support mechanisms may often produce undesired side-effects. Direct income support to farmers keeps consumer prices for food products at a low level, which hinders the appreciation of food products and has the potential to incentivise FLW (Garske et al., 2020). Furthermore, the European Court of Auditors has argued that current coupled payments could stimulate production for products for which there may be no demand and thus promote the occurrence of food waste (European Court of Auditors, 2016). Under CAP, Member States may currently provide coupled support to those sectors or to those regions where specific types of farming or specific agricultural sectors that are particularly important for economic, social or environmental reasons undergo certain difficulties. In addition to that, market intervention measures which include market withdrawals, private storage, green or non-harvesting directly and indirectly contribute to FLW (Garske, 2020).

**Economic/Financial barriers**. The issue of resourcing FLW reduction initiatives undertaken by private businesses represents a crucial aspect of what authorities can expect from industry in terms of ambition and commitment to the common target. Indeed, accurate measurement methods are often more expensive, while more affordable methods tend to be less accurate (IAMO, 2018). Although resource efficiency is generally investigated through quantitative measures, measuring FLW in terms of value loss is considered to provide a more useful framework for putting forward transformative action (Bellemare et al., 2017). Regarding the issue of waste valorisation, choices related to waste management in the private sector are dependent on cost-benefit analyses. Consolidated business-as-usual practices can therefore constitute a significant obstacle to transformational, eco-friendly innovations, unless a clear business case for change is made (Clowes et al, 2019).



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*Enablers for breakthroughs*

**Technological/administrative enablers**. An increasing body of technological solutions to support rapid and cost-effective measurement and reporting is emerging and will soon allow gaining more insights on the impact of implemented reduction actions. For instance, the start-up Winnow encourages businesses to prevent food waste by easily pinpointing waste, helping them to cut costs and save time to run more profitable and sustainable kitchens. Thanks to a sophisticated AI software, Winnow weighs the amount of food as it is discarded in order to measure how much food is wasted and identify waste patterns (Winnow, 2020). Technological innovations supporting the scaling up of circularity models include new research on bio-based chemicals, packaging and transformation of waste into feed, as well as increased connections between innovators and entrepreneurs through hackathons, incubators and accelerators (EIT Food, 2019b). Administrative enablers include a more consistent approach to EU date labelling in order to enhance consumer choice, as well as more coherent applications of EU legislation regulating minimum criteria for donating surplus and transforming waste into new products.

**Social enablers**. Awareness campaigns and other initiatives by grassroot movements and community leaders are helping citizens to shift social norms regarding the unacceptability of FLW in public and private contexts. International efforts to curb FLW have gained momentum among EU citizens, as it is showed by the increasing success of organic food irrespective of industrial cosmetic standards; the demand for food derived from surplus vegetables; and the popularity of apps enabling sale/swapping of still-safe-to-eat-after-expire food products. Regarding businesses, participation in FLW measurement and reduction efforts is increasingly recognised as an effective way to earn positive branding for corporation as consumers demand more and more transparent supply chains (WRI, 2019).

**Economic/Financial enablers**. Public authorities dispose of sufficient evidence to make a consistent business case for FLW reduction at the country level, including with regard to businesses and private households. By using their purchasing power to choose environmentally sustainable and healthy food products for the public restaurants and canteens they operate in schools, administrations and hospitals, they can make an important contribution to sustainable consumption and production. Such practice, known as green public procurement (Schebesta, 2017) can provide a practical proof of concept for the triple win related to public health, protection of the environment and economic savings. The involvement of philanthropic foundations and private donors in VAs and National Waste



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Strategies can contribute to overcome issues relating to funding innovation in FLW reduction initiatives, thus boosting measurement efforts and market uptake of concrete actions.

### Potential for sustainable social and economic breakthroughs

*Social breakthroughs*

**Informed consumers and food labelling**. Consumer behaviour is shaped by several factors, including information flows. Prices alone do not reveal full information on food supply chains mechanisms, including the financial costs and environmental impacts of processing, length of transport, energy usage, treatment of workers, animal welfare standards, and other important elements of food systems. Exhaustive and unbiased food labelling – providing digitally smart, standardized and integrated indicators on whether a pr food product is environmentally sustainable, healthy and nutritious, and its production is ethical and fair - is a crucial. In particular, food labellin is a useful vehicle to account for the social and environmental costs of consumers' different daily food choices. Better understanding and use of date marking on food, i.e. "use by" and "best before" dates, by all actors concerned, can prevent and reduce FLW. A 2018 study carried out by the European Commission estimates that up to 10% of the 88 million tonnes of food waste generated annually in the EU are linked to date marking (European Commission, 2018b). Misinterpretation by consumers of the meaning of these dates can contribute to household food waste. How date marking is utilised by food business operators and regulatory authorities in managing the supply chain can also have an impact on food waste. For example, the approaches followed by food business operators in defining date marking (e.g. whether to utilise a "use by" or "best before" date), market practices (such as the amount of shelf life required by retailers on product delivery) and national rules on the further distribution and use of foods past the "best before" date can all influence the generation of food waste in the supply chain.

**Active citizenship and education**. Food and nutrition education should start early to shape food habits from youth and across different social groups. Early-age educational interventions act as a driver of healthy eating and valuing food. Education gaps and lack of information are adverse to the exercise of active citizenship. In spite of the importance of awareness and education initiatives, the persistent socio-psychological gap between knowledge and food choices also needs to be accounted for. People do not always choose their food on the basis of the nutritional information available. A complex web of psychological, cultural, emotional and social drivers influences the last-minute decisions consumers take when they are to purchase food (WRAP, 2013). An increased understanding of why people choose



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food products can help producing useful guidelines for education on nutrition and prevention of food waste.

**Co-creation and Living Labs**. Living Labs are open-innovation ecosystems that facilitate processes of co-creation in real-life contexts and the inclusion of diverse actors in these processes. The 9 Acceleration Labs set up by the EU FoodShift 2030 project, for instance, bring entrepreneurs and citizens together to tackle food waste, challenging citizens to upcycle and transform leftovers (FoodShift 2030, 2020). Another example is provided by the Leeds University Living Lab for Food Waste, which is researching innovative solutions that address the food waste challenges on campus, particularly catering waste. Three Leeds University PhD students in bioenergy have been carrying out a feasibility study into potential technological and behaviour change solutions, including a University-wide 'virtual food waste lab' – a network of interdisciplinary spaces where schools are researching sustainable food waste management (EPSRC, 2020). Labs, due to their multi-actor, multi-level, local and inclusive structure have the potential to be the appropriate tool for engaging diverse actors from industry, as well as final consumers, public authorities and NGOs in constructive action towards FLW reduction. Thanks to the interactions, cross-fertilisation of ideas and exchanges happening within Living Labs, they may contribute to shape more healthy and sustainable food environments for citizens. They also have the potential to provide scientists with tools to better understand rationales behind consumer food choices and FLW drivers, and to design food supply in order to reduce unsustainable purchasing in the future.

*Economic breakthroughs*

**Voluntary Agreements**. VAs between private businesses and public entities are proven methods for tackling FLW focusing on prevention rather than diversion. By working together to achieve collective goals, organisations from across the food and drink sector can learn from each other, collaborate, and deliver change in efficiently. If implemented correctly and with sufficient commitment from all parties, VAs can be flexible instruments apt to quick implementation and swift adaptation to changing circumstances. Private businesses not only can benefit from the reputational boost associated with taking action against FLW, but they can also operate in a pre-competitive space where commitments are not established by hard regulation (REFRESH, 2019). The respect of a number of conditions is however essential to the success of VAs. Firstly, it is necessary to identify a trustworthy and independent lead organisation to engage members, enlist government support and funding, manage conflicts, and develop objectives. Second, overall and specific targets need to be aligned with national and international initiatives. Third, the right combination of public and private funding needs to be



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secured to ensure commitment from all the parties involved. Fourth, a gap analysis carried out among the VA members is essential to identify and establish relevant FLW reduction actions. Fifth, measurement and evaluation of results need to be carried out by using a recognized reporting standard and against a baseline figure (REFRESH, 2019). An example is provided by the VA signed in 2013 between the Romanian Ministry of Environment and Forests and a large distribution and recycling companies to develop tools for packaging waste prevention and improve recycling. The agreement's goal is to increase the volume of packaging collected by 25% by 2030. The project is now implemented in 14 major cities in Romania and its deployment will continue progressively in other cities. One of its activities involves offering vouchers to clients in several supermarkets in Romania (Carrefour and Cora in 12 Romanian cities) when bringing end-of-life home appliances or plastic packaging (European Commission, 2015).

**Smart packaging.** Digital solutions may provide an important added value to traditional packaging, which currently mainly provides a protective barrier against external stressors like temperature, light, bacteria influencing product life. Smart packaging comprises materials and articles that monitor the condition of packaged food or the environment surrounding the food (European Commission, 2004). Smart packaging has the potential to play an important role in reducing FLW by maximising the shelf life of products and informing consumers with accurate information through smartphones, thus preventing damage and spoiling throughout the supply chain. The consume by/best before' labelling issue could be also be addressed in case smart packaging developers identify a protocol to test whether food is still safe to eat. For that purpose, an electronic sensor circuit is needed in packaging to monitor the acidity level of the food which could be read with a scanner or smartphone to assess the freshness of food contents (Commodity Inside, 2017). However, the uptake of smart packaging technologies faces a number of challenges of different kinds. In terms of costs, smart packaging requires the essential silicon ICT material, which is currently very expensive on the market. Furthermore, there are ethical concerns related to collecting sensitive information about companies and customers. Regarding businesses, whereas the process of collecting business data adds to the transparency of supplied products and is positively perceived by the public it may still be viewed with suspicion due to potential breaches of business privacy and industrial secrecy. The collection and storing of sensitive citizen data on customer identity, behaviour and shopping habits, on the other hand, may be in contrast with protection of personal data as established in the EU General Data Protection Regulation (European Commission, 2016).



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## Impact & Co-benefits

The successful adoption of initiatives designed to reduce FLW requires a systemic approach designed to stimulate and accelerate social, economic, environmental, institutional, organisational and technical innovation across the whole food value chain. The hotspots and underlying causes of FLW vary across the EU, and within each Member State, particularly in relation of levels of economic development. Therefore, collaboration among European (and international) stakeholders is essential, and requires engaging actors as different as producers and suppliers, technical experts, government authorities and consumer organisations. Employing a food systems approach with respect to the issue of FLW reduction means anticipating potential trade-offs and knock-on effects across the value chain, including the risk that targeted interventions may simply shift FLW across a different sector of the food chain. To avoid this, it is crucial to produce **impact assessments aimed at designing complementary actions** to redress unwanted consequences of interventions. Given the fact that figures related to amounts of food waste prevented by a specific measure are elaborate theoretically, neither the ecological impacts nor monetary costs associated with food waste measures can be assessed easily. According to an assessment carried out by Reynolds, no reviews currently exist assessing the extent to which ecological impacts, monetary costs or savings, and efficiency of food waste measures are considered (Reynolds, 2019). Several studies have however stressed that, in case monetary aspects are taken into account, these tend to be restricted to the costs embodied in the food itself (e.g. based on retail prices), whereas disposal related costs are neglected (Koester et al., 2018). To address this and other measurement issues, the European Commission has established a framework for the evaluation of FLW prevention actions to guide the action of the EU Platform on FLW in developing recommendations for action for each stage of the food supply chain. In 2019, a total of 99 actions on all sectors of the value chain were reviewed. The main gap observed was the **absence of Smart, Measurable, Achievable, Realistic and Timely indicators for the objectives, baseline values, and a monitoring system** to track progress made towards the stated goals (Caldeira et al., 2019). To evaluate the efficiency of a food waste prevention action, it is crucial to fully capture the total cost and benefits associated with the action's implementation, which should reflect all resources used to implement the action and the multiple possible benefits. Measurement of the food waste amounts should be carried out prior to the intervention in order to establish a baseline against which progress may be monitored. Comparison of food waste levels pre- and post- intervention is needed to assess whether the action was effective in achieving its goals. Finally, such measurement should be done following a defined methodology clearly stating what is the definition of food waste used in the accounting exercise.



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Tackling the FLW reduction issue would produce significant positive effects on the environment, easing pressure on a number of planetary boundaries. The estimation of EAT-Lancet commission suggests that **halving global food loss and waste could reduce agricultural GHG by 5%, lower water use by about 13%, decrease use of each nutrient (nitrogen, phosphorus) by up to 15%, and reduce projected biodiversity loss by up to 33%** relative to the business-as-usual scenario (Willet et al., 2019). In the EU, having food waste would produce agricultural land use **savings of up to 9 554 kilometres squared, or 0.5% of EU agricultural land**. The largest savings come from sectors that contribute more to household waste, such as vegetables, fruits and meat. **GHG reductions would from 7 (-1.6%) to 16 (-3.5%) million tonnes, largely driven by agriculture**. For water abstraction, food waste reductions would drive **water savings of between -121 million cubic metres and -316 million cubic metres**, e.g. between 0.2% to 0.6% of the baseline and largely driven by horticulture (Philippidis et al., 2019). In particular, food that is lost and wasted each year in Europe accounts for an estimated 8 percent of annual GHG emissions and consumes a quarter of all water used by agriculture, two unintended consequences that would greatly benefit from FLW reduction targeted interventions, as pointed out by the DrawDawn project, that listed **FLW reduction as the third most impactful solution** available to tackle climate change (DrawDown, 2020).

Since more than 30 million tonnes of waste in the EU are generated in households, food services and retail, reducing FLW would produce remarkable savings in natural resources. Valorisation of food and waste, for example through surplus donation and exchange, and creation of bio-based packaging, chemicals and animal feed from waste would open the door **to scale economies for innovative companies**, thus contributing to make a business case for the sustainable transition to a circular economy model. **Net effects on EU competitivity are however not clear**, as FLW reduction actions will not come for free. In a pioneer study on the potential economic impacts of halving food waste in Poland, Germany, and Spain, researchers found that since households generate the most food waste of all sectors, a reduction of 50% would have an of impact of €28 293 million saved due to unnecessary purchases in Germany, €11 468 million in Spain and €634 million in Poland. Regarding the wholesale and retail sectors in Poland, however, reducing food waste would save €246 million at a loss of production and GDP of 0.33% and labour reductions of over 36 000. In Spain, the sectors' economic savings would amount to €108 million with a decrease in production and GDP of 0.07% and a fall in labour of over 11 000. The German wholesale and retail sectors would register the smallest impact, with savings up to €73 million, a minimal effect on production and GDP (-0.02%) and a reduction in employment of just 6 400 (Campoy-Muñoz et al., 2017)



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Reducing FLW is intimately linked to shared norms on the social value of food and would thus have a **positive effect on community bonds**. Surplus redistribution and a more efficient reuse of food available, for example, have the potential to **alleviate poverty and partially reduce inequalities**, especially in the framework of current food systems still plagued by the persistence of large numbers of both obese and undernourished people. It is important to note, however, that redistributing surplus food provides little incentive to change the practices that often lead to the generation of surplus food, or to improve long-term food access for households and communities (WRI, 20219). Introducing innovative actions to reduce FLW among new generations in Europe would also resonate with the traditional values of older generations and the cultural memory of food scarcity, thus bringing different segments of society together. Promoting ethical considerations regarding food loss and waste would also push the business community to adapt, as companies are increasingly under pressure to reduce FLW as it is perceived as the "the right thing to do" (Hanson and Mitchell, 2017, p. 17).

There are no straightforward indicators to assess how reduced FLW might translate into improved EU food security, as not all food saved and recovered would reach those in need. However, **savings can help increase the amount of food that remains available for human consumption**, increasing the amount of people who can be fed with the same amount of food. FLW is often measured in weight and therefore estimates do not account for the nutritional content of different foods. Foods such as fish and seafood account for a small amount of FLW by weight but constitute the primary source of protein and micronutrients for millions of people. Furthermore, nutritious foods such as fruits, vegetables, and dairy products are highly perishable and thus are disproportionately vulnerable to FLW. Research suggests that significant amounts of nutrients are lost when such food is lost or wasted (WRI, 2019). The monetary value associated with savings can be reinvested in purchasing food with high nutritional value, thus providing a proper food security dimension to the case for FLW reduction. At the global level, it has been found that reducing the rate of food loss and waste by 50 percent by 2050 would close the gap between food available in 2010 and that needed in 2050 by more than 20 percent (Searchinger et al., 2018). Although such figure would probably be lower in Europe due to the specificities of its context, a significant improvement can be expected, as the EU Platform on Food Losses and Food Waste states that: "Food loss and waste reduction programmes will have an impact on a number of other areas of food policy, including agricultural production, health/nutrition and food safety" (EU Platform on Food Losses and Food Waste, 2019). Reducing FLW can therefore be a lever in creating a more nutrition-sensitive food system and can increase the availability of nutrients essential for a healthy life.



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## Policy alignment

*Alignment with EU policy frameworks*

Exploiting the full potential of the pathway areas on FLW reduction resonates with some of the most relevant policy priorities of the EU and its Member States as for what concerns the just transition to sustainability highlighted in the overarching vision of a European Green Deal (European Commission, 2019c). The recent May 2020 **Farm to Fork Strategy is quite explicit in setting FLW reduction targets**. The document reiterates the EU's commitment to halve food waste and reduce food loss by 2030, as well as to review its own rules on date marking, so as to enhance consumer' informed decisions and thus reduce the risk of unnecessary FLW proliferation (European Commission, 2020a). Besides the Farm to Fork strategy, the EU Commission took other important steps to FLW reduction with its new **Circular Economy Action Plan (CEP)** aimed at developing a sustainable and competitive economy by maintaining the value of resources for as long as possible (European Commission, 2020e). In the framework of CEP, FLW reduction has emerged as a top priority in correspondence of the entry into force of four significant directives. Under the **Revised Waste Framework Directive**, Member States will have to ensure they recycle at least 55 % of their municipal waste by 2025, 60 % by 2030 and 65 % by 2035 (European Commission, 2018). The Revised Waste Framework Directive has also created momentum for renewed efforts on measurement and reporting of FLW levels in Member States. The The **Delegated Decision establishing a common EU methodology to measure food waste** is the first concrete effort to establish harmonised criteria for FLW measurement, mandates EU countries to start collecting FLW data from 2020, with the objective to produce a baseline report and establish binding targets from 2023 (European Commission, 2019). The **EU Platform on Food Losses and Food Waste** monitors progress, drafts measurement guidelines and provides recommendations to Member States to steer the process, including by sharing national best practices on surplus redistribution and data labelling (European Commission, 2019d). The updated **Bioeconomy Strategy for Europe** and the renewed **EU Industrial Strategy** have paved the way for an increased valorisation of side-waste streams and have the potential to increase interest and profitability in technological valorisation options available. Last but not least, the two overarching EU framework regulating agri-food production, the **Common Agriculture Policy (CAP)** and the **Common Fisheries Policy (CFP)**, have also been including some provisions to reduce FLW in recent years. Such overarching policies have the potential to promote FLW reduction knowledge transfer, stimulate innovative marketing and valorisation activities, and even provide funds to support the collection of data at farm level, thus bridging the requirement on FLW mandatory measurement contained in the EU Delegated Decision on a common methodology. CFP can have a significant impact with regard to the regulation of by-catch fish, as well as of norms banning specific fishing tools that allow overfishing and indiscriminate



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catch. CAP can also have an influence on the FLP proliferation in the production, processing and retail stages of the food supply chain, through mechanisms such as direct payments, market measures and rural development payments. However, such potential, that could open the door to investments in sustainable infrastructure or physical assets (such as stocking centres), farm advisory services, animal welfare measures, risk management, and community-led social innovation projects, has remained largely untapped, with **Member States that have so far not prioritised FLW reduction interventions in their CAP national plans** (European Court of Auditors, 2016). While the potential of CAP has remained underexplored, in recent years several Member States such as Spain, Portugal, Germany and the Netherlands have started to develop their own National Food Waste Strategies, providing momentum to accelerate FLW reduction, prevention and diversion along the value chain at the national level (EU Platform on Food Losses and Food Waste, 2019).

*Alignment with international policy frameworks*

FLW reduction is an important issue towards the achievement of **UN Sustainable Development Goals (SDGs).** Most directly, reducing food loss and increasing waste reduction can help achieve SDG 12, which seeks to "ensure sustainable consumption and production patterns." **Target 12.3**, in particular, mandates for halving "per capita global food waste at the retail and consumer levels and reducing food losses along production and supply chains, including post- harvest losses," by 2030 (UN, 2015). This commitment has been transposed in EU regulation, as the targets included in the EU Farm to Fork strategy prove. Reducing FLW can also indirectly meet other objectives. For instance, farmers benefit from reductions in post-harvest and storage food loss through increased incomes, which is consistent with SDGs 1 and 8 to tackle poverty. The objective of Zero Hunger, underlined by SDG 2, can be addressed through surplus valorisation and redistribution. Reducing disposal of FLW in incinerators or landfills can help cities become more sustainable, as per SDG 11. Climate goals underlying SDG 13 can also be addressed by reducing greenhouse emissions, as well as fertiliser use and freshwater waste associated to the production of FLW. Moreover, reducing FLW can play a role in protecting biodiversity through easing pressure on land-based ecosystems (SDG 15) and limiting fish bycatch (SDG 14). Such objectives are also consistent with other international agreements such as the so-called **Paris Agreement on Climate Change** and the **Aichi Targets of the Convention on Biological Diversity**, which aim to limit the global temperature increase to 1.5 ◦C until 2050. Both agreements require significantly reduced animal farming and zero fossil fuels in all sectors worldwide in about two decades, which also implies major changes in agriculture and decisive action on FLW (Garske et al., 2020).



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**KROMKOMMER**


Kromkommer (a Dutch wordplay on the words 'cucumber' and 'crooked') was founded in 2012 with the mission to valorise fruits and vegetables that otherwise would be thrown away because of their appearance or over-production. Instead of being dismissed as waste and leave the food value chain, crooked vegetables are converted into soup. At the moment, the soup can be bought at over 50 stores throughout the Netherlands. Kromkommer's ultimate goal is to see wonky veggies on the shelves, for the same price as their "perfect" brothers and sisters.

For more information: https://www.kromkommer.com/english/ .

## KROMKOMMER

*Innovative circular business models*

### Assessment of added value

While EU legislation on minimum appearance standards has been amended over time so as to allow the sale of wonky vegetables and fruits, today between 5% to 10% of fresh produce is still discarded on the grounds of its appearance. Kromkommer adopts a truly circular approach to the issue of food waste by integrating efforts directed at the valorisation of produce that would otherwise become waste with awareness campaigns during which they sell hundreds of kilos crooked vegetables and fruits to encourage consumers to adjust their shopping behaviours to the common objective to reduce waste.

### Assessment of challenges

The main challenge for the success of Kromkommer is that its business model is based on a certain degree of ambiguity: while the sturtup's efforts to reduce food waste are laudable, its service delivery would not be possible if no wonky vegetable were discarded based on appearance only. Another key determinant of Kromkommer's success will be the fluctuation of food prices: should CAP subsides to fresh produce be lowered and prices increase consequently, less fruits and vegetables would be discarded on the grounds of appearance. Equally, the competitivity of Kromkommer's offer is based on the price of the soup derived from wonky vegetables. Consumers may refrain from purchasing Kromkommer soups should their cost be judged too high compared to the social benefit associated with supporting the product.

### Prospects for future development

In order to establish itself as a mainstream actor in the EU food systems, Kromkommer will need to expand its brand and increase its recognisability. While it is already engaging successfully a young target audience trhough social media and other awareness campaigns, producing more content in English will help expand its network and potential user base, thus allowing Kromkommer to sell its soups in other parts of Europe. Furthermore, should social norms on produce appearance shift, Kromkommer will need to adapt its business model, for instance by including in its valorisation efforts produce that has expired but is still safe to eat.



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**YONODESPERDICIO**


The mobile platform called Yonodesperdicio ("I do not waste") is creating a network of people who avoid waste by food donation or exchange. On the site, users can post food they have available to share, along with photos and expiration information, and an interested recipient can claim it and arrange pickup with the donor, all for free. Another important aim of the platform is to use technology to boost awareness of the problem of food waste. "Citizens are not aware of the environmental, economic and social impact that food waste generates. Raising awareness of this issue will contribute to responsible and conscious decisions," Laura Martos, the platform's awareness officer, says.

For more information, visit https://yonodesperdicio.org .

## YONODESPERDICIO

*Redistribution of surplus*

### Assessment of added value

The action carried out by Yonodesperdicio seems particularly relevant in light of the particularities of the Spanish policy landscape. Spain is in fact one of the few EU Member States where both a Voluntary Agreement (VA) and a National Strategy on Waste reduction have been put forward in the last few years, resulting in active measurements of food waste. According to the Spanish Ministry of Agriculture, food waste is on the rise in the country, which makes Yonodesperdicio's activities all the more significant. Adopting a food systems approach, Enraiza Derechos, the NGO controlling the app, puts together food retailers, local authorities (Ayuntamento de Madrid), a research institution (Centro de Innovacion en Tecnologia para el Desarollo Humano), a bank (BBVA) and a network of citizens to bring about sustainable change and contribute to SDG 12.3 (halve food waste).

### Assessment of challenges

The profound issue that needs investigation is the assessment of whether the redistribution model promoted by Yonodesperdicio can really represent a sustainable solution to the issue of food waste in the long term. Surplus redistribution, in fact, tackles the issues of resource efficiency and hunger, but do not produce incentives to reduce overproduction altogether. On the contrary, companies and household might even feel entitled to produce and stock surplus if they believe that it won't be wasted, thus producing the undesired consequences to put further stress on natural resources in a context of increasing scarcity and climate concerns related to unnecessary production.

### Prospects for development

Established in 2016, Yonodesperdicio is still in its consolidation phase. Over time, it should aim to extend and reinforce its national presence, while also focusing more on actual strategies to reduce food waste, especially at the level of households. It could, for instance, offer tutorial on how to carry out waste audits at home so as to adapt purchase, or provide recipes to make use of the products available at home before exchanging them.



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## Conclusion

**FLW in Europe produces negative social, economic and environmental impacts**. It contributes to food insecurity and represents an obstacle to nutrition. It aggravates the effects of climate change as food production is resource-intensive and FLW produces remarkable carbon, land and water footprints. It represents a financial burden for producers, consumers and national economies as it sensibly reduces incomes, purchase and investment power.

This chapter has discussed the grand challenge of reducing FLW in the EU by focusing on selected issues of particular relevance. First, reduction efforts have long been constrained by the **lack of an agreed definition of FLW, as well as of harmonised measuring methodologies and reliable data on the amounts produced by Member States, private companies and households**. The situation is expected to improve thanks to the European Commission Delegated Decision mandating Member States to collect their FLW levels from 2020 and report to the Commission from 2023 onwards. While the EU Platform on Food Losses and Waste will have an important role to play in setting guidelines, providing recommendations, and promoting harmonisation with the UN-sponsored Food Waste Index and Food Loss Index, **Member States and businesses need to step up their commitments and set up realistic targets, as well as clear strategies to achieve them**. Second, given that FLW occurs all across the food value chain, sectorial interventions risk to fail as they may simply produce a shift in FLW production up or down the chain. To avoid this, **coordinated action from actors from across all sectors is required through inclusive models of interest representation and food governance to make sure the main economic, cultural, political dimensions of the food systems are taken into account**. As FLW proliferation in Europe mainly happens at the household level, the strong behavioral aspect linked to the FLW production needs to be tackled through education activities, awareness campaigns and competence-building training. Finally, technological innovations aimed at accelerating the transition towards a fully circular model will play a major role in the achievement of EU objectives. Support for start-ups using **smart technologies to improve storing solutions, reduce plastic packaging, facilitate FLW audits and promote exchange of information among stakeholders will help Europe living up to its commitments** on FLW and thus accelerate the transition towards fair and sustainable food systems.

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# The Microbiome World

**“Micro-organisms may be small, but their impacts are mighty’’ (Jo Handelsman, White House Office of Science and Technology Policy (OSTP) in the United States).**

**Microbiology and the inter-disciplinary study of the microbiome have rediscovered microorganisms as a vast and untapped natural resource with great potential to shift the balance of the ‘nature – food systems – people’ equation back into the healthy zone (FAO, 2019). Numerous studies have investigated the role the human or animal microbiome in modulating health and disease, proving the link between gut dysbiosis and obesity and food-related NCDs like diabetes, cancer, heart disease, allergy, irritable bowel syndrome though also cognitive functioning (FAO, 2019). Besides the focus on human health and wellbeing, a growing amount of data indicates that by improving microbiome functions (e.g. in soil, plant, animal) it will also be possible to tackle other global challenges (Hyland & Stanton, 2016), such as food and nutrition security (Singh & Trivedi, 2017), waste management (Jurado et al 2020), or climate change adaptation and mitigation (Cavicchioli et al 2019).**



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## Societal, economic & environmental needs

**The microbiome is a characteristic microbial community** that forms a dynamic and interactive micro-ecosystem occupying a reasonably well-defined habitat which has distinct physio-chemical properties (Berg et al 2020). It is prone to change in time and scale, is integrated in macro-ecosystems including eukaryotic hosts, and here crucial for their functioning and health. The microbiome does not only refer to the microorganisms involved but also encompasses their area of activity, which results in the formation of specific ecological niches. The human microbiome, especially the gut microbiome is sometimes referred to as **an "essential organ"** by itself (Wang, 2017). The human microbiome is **involved in basic human biological processes**, including modulating the metabolic phenotype, regulating epithelial development, and influencing innate immunity and non-communicable chronic diseases such as obesity, inflammatory bowel disease, diabetes mellitus, allergy, atherosclerosis, heart diseases, or cancer (Wang, 2017).

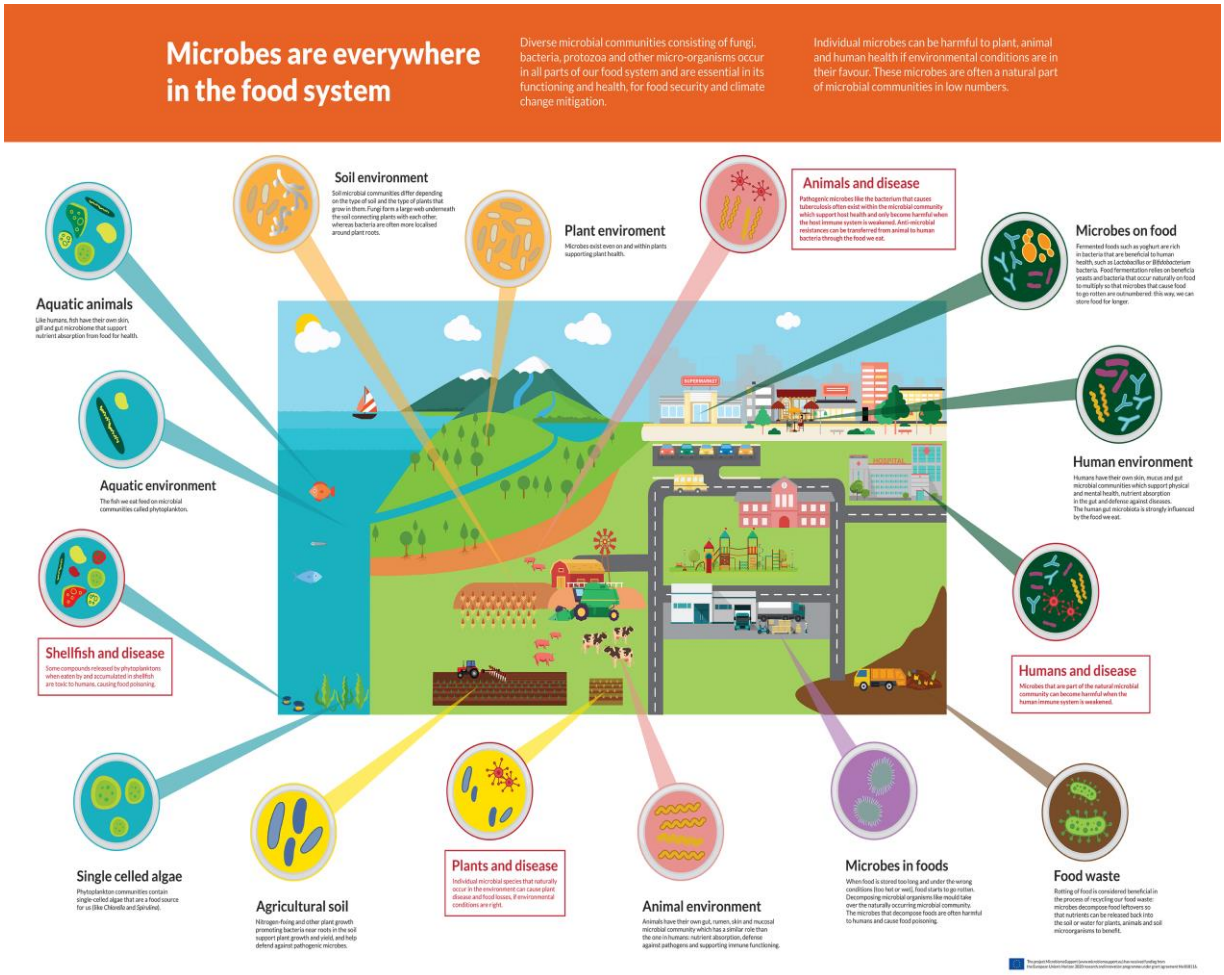


Figure 1: Microbes are everywhere. Source: The MicrobiomeSupport infographics (2018).



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The microbiome not only is of vast importance for the human body, animals and plants but also for example larger ecosystems like soils and oceans: **Microbiomes play a key role in maintaining life on earth.**

The marine microbiome produces most of the oxygen we breathe in the earth atmosphere and in a major link is responsible for the removal of carbon dioxide. Also, activities of the soil microbiome lead to the mitigation of greenhouse gas emissions (GHG) by carbon sequestration or methane oxidation and soil microbiota may also degrade otherwise toxic contaminants resulting in bioremediation. **Microbial degradation of dead plant and animal matter into simpler substances is essential for the provision of nutrients at the beginning of the food chain**, thus making microbiomes a key factor for plant / animal health in primary production. Further microbial activities are essential for food production and preservation. Microbiomes and microbial communities are important for **ensuring a sustainable future food production** and are present in every step of the food systems, which considers all elements and activities that relate to the production, processing, packaging, logistics, distributions, preparations, consumption, waste streams as well as human health and the environment.

**Non-communicable diseases (NCDs) resulting from unhealthy diets and imbalanced gut microbiome cause high social and economic costs** for individuals, families, communities and governments, posing a greater **risk to morbidity and mortality** than unsafe sex, alcohol, and drug and tobacco use combined. Almost 60 percent of the adult world population is overweight, of which nearly 25 percent have obesity according to the OECD analysis on the WHO Global Health Observatory 2018. Obesity and **obesity-related metabolic disorders are characterised by specific alterations in the composition and function of the human gut microbiome** (Davis, 2016). At the same time, one out of nine people in the world remains undernourished, and more than one out of three suffers from micronutrient deficiencies with its serious public health consequences (FAO, 2019; Wepner et al 2018). Furthermore, the health status of the population is an indicator of the resilience towards pandemics. In case of the current COVID-19 health crisis, scientific evidence shows that **people with obesity are at greater risk of serious illness or death from COVID-19** (EASO, 2020). A recent US study, looking at data from 75 studies including almost 400,000 patients, showed that people with obesity were twice as likely to be hospitalised and almost 75% more likely to be admitted at the intensive care units and were at a higher risk to die (Popkin et al, 2020).

Currently, public health national institutes define and communicate general nutritional guidelines for broad segments of the populations, often only distinguishing among certain subgroups like infants, pregnant women and elderly. A promising approach would be however to deliver more targeted nutrition advice in the continuum between health and disease or even targeting certain groups of



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individuals with the same characteristics and similar responses to specific nutritional interventions. A more targeted approach to nutritional recommendations could make it easier for consumers to change and sustain improved dietary behaviour. Since a healthy diet is not necessarily the same as a sustainable diet, it would be important to take sustainability into account when providing nutritional advice to citizens. There is still **no agreed definition of what constitutes a healthy gut microbiome**, since there is a **high variation between and within individuals**, however the resilience of the gut microbiome might be an important biomarker for health and personalized interventions could play a role in increasing the resilience of a healthy gut microbiome (Sommer et al, 2017).

Agriculture is a significant source of GHG emissions. Furthermore, due to the extensive use of fertilizers and pesticides, in a downward spiral with loss of biodiversity agriculture has contributed to a degradation of the soil and water quality (Blaser et at., 2016). The degradation of those has a worrisome impact on food production, food quality (nutrients) and safety. To achieve sustainable EU food systems, there is an urgent need to limit the amount of GHG emissions, to find alternatives for the use of fertilizers and pesticides and to implement a recovery strategy for the soil and water quality. This also applies to industrial aquaculture, where **controlling the microorganisms that are associated with aquaculture systems (i.e. the aquaculture microbiome) has always been essential in high intensity rearing of fish** (Dittmann et al., 2017). It is estimated that around 20% of food produced is wasted, this equals around 88 million tons of food waste for 2012 (Stenmarck, Jensen et al., 2016). **Microbiome may be especially important during crop storage** by either preventing or favouring rots, or quality loss due to, for example, sprouting, saccharification, water loss or spoilage. The potential of plant microbiome to influence postharvest losses is largely unexplored. Exploring the role of the plant in storage stability of crops could ensure food supply and food quality in the future by employing microbial-based solutions from the field to the fork (Buchholz et a., 2018).

On the one hand, the current way the food system is operating depletes the natural resources. On the other hand, the price that society has to pay for the growing amount of overweight and obesity is enormous. The associated, global costs of overweight and obesity are $2.0 trillion per year – taking into account direct and indirect costs, such as associated health care costs, loss of labour productivity and quality of life. Overweight reduces employment and workers' productivity. The impact can be quantified as equivalent to a reduction in the workforce of 54 million people per year across the 52 countries analysed, which include OECD, EU28, G20, OECD accession and selected partner countries (OECD, 2019). **Microbiome science** could play a role in reducing these environmental burdens and associated economic costs and **provide real opportunity for new business models.**



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### R&I action required

- **Adopt a food systems approach to the study of the microbiome**. Microbiome science is an emerging and rapidly developing research field and the number of projects and scientific publications has increased rapidly over the past decades. The numbers of publications in all fields of microbiome research have increased 7 times from 2009 to 2019 (MicrobiomeSupport, 2020). A Pubmed analysis on the number of publications linked to the term 'human microbiome' found an increase from 80 in 2007 to 1528 in 2015 (Eid et al, 2017). The Gut Microbiota for Health digital community reported a total amount of 4900 articles in 2019 (Gut Macrobiota for Health, 2019). Scientific discovery and innovation are taking place ever more rapidly. However, at present R&I actions happening in a very fragmented landscape and in through sectorial disciplines addressing only specific components rather than the whole interconnected system**.** The fact that microbiome science cuts across traditional borders of scientific domains, technical disciplines and economic sectors adds to the complexity of the policy, regulatory and institutional implications of these developments. The speed at which new knowledge from the microbiome field leads to policy debate and change remains extremely slow. It is, however, time to start a systematic study of micro-organisms, as they may be the key to explain the missing links and fill the gaps in our knowledge to address the biggest challenges of our time (FAO, 2019). The rapid growth of Microbiome science as well as the rapid development of related technology have made it difficult to compare results across studies due to the ever-variation of fundamental indicators, such as the procedures used to analyse the microbiome and study designs (Bik, 2016). In relation to the human microbiome, the variation in genetic and dietary backgrounds of the study population is another barrier to compare research results. There is still a need to understand the causal relationship between food, diet and functional changes in the intestinal microbiome and as a response on this physiological effect in the human body. Although there are many scientific results that associate various diseases with change in the intestinal microbiome, there is still a lack of evidence to ensure these changes are the cause of the disease rather than a consequence. To illustrate the challenge still ahead, a recent report on health and the microbiome states that "an important challenge is to characterize the gut metabolome, i.e. the collection of metabolites generated by the gut microbial flora that interact within the gut microbiome and with the host. Understanding the role of the gut metabolome will generate understanding of how it functions. So far however, only 2% of the metabolites produced by a typical microbial community corresponds to known structures – and of these, only a small fraction is on known biochemical pathways" (OECD, 2019).



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- **Produce impact assessments to inform policymakers and the public opinion of the added value of the microbiome**. Furthermore R&I strategies addressing the whole system considering microbiomes in different environments in a multi-disciplinary approach should be developed. Such an approach has to go also beyond the description of the system but has to address functional aspects elucidating microbiome activities and the complex network of interactions and the services for our society. To achieve this goal, large infrastructures are required enabling data management and bioinformatics as well as biobanking of food system and environmental microbiomes. This involves strong international cooperation with multiple partners and stakeholders from different continents and a frame of large programmes for finding global solutions to ensure also the availability, quality and use of data. Better integration of microbiome-based concepts in soil and primary production of plants and animals is one important step towards more sustainable production of healthy food reducing the dependence on chemical input. The projected increases in population size and the desire to provide high-nutritional- quality crops to a larger fraction of the population, combined with limitations in arable land and the need to maintain or enhance ecosystem services while simultaneously increase crop yields, reinforce a need to understand the impact of plant-soil-microbe interactions on agricultural productivity. Determining how the interactions of microbes, plants, and soil conditions confer resistance to abiotic and biotic stress or impact nutrient availability under current or future local climate conditions is likely key to producing sufficient food for a growing population, providing the underpinnings of microbial enhancement of plant performance (Blaser et al, 2016).

*Barriers to systemic change*

**Technological/ administrative barriers.** Although there have been significant advances in obtaining microbial genomic information, fundamental challenges exist regarding the scalability and portability of microbial readout technology (Blaser et al, 2016). There is a need to increase the translation of scientific data into development of products and improve the dialogue and cooperation between academics and industry. Success in understanding, predicting, and potentially manipulating microbiomes for societal benefit will require a broadly interdisciplinary approach. Unintended consequences and risks must be thoroughly evaluated, and expectations managed. Furthermore, there is an urgent need for clinical trials related to the human microbiome, standardizing methods and study designs and sharing and integrating datasets.



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**Political barriers.** The potential application of the microbiome challenges several national and international regulatory frameworks. In the field of health, the application of the microbiome via pre- or probiotics makes the traditional distinction between what is considered as food supplement and what as drugs blurry. In the current EU regulatory system, food is not recognised as a medicine and food operators or physicians are not allowed to claim it can treat diseases. Throughout Europe in the scientific policy area, different approaches are taken to clinical trials with pre- or probiotics depending on if scientific ethical committees handle the pre- or probiotics as a drug or food supplements. An agreement on how to assess pre- or probiotics and related health claims would be an important step forward. Furthermore, terminology in different regulations should be harmonised. Blaser et al. (2016) state that microbiome research and applications present unique challenges to the existing global regulatory systems because traditional risk structures — the risk-benefit analyses used for traditional biotechnology products such as protein therapeutics — do not apply and because microbial communities have the potential to evolve and interact with ecological networks that cross ecosystems and national borders.

*Enablers for breakthroughs*

**Technological/administrative enablers.** There is an increased recognition that interdisciplinary and multidisciplinary science is needed to move the field of microbiome forward – which should already start at the level of education. The OECD recommendation to train the scientists of tomorrow to combine more classic microbiology with technical skills like modelling, bioinformatics and engineering (OECD, 2017) has – to some extent – been taken up. The One Health concept – frequently used in the context of the battle against antimicrobial resistance - which highlight the interconnectedness of the human, animal and environment (land, water and sea) dimensions, can prove useful when designing targeted interventions. According to the WHO, One Health is an approach to designing and implementing programmes, policies, legislation and research in which multiple sectors communicate and work together to achieve better public health outcomes, and it is deemed particularly relevant for food safety, the control of zoonoses and combatting antibiotic resistance (WHO 2017). Fostering the dialogue and cooperation between academics and industry and across disciplines is another step forward, as can already be seen in recently funded EU projects, such as MicrobiomeSupport, SIMBA, CIRCLES, MASTER or HoloFood. To advance the microbiome research field and ensure high quality data output that results in applications which are beneficial for humans and the earth, it is essential for the research field to have basic foundations such as biobanks in place (Ryan et al, 2020). Current agricultural practices cannot cope with the increasing demand for food production. Innovative solutions and the application of new technologies are required to increase productivity and nutritional quality, while ensuring sustainability and environmentally friendly methods. Advancements in (food)



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biotechnology such as genetic engineering and sequencing, metabolomics, and proteomics combined with computation-based bioinformatics have allowed a big step forward, also in microbiome research and application. At the same time, innovation in medical research allows to track individual health indicators, enabling the examination of multiple human and environmental conditions that impact health. As the microbiome is strongly associated with NCDs, changing the gut microbiome of a person through new and cost-effective interventions in a way that would be optimal for health and reduce the associated health-care costs.

**Social enablers.** There is a need to improve key stakeholders and societal awareness on the importance and potential of the microbiome on the bioeconomy to increase acceptance of new microbiome applications and achieve involvement of citizens in targeted R&I actions. Integration of the microbiome as a subject since early educational levels is an essential step towards awareness building. The development of ethical guidelines and appropriate expectation management will support this effort as the microbiome understanding and related innovations are still in an early stage of development. Promoting active citizenship and technical education is a positive approach to increase awareness of customers to understand the interconnectedness between food, health and well-being, as well as the link between a sustainable food production, healthy environment and healthy diets. This leads to an increased pressure on food industry and agriculture to return to sustainable, resilient, environmentally friendly ways of production with an integrated system thinking approach. Ongoing citizen science initiatives have generated broad enthusiasm for the field of microbiome and are supportive towards enabling societal dialogue and communication. It is important to continue to bring together regulators, scientists, citizens and industry to enable further innovation, as stated by the OECD (2017). Education providers are increasingly focusing on closing the gap between scientific expertise in the agri-food sector and business skills in the market, so as to enable the practical application of research models and full absorption of disrupting ideas. Dynamic partnerships between scientists and industrial managers must be at the core of the efforts to catalyse food entrepreneurship as a channel to foster knowledge, innovation and greater societal engagement. Hackathons designed to help aspiring entrepreneurs find solutions to pressing challenges in the food system and meet like-minded peers are examples of new methods to promote and accelerate transfers between research, business and public authorities. New education methods allow agri-food start-ups to benefit from Business Accelerators and Innovation initiatives, through mentoring programmes held in partnership with established companies and matching exercises with businesses offering complementary services, as it is the case for the Microbiome-Push project funded by EIT Food (EIT Food, 2020). Targeted training on innovation capabilities can help small and medium enterprises to overcome existing skill gaps and thus unlock untapped market opportunities. Public–private



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partnerships (PPP) can also be an efficient means to advance scientific discoveries and boost innovations needed to bring microbiome applications to the market.

**Political enablers.** Through standardizing methods, study designs, sharing and integrating datasets a huge barrier could be overcome to foster transdisciplinary research across countries. It is necessary to institutionalise and apply a holistic approach to the food system per se. New or adapted regulations regarding registration enable the development and application of a new generation of microbiome products with the contribution of complex partner consortia rather than individual strains. By supporting international cooperation with multiple partners and stakeholders from different continents large infrastructures could be established enabling data management and bioinformatics as well as biobanking of food system and environmental microbiomes. Innovative solutions designed at the consumer and producer/processer/retailer levels require an enabling regulatory environment to produce large-scale positive effects. In regard to the application of the microbiome for health claims clarification, harmonisation and simplification could create a supportive environment to boost innovation (OECD, 2017).

**Economic/Financial enablers.** The major drivers for economic development of the plant microbiome sector are the global demographic development and the increasing yield loss due to abiotic stress (e.g. drought); the lack of chemistry and active ingredients with new modes of action; resistance development of pathogens and pests against chemical treatments; the pressure from society and regulators for reduced pesticides on food and the environment; the adoption of integrated pest management in Europe and other countries; as well as arising opportunities in the organic food sector (Sessitsch et al, 2018).

### Potential for sustainable social and economic breakthroughs

Microbiome research holds one of the keys to the intertwined goals of food system sustainability and healthy diets for all. It provides insights into how to produce more with less, reduce external input use, regenerate the fertility and health of our soils and water bodies, enhance food production and productivity, and help people prevent and treat various NCDs, as well as infections that have become resistant to antibiotics (FAO 2019). In this way, the microbiome research could be seen as a key component of possible breakthroughs to overcome several bottlenecks in today's EU food systems.

**The microbiome for the health of people and the environment**. The human microbiome has opened new frontiers in human medicine leading a pathway to treatment of various diseases (World Economic Forum, 2018). Like the human microbiome, the plant microbiome has opened new frontiers towards



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improving the health status of plant and soil (World Economic Forum, 2018). The environment of microorganisms in and around the roots, in the soil, on the leaves and within the plant itself has the potential to change modern agriculture and to reduce its negative impact on the environment. Advances in engineering of environmental microbiomes will replace toxic chemicals in agri-, horti-, and aquaculture in the future and stimulate a more sustainable use of environmental resources, as well as improve our food processing (Berg et al, 2020). The expected results are impressive: abundant, healthier crops that are more resistant to droughts, low nitrogen, high temperatures, salty soils and harmful insects (World Economic Forum, 2018). New approaches to food production start with agricultural production and include breeding; new techniques and applications; smart farming; phytoextraction; non-conventional production systems; reduction of impact of production; new value systems; new aquaculture systems. "Currently, there are great expectations in the application of microbial inoculants as promising results have been reported and so far, this approach has been hardly applied in crop production with the exception of $N_2$-fixing rhizobial inoculants for legume production. In many parts of the world, a number of start-up companies have emerged exploring microbial inoculants and sophisticated ways to make use of the plant beneficial activities of microorganisms" (Sessitsch et al, 2018, p 801).

### Impacts & Co-benefits

The potential impact of innovation in the field of the microbiome could deliver solutions across the whole food value chain and provide potential solutions to health, nutrition and economic problems. As outlined before microbiomes play an important role in climate change mitigation and find numerous potential applications in various sectors including human medicine. This way, the microbiome can be an **important player in the delivery of nutritious foods using environmentally sustainable production methods** creating health and economic and environmental benefits for farmers, businesses, and consumers.

All over the world scientists work on mapping and understanding the human microbiome, not only the gut microbiome, but also others like skin microbiome. Key questions are the composition of the microbiome, how the microbiome changes during the life course, how the microbiome influences health and the role of nutrition/ diet to change the microbiome. Although there are still many questions that need to be answered, it is clear that the microbiome communicates with the human body in various ways which supports the hypothesis that there is a causal relationship between the microbiome and health (Wade et al, 2020). It is clear that the microbiome plays an **important role in the digestion of food and in the immune system** (Wang et al, 2017). Besides the direct role of the



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microbiome in the defence system of the human body against pathogenic micro-organisms, there is also growing scientific evidence that in early life the microbiome contributes to teach the immune system to recognize real health threats (Wang et al, 2017; Zhuang et al, 2019). If validated, such finding could play a role in **reducing the incidence of various chronic diseases of the immune system associated with chronic inflammation of the organism**. Another hypothesis shared by an extensive amount of scientists is that the microbiome has a considerable role in **influencing the communication between the intestine and the human brain through the vagus nerve**, and a possible correlation between the microbiome and e.g. Autism, ADHD and dementia (Wang, et al, 2017; Svoboda, 2020). A better understanding of the causal link between diets, the gut microbiome and health is seen as a key element of the pathway towards personalised or precision nutrition. Such an understanding could furthermore lead towards health claims of pre- and probiotics and to work toward developing cost-effective dietary interventions to prevent diet related and behavioural disorders.

A recent World Economic Forum report estimates that **microbiome technologies could reduce GHG emissions by up to 30 megatons of $CO_2$ eq. and increase primary production by up to 250 million tons**. Microorganisms make a major contribution to carbon sequestration, particularly marine phytoplankton, which fixes as much net $CO_2$ as terrestrial plants. For this reason, environmental changes that affect marine microbial photosynthesis and subsequent storage of fixed carbon in deep waters are of major importance for the global carbon cycle. Terrestrial microorganisms also contribute substantially to GHG emissions via heterotrophic respiration ($CO_2$), methanogenesis ($CH_4$) and denitrification ($N_2O$) (Cavicchioli et al, 2019). T**he use of fertilizers could potentially be reduced** though consideration of plant and soil microbiomes, thus **resulting in reduced emissions of 15-30 megatons of $CO_2$-equivalent** (World Economic Forum, 2018). The application of microbials with plant growth-promoting or biocontrol activity could at least partly substitute agrochemicals, thereby reducing their release into soil and water and consequently the negative effects on the environment. **Some plant-associated microorganisms may also improve plant stress resilience**, e.g. against drought stress, and thereby increase yield stability. Apart from preventing contamination, **plant microbiota can also be employed for decontaminating polluted soils.** Soil and particularly plant microbiota may degrade organic pollutants (Afzal et al. 2014), whereas specialized plants via the help of microorganisms can phytoextract heavy metals from soils (Sessitsch et al. 2018). Current agricultural practices cannot cope with the increasing demand for food production. Innovative solutions are required to increase productivity and nutritional quality, while ensuring sustainability and environmentally friendly methods. In particular the microbiome provides potential for the following businesses:



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1. **New approaches to fertilizers:** to substitute non-organic fertilizers by bio-fertilizers, consisting of soil/plant bacteria, fungi, nematodes or protozoa, to convert unavailable plant nutrients to an available form for plant uptake.
2. **New approaches to pesticides:** chemical pesticides, of which many are considered hazardous for the environment or humans if used in large quantities, are replaced by new solutions that have no or less impact on natural environments, biodiversity and human health.
3. **New approaches to animal antibiotics:** the excessive use of antibiotics in livestock has resulted in the development of antibiotic resistance genes, which rapidly spread, and antibiotic-resistant bacteria, which are difficult to eliminate with the existing antibiotics. Novel research approaches seek alternatives, e.g. probiotics, to reduce antibiotic use while maintaining animal health.

Microbiome-based products for application in industrial aquaculture are today a reality, but the full potential is far from exploited. Despite decades of experience and an increasing number of microbial biotechnological products, there is a large innovation potential. From the discovery of new probiotic microorganisms of marine origin and large-scale cultivation strategies to steering the political, regulatory landscape and disseminating the use of probiotics to ensure future, sustainable technologies for high-quality protein production future research is needed to fully harness the benefits linked to the exploitation of the microbiome (Dittmann et al, 2017).

## Policy alignment

To harvest the enormous potential of solutions to various bottlenecks in of the todays food system that the microbiome offers us a systemic approach is needed with a focus on standardisation, collaboration and system thinking both within and between the scientific, industry and political/ regulatory domain. Microbiome science has so far not been fully integrated in policies and is currently perceived as a tool to solve societal issues rather than a policy goal on its own in contrast to for example to food waste reduction, eradication of NCDs or improving the quality of soil.

*Alignment with EU policy frameworks*

The microbiome is mentioned as a 'key area of research' in the **EU Farm to Fork Strategy** (2020). The interconnected **EU Bioeconomy Strategy** goes beyond by stating that "Recent key discoveries on microbiomes offer the potential to improve primary production and food systems, to protect our crops, to restore and better manage soils, to improve human and planetary health, and to spawn new sustainable solutions and economic opportunities for growing bioe-conomies, while preserving the intrinsic value and biodiversity of our ecosystems. Having recognised the key importance of



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microbiomes, the international community has called for a global initiative on microbiomes (Dubilier et al, 2015). The **International Bioeconomy Forum** established by the European Commission in 2017, together with several international partners, includes a working group in microbiomes, which plans further collaborative activities to harness the potential of microbiomes for the sustainable bioeconomy. In a recently published article, the **European Food Safety Authority** (EFSA) states: "There is the opportunity for EFSA to embark on a thematic area of microbiomes. Such an initiative would be aimed at addressing the following questions: How to evaluate the impact on microbiomes by various substances under EFSA assessment, and How to evaluate the impact of microbiomes on human, animal and plant health?" (EFSA, 2020). The EFSA has opened a grant to collaborate with EU Member States to build capacity to understand the role of the microbiome in relation to risk assessment challenges. EFSA furthermore puts emphasis on collaboration and mutual understanding between food and chemical assessment authorities.

*Alignment with international policy frameworks*

The relatively young and promising scientific discipline of the microbiome and its application needs policy coordination, programming and regulation at the international level. Rather than a societal challenge or a mission, it is a cross cutting area that could deliver solution towards various of these challenges. The OECD (2017) has mapped the scientific institutional landscape of public microbiome science and consulted experts on the way forward. The inventory showed large and continuous investments by public funders on the national and international level. However, there is a call for more multi-continental (especially Europe-USA/Canadian) collaboration and to connect different microbiome research fields (human, health, soil etc.) next to a continuation of the significant investments on the national and international level. Furthermore, the need for more harmonisation of the regulatory framework and standardization was stressed.

The microbiome could provide valuable contributions towards various **UN Sustainable Development Goals (SDGs)** amongst which but not limited to the following: antimicrobial resistance (SDG 3), climate change (SDG 13), biofuels (SDG 7) and food security (SDG 2). In a non-policy publication titled 'Microbiome, the missing link', **FAO** defines its role towards boosting the microbiome research field by investing in the science-policy interface to engage with multiple stakeholders and to bridge boundaries between science and policy (FAO, 2019). As food production is global and sourcing of microbiomes is an important aspect for novel innovations, there is a need for clear guidelines aimed at aligning microbiome sourcing with the **Nagoya Protocol on Biological Diversity** to allow fair and equitable sharing of benefits arising from the use of natural microbiome resources.



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**Early Vir**

EarlyVir was a European project (2016-2019) that gathered research groups from Denmark, Canada and France. Funded by JPI HDHL with contributions from the Horizon2020 programme, its outcome report is the largest single human virome study to date. The study focussed on bacteriophages (viruses attacking bacteria) and their role in shaping gut microbia in early life. EarlyVir aimed to investigate how the gut virome is influenced by diet, and to study its role in the origins of chronic childhood disorders.

For more information: https://www.healthydietforhealthylife.eu/index.php/projects/research-area-supported-project/report/213?s=1.

EARLYVIR

*Eradication of Non-Communicable Diseases (NCDs)*

## Assessment of added value

The majority of research projects funded in the field of (human) microbiome and health focus on bacteria. Viruses are however largely neglected and little is known about how they can shape the immune system and potentially protect the organism from chronic diseases. This project focused on the exploration of viruses in the intestine of healthy babies investigate on whether viruses can be part of a healthy gut flora. The project discovered over 8000 viruses previously unknown and ascertained that none of those were currently causing diseases in the subjects examined. By studying individuals as they grow from infants into adults, the project has gathered data useful to identify which of these viruses may morph from protecting children to developing chronic diseases in adults. The project result will thus be useful in the prevention and treatment of chronic diseases associated to the identified viruses.

## Assessment of challenges

The study focussed on understanding the composition of viruses in the human microbiome and its relation to health, as well as on the role of diet during pregnancy and early life on this composition. The research on viruses, even more than on bacteria, is relying on database-independent methods as well as innovation in technology which makes it difficult to build on previous research efforts or to compare findings. Furthermore, cohort studies are essential to advance in this area but the number of dedicated studies is still limited.

## Prospects for future development

Continuity to the research undertaken by the project is assured by the Danish Capital Region and the Novo Nordisk Foundation who have committed new funds to ensure the sustainibility of ongoing studies. So far, patents have been registered for the isolation of 6 viruses discovered in the framework of the EarlyVir project. More viruses are being isolated currently, with the ambition to isolate a large number of the 8000 identified viruses in order to use them in intervention studies to investigate their potential in protecting us from chronic disease.



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**MASTER**

The MASTER project is a Horizon2020 initiative (2018-2020) with the aim to take a global approach to the development of concrete microbiome products or processes with high commercial potential. will be achieved through mining microbiome data relating to the food chain, developing big data management tools to identify inter-relations between microbiomes across food chains, and generating applications which promote sustainability, circularity and contribute to waste management and climate change mitigation.

For more information: https://www.master-h2020.eu/theproject.html.

## MASTER

*Resource efficiency*

### Assessment of added value

The MASTER project addresses the significant challenge of microbiome applications for sustainable food systems by virtue of its relevance to microbiomes along the entire food chain, yielding outputs of commercial relevance across many products and processes areas. The project takes a global approach to the development of concrete microbiome products, foods/feeds, services or processes with high commercial potential. The idea is that if plants and intensively farmed animals need fewer resources – like food, antibiotics, chemical inputs – and there is less waste caused by disease and spoilage, it will decrease pressure on the environment. It is envisaged that this will benefit society through improving the quantity, quality and safety of food, across multiple food chains, including marine, plant, soil, rumen, meat, brewing, vegetable waste, and fermented foods.

### Assessment of challenges

Although micro-organisms dominate almost every ecological niche in our planet, it is only since the last 10-15 years that we have begun to gain insights into the composition and function of microbial communities (microbiomes). The insights gained in this and similar projects need to be further taken up by industry to bring new and cost-effective commercial applications to market. It is necessary to improve professional skills and competencies in the food sector and bioeconomy - another aim of the project - but this will take time probably beyond the timeline of the project.

### Prospects for development

A number of projects have been funded by the EU in the last few years with the aim to contribute to the design of novel functional foods on the basis of the study of available data on food/human gut microbiome relationship. The aim is to provide effective tools to test the potential of food ingredients to enhance healthy gut microbiota or to foster the science-industry cooperation, networking and exchange. Further funding and initiatives should encourage this pathway generating applications of microbiome which promote sustainability, circularity and contribute to waste management and climate change mitigation, improving the professional skills and support the creation of new jobs in the food sector and bioeconomy.



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## Conclusion

The microbial community of the microbiome forms a dynamic and interactive micro-ecosystem playing a key role in maintaining life on earth. **Improving microbiome functions will foster a natural resource with great potential to shift the balance of the 'nature – food systems – people' equation back into the healthy zone** (FAO, 2019). Microbiome research is seen as one of the keys to the closely entangled objectives of food system sustainability and healthy diets for all. Increasing evidence proves that microbiome functions can contribute to tackle global challenges as health and wellbeing, food and nutrition security, waste management or climate change adaption and mitigation.

Microbiome research provides **insights into how to produce more with less, reduce external input use, regenerate the fertility and health of our soils and water bodies, enhance food production and productivity, and help people prevent and treat various NCDs, as well as infections that have become resistant to antibiotics** (FAO 2019). New approaches to food production have potential for application of microbiome research results, starting with integration of microbiome-based concepts in primary production of plants and animals as a step towards more sustainable production of healthy food reducing the dependence on chemical input. There is also still a **need to understand the causal relationship between food, diet and functional changes in the intestinal microbiome and as a response on this physiological effect in the human body.**

Microbiome research cuts across traditional borders of scientific domains, technical disciplines and economic sectors and adds to the complexity of the policy, regulatory and institutional implications of these developments. It is of utter importance to develop standardised methods and study designs while sharing data sets and results. Furthermore, **R&I strategies addressing the whole system considering microbiomes in different environments in an inter- and transdisciplinary approach** should be developed. This involves strong international cooperation with multiple partners and stakeholders from different continents and a frame of large programmes for finding global solutions to ensure also the availability, quality and use of data.

**Research results have to be increasingly translated into development of products through improved dialogue and cooperation between academics, industry, public sector and civil society**. Success in understanding, predicting, and potentially manipulating microbiomes for societal benefit will require a broadly inter- and transdisciplinary approach; unintended consequences and risks must be thoroughly evaluated, and expectations managed.

To develop new microbiome applications that are desirable and acceptable to citizens, their **involvement in certain R&I actions** is crucial. There is a related need to improve stakeholder's and



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society's awareness on the potential relevance of microbiomes which should already start at the level of education.

Microbiomes play an important role in climate change mitigation and find numerous potential applications addressing various issues including human medicine, sustainable food systems or climate change. A systemic approach is needed with a focus on standardisation, collaboration and system thinking both within and between the scientific, industry and political/ regulatory domain. This way, the microbiome can become an important player in the delivery of nutritious foods through environmentally sustainable production methods while also creating health and economic and environmental benefits for farmers, businesses, and consumers.

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# Transition Towards Healthy, Sustainable and Personalised Nutrition

**Around the world, 50% of people have unhealthy diets and 60% of the people are overweight of which 25% obese (OECD, 2017). In the EU, over 950,000 deaths (one out of five) and over 16 million healthy life years were lost in 2017 to unhealthy diets. In parallel, the food demand of a growing population has an increased environmental burden. It is estimated that the food production accounts for between 19 and 29% of global greenhouse gas emissions (GHG), and around 70% of global freshwater use (Ritchie et al. 2020). In Europe, there is a need for drastic change and behavioural shifts towards healthy and environmentally sustainable diet patterns and lifestyles. To empower citizens to adhere to a long-lasting, healthy, pleasurable, nutritional and sustainable diet tailored to individual parameters, R&I policies should be deployed to better understand the drivers influencing consumer behaviour and generate smart products, services, digital innovation, new technologies and processes, new business models to reduce risk factors for NCDs, reduce malnutrition and micronutrient deficiencies.**



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## Societal, economic & environmental needs

According to the OECD, 50% of people have an unhealthy diet measured against the national guidelines and 40% do not consume a sufficient amount of fruit and vegetables (OECD, 2019). **Unhealthy diets are associated with an increased prevalence of obesity, cardiovascular diseases, diabetes, cancer**, and other lifestyle-related diseases. Within Europe, **lifestyle-related diseases are estimated to be responsible for 80% of the deaths** of which more than 25% are considered premature. Furthermore, **77% of the diseases are diet-related in Europe** (WHO, 2013). As defined by the WHO, the 'double burden of malnutrition' is the coexistence of undernutrition (stunting, wasting, vitamin and mineral deficiency) along with overweight, obesity or lifestyle-related diseases – within individuals, households and populations and across lifespan. According to the OECD, 60% of the population is overweight of which 25% is obese (OECD, 2017). At the same time, following recent reports from the WHO, nearly 800 million people remain chronically undernourished and 159 million children under five years of age are stunted. Approximately 50 million children under 5 years are wasted; over two billion people suffer from micronutrient deficiencies.

The societal and economic impact of the double burden of malnutrition is serious and lasting, with low and middle-income groups bearing the greatest burden. In Europe, despite an increase in the overall life standards, there is still food insecurity within the groups of society which depend on social support structures like food banks (Cooper et al., 2014; Neter et al., 2014). Indeed, **nearly 10% of the EU population is not able to afford a regular quality meal every second day** (European Commission FOOD 2030 Independent Expert Group, 2018). **The health gap between people from higher and lower socioeconomic classes is widenin**g. The first group often has the knowledge, motivation, and financial means to make healthier food choices. Individuals from the second group tend to have less-healthy dietary patterns and lifestyles, which negatively impacts their overall health status. **Less income, lower education, and instable jobs are factors contributing to the increased consumption of cheaper foods, often dense in fat and sugars. This leads to shorter lives, and fewer years experienced as healthy.** Public health guidelines towards healthy nutrition do not differentiate towards many different groups in society. To allow successful lifestyle changes, solutions should be easily integrated in people's lifestyle. A promising approach would be to deliver more **targeted nutrition advice taking into account social, psychological, and biomedical aspects of (groups) of individuals.** Research also indicates that physical and social environments have an impact on the dietary choices of consumers, e.g. the food available in canteens and at work, the influence of social media and marketing, etc. (Caswell et al 2013).



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In addition to the nutritional aspects of diets, the sustainability of current eating patterns of EU citizens is a growing concern. Indeed, there is an increasing awareness on the **important relationship between food and the environment**. Healthy and sustainable diets are not necessarily the same and consumers do not always know how to shift towards a more sustainable diet (OECD, 2017). However, availability of information for consumers is necessary to achieve the shift towards healthy and sustainable diets.

Indeed, modern chaotic lifestyles limit the time available to plan and prepare meals, let alone analyse various food products and carefully read food labels containing complex information on the health and environmental impacts of each product. Yet the growing population, the high consumption of animal proteins, as well as climate change and scarcity of natural resources put an enormous pressure on the sustainability of our food system. The food supply chain is challenged by climate change which impacts soils, water quality and agricultural yields (Leclère et al., 2013)**.** Conversely, greenhouse gas (GHG) emissions from agriculture are also one of the main contributors to climate change (Bindi and Olesen, 2011; Ciscar et al., 2010). Adjustments in the way food is produced and in the demands from both industries and consumers are required to future-proof our food system. **A change towards healthy and sustainable diets entails changes in food quantities and quality that require public support to facilitate structural adjustment of the agri-food sector** (FIT4FOO2030, 2020). A change in dietary behaviours should be achieved including a higher diversity of the diet, especially a higher consumption of non-meat proteins which have a less negative impact on the environment. Novel foods (such as alternative protein sources like algae and insects) the valorisation of traditional diets rich in plant-based proteins (e.g. pulses) could be part of the solution. A dietary shift would also mean that certain businesses in the agri-food chain will become smaller or even disappear in the long term. To ensure economic sustainability, it is important to identify new products, markets and business models to replace the incumbent, for instance by investing in novel non-meat based protein sources. The economic consequences of a dietary shift on the short and mid-term should be monitored and studied.

The **costs of overweight and obesity around the world are estimated in $2.0 trillion per year** – taking into account associated health care costs, loss of labour productivity and quality of life. According to the OECD (2019), **a 20% reduction of calorie content in energy dense foods could avoid 1.1 million cases of NCDs per year**, which would lead to $13.2 billion saved every year due to reduced health care cost. Over-weight reduces employment and workers' productivity. The impact can be quantified as equivalent to a reduction in the workforce of 54 million people per year across the 52 countries analysed, which include the OECD, EU28, G20, OECD accession and selected partner countries (OECD 2019). **Depression, musculoskeletal diseases, and unhealthy lifestyle factors like physical inactivity**



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**are also associated with reduced on-the-job productivity**. Evidence suggests that ill-health in the EU working population leads to substantial productivity losses, including absenteeism at 3% to 6% of working time, representing a yearly cost of about 2.5% of GDP, job loss (10% of the people who were previously employed left their job mainly for health reasons), premature retirement or premature mortality. Almost a quarter of people currently employed, suffer from some form of chronic disorder, many of which affected by obesity. Furthermore, the health status of the population is a factor in the resilience towards pandemics. As it is demonstrated by the current **Covid-19 health crisis, the virus puts people who are overweight or obese at a greater risk of serious illness or death** as compared to others (Centers for Disease Control and Prevention, 2020). Since the economic depression caused by the Covid-19 pandemic is worsening the position of vulnerable groups, there is a high likeliness that this will impact the overall health status of such social groups.

### R&I action required

To work towards a future proof food system, it is key to work towards a more integrated approach between the nutrition and health challenges as well as the agriculture and environmental challenges EU food systems face. An important base for the knowledge needs to work towards healthy, personalised nutrition is set in the strategic research agenda of the Joint Programming Initiative a Healthy Diet for a Healthy Life. The main research areas are mentioned in figure 1. A combination of research efforts should set out to investigate: (1) understanding, monitoring and influencing behaviour with (2) more insights in the underlying biomedical mechanisms of diet/ nutrition on human health and between individuals, and (3) how food processing could play a role in influencing these underlying mechanisms in a beneficial way while also taking into account sustainability aspects.

- **Citizens, diets, and behaviour**. R&I should look into interventions that target society as a whole as well as interventions that target specific groups of individuals. Food environments (e.g. the physical, social, economic, cultural, and political factors that impact the accessibility, availability, and adequacy of food within a community) are dynamic and more research is needed to understand the role of key drivers and their influence on consumption, and how to effectively influence the food environment to provide more sustainable and healthy options in both low- and middle-income countries (LMICs) and high-income countries (HICs) (HLPE, 2017). This should also include gathering a better understanding on the impacts of fiscal policies such as subsidies, taxes, and policies aimed at exposing the true cost of food. More R&I is needed to understand many factors influencing consumer behaviour in regard to decision making and purchasing. Attention should be geared towards food, environments



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consumer empowerment and the specificities of different geographical and cultural traditions (Spaargaren & Oosterveer, 2010; Verain et al., 2012; 2017; 2020; Brug et al., 2017). Especially more research is needed to better understand and target dietary behaviour of low-income social groups. Besides targeting the consumer, a better understanding of behavioural drivers of important actors on the production, processing, retail and service sectors of the food chain is also important.

- **Digital tools and labelling**. Front-of-the-package labels need to be improved to support consumers to make an informed and responsible choices. Information such as the link between healthy and safe food (e.g. expiration date) and aspects such as sustainability, attention to biodiversity and limitation of food waste could be included in a new labelling framework that would use R&I to understand its impacts and feasibility. Consistent, harmonised and understandable labelling on food packages is needed to allow consumers to compare food products and diets. This could drive consumers towards sustainable and healthy food choices. Further research is needed to enable dietary guidelines and labelling to link such aspects.

- **Food for health & sustainability.** Further R&I investments are needed to support innovation towards more environmentally friendly processes and technologies for food production and food processing, taking into account public health (European Commission, 2016). The importance of different tastes, affordability, nutritional value, personal preferences, cultural aspects and the health status of targeted groups are factors that should all be taken into account when designing new food products. Special attention should be paid to the needs of vulnerable groups such as children, the elderly, and people with a low-economic status. Sustainable production practices need to be closely connected with market opportunities. Farmers and fishers need an adequate remuneration for the production of safe and nutritious foods to be able to react to the changing consumer and societal demands (Jongeneel et al., 2020). Dedicated research projects should be developed to accelerate the investigation of nutraceuticals; the advent of multi-omics in combination with metabolomics and metagenomics; the study of new protein sources; improvements in food product formulas containing more vitamins and less saturated fats and sugar in the respect of high food safety and quality standards.



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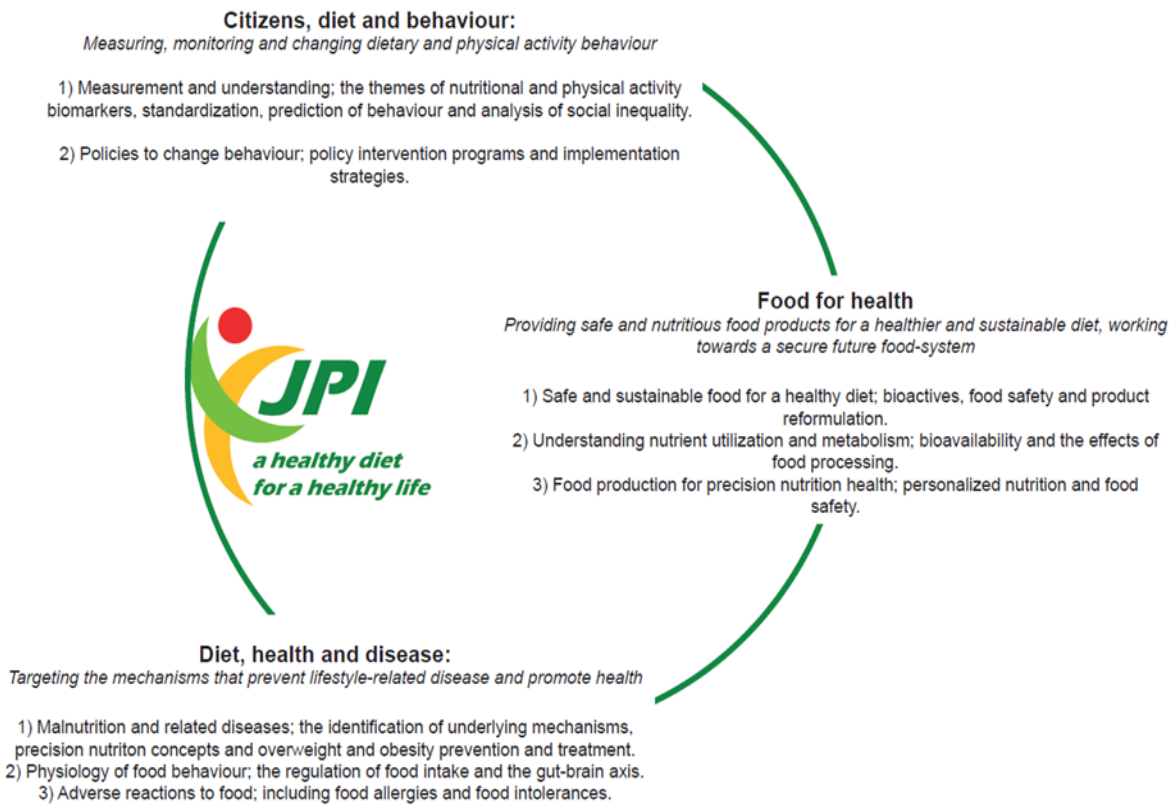


Figure 1: Overview of the JPI HDHL Strategic Research Agenda. Source: JPI HDHL (2019).

*Barriers to systemic change*

**Technological/Administrative barriers**. Research infrastructures are the backbone of a research domain and crucial for efficient investments. While the EU agricultural and health care sectors benefit from important R&Is initiatives deployed by Member States and private actors, the European Strategy Forum on Research Infrastructures (ESFRI) acknowledges the lack of an integrated research infrastructure to study the relationship between food, nutrition, and health. In addition, the development of digital tools and data connectivity is needed to combine insights on consumer behaviour, dietary intake, food environments. The lack of standardisation of data gathered on food intake represents an obstacle to fully reveal the relation between food, nutrition, and health. Indeed, this lack of standardisation makes it particularly challenging to integrate consumer and public health issues (CommBeBiz, 2018).

**Social barriers**. Focus on transparency of production processes and product formulation is important for consumers to make informed choices (FIT4FOOD2030, 2018b). Information provided to consumers should also include the environmental impact of production, processing, distribution and consumption. However, concerns exist regarding potential conflicts of interest in industry-sponsored



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research and industry influence on nutritional and public health agenda (FoodDrinkEurope, 2016; ALLEA, 2017). These concerns could be alleviated with the commitment to a clear and transparent code of conduct, including disclosures of potential conflicts of interests. In addition, co-creation and co-development of industry-sponsored projects could increase the reliability of research findings. To this extent, a multi-actor process establishing a structured collaboration of stakeholders from the private and public sectors should be established in the framework of research projects, as well as dedicated structures enabling such collaboration.

**Political barriers.** The food and drink industry is EU's biggest manufacturing sector in terms of jobs, value and assets in trade with non-EU countries. Research and Development (R&D) in food and drink industry has a critical role in understanding how marketing and front-of-packaging labelling influences consumers behaviour/choices. However, data show that EU food and drink industry R&D and innovation investments lag behind countries such as Japan and the USA. One potential explanation is that EU food and drink industry is largely composed of SMEs, with limited capacity for large R&I investments (Food Drink Europe, 2016). The current R&I policy landscape lacks a comprehensive food system approach and is scattered across different sectors and stakeholders, with weak Food Nutrition and Security (FNS) R&I policy coherence and coordination encompassing food security, public health, and environmental protection. There is a lack of integration and policy alignment, including of data and knowledge pertaining to the amount of R&I investments promoted by each Member State, which may lead to the sub-optimal use of resources. The actual impact of policies favouring R&I investments needs analysis especially in view of the low market uptake of R&I and the slow adoption of emerging technologies and new ways of doing science.

**Economic/Financial barriers**. An EU centralised data repository of Member States R&I funding initiatives is lacking along with better ways to measure FNS R&I output and impact. Funding institutions can take a role in developing programmes that connect several subsystems, such as policy, business economics, and biology and health, in order to bring about change in the entire EU food system. Current funding mechanisms do not support the long-term follow-up of cohorts. For instance, it is difficult to support studies that follow children through key transitory periods into adulthood or to examine the impact of public health nutrition interventions (European Commission, 2017).

*Enablers for transformation*

**Technological/administrative enablers**. Advancements in food biotechnology such as genetic engineering and sequencing have allowed a big step forward, in particular in the field of the microbiome research and application that could prove particularly fruitful to develop new healthy and



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sustainable food products. R&I in medical research allows to track individual health indicators, allowing the examination of multiple human and environmental conditions that impact the relation between diets and health. The development of new ingredients and new sources for nutrients, the reformulation of recipes in the sense of less energy-dense foods; mild processing treatments; and the development of a digitalised food industry are processes that are creating new opportunities for healthier and sustainable diets (ETP, 2016).

**Social enablers**. Research aimed at promoting healthy and sustainability consumption patterns should involve co-design, and co-implementation. Involving citizens and other stakeholders who are usually not engaged in food related R&I (such as retailers, caterers and restaurants) in the making of research priorities is likely to raise novel topics to the research agenda and can successfully disrupt established forms of expert-based development of research priorities. Research results are often lost in translation, there is a need for more exchange between scientists, policy makers, governmental institutes, and private sector dealing with behavioural change and better mechanisms for such interfaces (European Commission, 2017).

**Political enablers**. The recent EU policy developments included in the Farm to Fork Strategy (European Commission, 2020) shift the focus of food systems action from production/ supply to consumers/ demand. This change has the potential to boost innovation in the field of personalised nutrition and could contribute to promote healthy food consumption, as "citizens will only change consumption patterns when the food environment - described as the 'interface' between food systems and diets -- provides norms, opportunities and incentives to change behaviour and facilitates an equitable access to affordable, sustainable and healthy food and supporting infrastructures" (FIT4FOOD2030, 2020). Research is needed to evaluate the effect of policy interventions across the value chain (through regulations, taxes, subsidies, trade policies) on the shift towards healthier diets.

### Potential for sustainable social and economic breakthroughs

In Europe, aligning diets with dietary recommendations would significantly reduce the environmental footprint of food systems (European Commission, 2020). Currently, interventions to promote dietary change often fall short on producing the intended impact. One important insight that behavioural science has shown – though it is often neglected n practice – is to not solely focus on knowledge transfer and education. The fact that human behaviour is governed by a system of unintentional behaviours that respond to social inputs and to its social environment (e.g. family, friends and the food environment) should also be taken into account.



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**New tools to empower informed & engaged consumers.** Within society, consumers begin to understand that dietary choices have an impact on their personal health, as well as the environment. Consumers have an increasing interest in the origin of their food and how it was produced. Such an understanding and willingness to reflect upon dietary behaviour is an important base to move from a supply-oriented food chain towards a consumer value-oriented food system. New tools that easily assess consumers' dietary behaviour – such as bio-feedback and self-monitoring tools – are being developed to increase food systems transparency. New technologies support consumers getting more insight into their own dietary behaviour, for example apps keeping track of their own food intake and providing insights on their individual diets. These insights empower consumers to make decisions to improve their diet. Smart packaging techniques, as well as a clearer and more informative front-of-packaging labelling could increase consumer awareness, but they need to be supported by robust scientific evidence.

**Personalized nutrition**. Targeting the 'right' consumer at the 'right' time is crucial to achieve and sustain behavioural change. Research shows that chances of long-term dietary shifts are higher when citizens initiate changes in the occasion of particularly marking events (e.g. marriage, birth of first child, retirement, diagnosis of diet-related disease, etc.). Interventions could make use of these opportunities for change. Furthermore, in relation to behavioural changes towards more sustainable diets, consumers show different patterns of openness and resistance. Some are very reluctant to change their unhealthy dietary behaviours; others are willing to select healthier alternatives from the same kind of product range; and others are open to cut down on certain unhealthy products altogether (Verain et al., 2015; Verain et al., 2020). Health concerns, rather than environmental drivers, seems to be the main reasons for EU consumers engage in dietary shifts. Emphasizing the synergy between health and environmental sustainability seems a promising route in promoting healthy and sustainable products and diets (Verain et al., 2017). The market for personalised nutrition is expanding due to a general increase in consumer care for fitness including calorie intake, daily steps, etc. Advances in computer science, Artificial Intelligence, and new interdisciplinary science such as systems biology are enabling the development of new strategies in molecular biology. New technologies deriving from these scientific efforts allow to track down individual health indicators, allowing examination of multiple human and environmental conditions and their role towards health and disease. These developments can be further stimulated by creating a more supportive environment that fosters innovation, for example by promoting public-private partnerships and providing incentives for tech start-ups.



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## Impacts & Co-benefits

For EU citizens, the average intake of energy, red meat, sugars, salt, and fats continues to exceed WHO recommendations; while the consumption of whole-grain cereals, fruit and vegetables, legumes and nuts remains insufficient. **Moving to a more plant-based diet with less red and processed meat and with more fruits and vegetables will reduce not only risks of life-threatening diseases, but also the environmental impact of the food systems**. As part of the EU Green Deal (European Commission, 2019), the Farm to Fork strategy aims at future proofing the European food systems and ensure "that the food chain, covering food production, transport, distribution, marketing and consumption, has a neutral or positive environmental impact, preserving and restoring the land, freshwater and sea-based resources on which the food system depends; helping to mitigate climate change and adapting to its impacts; protecting land, soil, water, air, plant and animal health and welfare; and reversing the loss of biodiversity" (European Commission, 2020). Shifting citizens diets towards dietary guidelines will enable this transition towards carbon neutrality and low environmental impact of the food systems.

The OECD has found that **every dollar spent on actions aimed at preventing obesity generates up to a six-fold economic return in investment** (OECD, 2019b). A recent study indicates that a 20% reduction in the consumption of calorie content in energy-dense foods across 42 countries, including EU Member States, could lead to 1.1 million cases of non-communicable diseases avoided per year; 13.2 billion dollars saved every year due to reduced healthcare expenditure; 1.4 million additional full-time workers per year; and a 0.5% average increase in GDP (OECD, 2019). Furthermore, **shifting to healthier diets could also contribute to improve the cohesion in societies, as overweight and obesity are often associated with social inequalities**. OECD states that "children with a healthy weight are 13% more likely to report good school performances than children with obesity. In adulthood, individuals with at least one chronic disease associated with being overweight are 8% less likely to be employed the following year" (OECD, 2019). A better understanding of the mechanisms that prevent lifestyle-related diseases and promote health in combination with innovations in the food processing and novel foods are key elements towards personalised nutrition and precision nutrition. Such an understanding could assess the added value of pre- and probiotics and other potentially functional foods in improving health, thus leading to the development of cost-effective dietary interventions to prevent diet-related and behavioural disorders (Pandey et al 2015).



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## Policy alignment

*Alignment with EU policy frameworks*

There is no single EU food policy or strategy targeting sustainable and healthy food and nutrition for consumers. The current landscape consists of various regulations and policies attached to different governance areas. The most relevant food-related policies are the **Common Agricultural Policy (CAP)** and the **Common Fisheries Policy (CFP)** at EU level, while health and food safety legislation is developed mostly at Member State level (CommBeBiz, 2018). The CAP is shifting its focus from a "productivity first and sustainability as a way of reducing environmental impacts" approach to a policy that recognises the importance of protecting the environment and emphasizes "the provision of public goods, such as safe and healthy food, nutrient management, response to climate change, protection of the environment and its contribution to the circular economy" (FIT4FOOD2030, 2020).

A broader framework, such as that contained in the proposal for the CAP reform currently under negotiation (e.g., decreased use of pesticides, support for agro-biodiversity and responsible water use, etc.), would contribute to move away from the search for narrow technical solutions (EEA, 2019) towards a true reward for farmers for their contribution to public health and to the management and conservation of public goods, including carbon sequestration and the conservation of natural resources, landscapes and biodiversity.

A promising development towards a consumer-focused policy comes through the recent communication on the **European Green Deal** (European Commission, 2019). The Green Deal is an integral part of the von der Leyen Commission's strategy to achieve the United Nation 2030 Agenda Sustainable Development Goals. The European Green Deal sets out how to make Europe the first climate-neutral continent by 2050. **The Farm to Fork Strategy** is at the heart of the Green Deal and could be seen as a first step towards a common EU Food Policy. A necessary condition is the creation of an enabling regulatory context (e.g., labelling regulations, taxes, and subsidies) for food producers to support them to take concrete steps to reduce their impact on the environment while offering healthier options to consumers. The Farm to Fork Strategy includes both regulatory and non-regulatory initiatives and connects with both the CAP and CFP (European Commission, 2020). The Farm to Fork Strategy highlights amongst others R&I as an important instrument to enable and accelerate a food systems transition.

The transitions towards healthier lifestyles contributes to the first **FOOD 2030** policy framework priority focused on fostering R&I on nutrition for sustainable and healthy diets. The challenges under this priority include tackling malnutrition and obesity; improving nutrition for healthy ageing; sourcing



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protein alternatives to reduce meat consumption; developing new food authenticity and safety systems; reviving forgotten crops for nutrition and resilience; and supporting healthier and more sustainable diets in Africa. This priority aims at supporting the further development and implementation of EU food safety policies, the **EU Nutrition Policy Framework**, and relevant targets of the Sustainable Development Goals 2, 3, 8 and 10 (European Commission, 2016). Most Member States now have framework policies that aim to promote healthy diets, tackle the growing rates of obesity, and ensure nutrition and food security. Policy developments indicate that improvements to nutrition and diet require the engagement of many different government sectors and will need to involve action by both the public and private sector (European Commission, 2016).

FNS is at the heart of the bioeconomy, e.g. the production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products, and bioenergy. The **Updated EU Bioeconomy Strategy** proposes the bioeconomy as a viable alternative to depleting fossil fuels and as a sustainable natural alternative in the shift to a post-petroleum society. The strategy streamlines existing policy approaches in this area, and is structured around investments in research, innovation, and skills; reinforced policy interaction and stakeholder engagement; enhancement of markets and competitiveness (European Commission, 2018). It calls for new R&I and supports science and technological leadership to drive tangible improvements in Europe's social, economic, and environmental welfare. FNS is an integral part of the EU Bioeconomy strategy (European Commission, 2016).

**'Together for Health'** is a EU programme adopted in 2007, which focuses on smart investments in sustainable health systems, particularly through health-promotion programmes and health coverage as a way of reducing inequalities and tackling social exclusion. The **Third Health Programme** is the main instrument that the Commission uses to implement the **EU Health Strategy**. This programme sets co-funding actions to (1) promote health, prevent diseases and foster supportive environments for healthy lifestyles taking into account the 'health in all policies' principle, (2) protect Union citizens from serious cross-border health threats, (3) contribute to innovative, efficient and sustainable health systems, and (4) facilitate access to better and safer healthcare for Union citizens (European Commission, 2014).

*Alignment with international policy frameworks*

The **Sustainable Development Goals** (SDGs) were established by the United Nations in 2015 as the new global sustainable development agenda for 2030. 6 of the 17 Sustainable Development Goals are directly related to food, nutrition, diet and health: Goal 2: End Hunger; Goal 3: Ensure healthy lives;



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Goal 10: Reduce income inequality; Goal 12: Ensure sustainable consumption; Goal 14: Conserve and sustainable use our oceans and Goal 15 Protect, restore and promote sustainable use of terrestrial ecosystems. Though the importance of healthy nutrition can be seen as cross cutting, links towards many if not all sustainable development goals could be made. Although the SDGs and their many underlying targets are intertwined, the most relevant SDG targets related to dietary shifts and healthy lifestyles by 2030 can be summed up as follows:

- e**nsure access to safe, nutritious, and sufficient food all year round to all people**, in particular the poor and people in vulnerable situations, including infants.
- **end all forms of malnutrition**, including achieving, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons, by 2025.
- **ensure sustainable food production systems** and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.
- **correct and prevent trade restrictions and distortions in world agricultural markets**.
- adopt measures to ensure the proper functioning of food commodity markets and their derivatives and facilitate timely access to market information, including on food reserves, in order to help **limit extreme food price volatility**.
- implement the **10-Year Framework of Programmes on Sustainable Consumption and Production Patterns**, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries.
- achieve the sustainable management and **efficient use of natural resources**.
- **ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles** in harmony with nature.
- **support developing countries to strengthen their scientific and technological capacity** to move towards more sustainable patterns of consumption and production.

In regard of Goal 2 End Hunger, the UN acknowledges **the Committee on World Food Security** and the **Rome Declaration on Nutrition** and the **Framework for Action called 'Decade of Action on Nutrition'** which commits governments to exercise their primary role and responsibility for eradicating malnutrition. This includes addressing under- and overnutrition, nutrition lacking specific, essential micronutrients, and reducing the burden of lifestyle-related diseases across all age groups.



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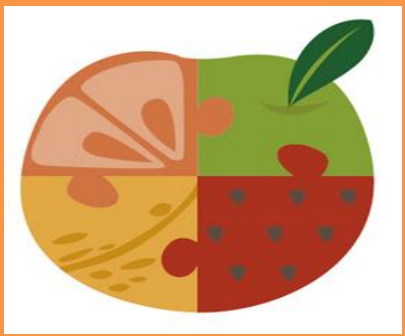
**Stance4Health**



The EU-funded Stance4Health (Smart Technologies for personalised Nutrition and Consumer Engagement) project (2018 – 2020) is developing a complete Smart Personalized Nutrition service based on the use of mobile technologies as well as tailored food production that will optimize the gut microbiota activity and long-term consumer engagement. The Smart Personalised Nutrition approach will be tailored to different target groups, from healthy children and adults to children with coeliac disease or food allergy, as well as overweight children and adults, which will have an impact on the development of NCDs such as obesity or type 2 diabetes.

For more information: https://www.stance4health.com/.

## STANCE4HEALTH

*Personalised Nutrition*

### Assessment of added value

The overall objective of Stance4Health is to facilitate the transition towards healthy diets of EU citizens through the adoption of better personalised nutrition based on the use of smart mobile technologies, as well as tailored food production. A set of new tools developed within the project will allow for the shift to healthy, pleasant and sustainable dietary patterns, while also encouraging citizen engagement for an improved understanding of what involves living a healthy lifestyle.

### Assessment of challenges

As the project is still ongoing, further work needs to provide strong scientific basis for the development of food databases that will be implemented and included in the mobile app developed as part of project activities. Data are not yet available to provide evidence that personalised nutrional recommendations actually produce a significant improvement of user lifestyles, and to what extent. Citizen engagement and large-scale validation of the results are essential to reach the objectives of the project and ensure EU citizens' commitment to switch to healthier and sustainable diets.

### Prospects for future development

The project will develop a wide array of tools and solutions: from the development of food databases used in a new mobile app to the design of customized foods for specific target groups. This will lead to mobile that will provide individualized counselling about what foods are more recommendable to consumers according to their overall needs/preferences (e.g., health status, gut microbiota composition, lifestyle, race, food preferences, and socio-economic status). All tools developed will be subject to a large-scale validation process. This will ensure that the tools developed will allow for an adoption of healthy, pleasant and sustainable dietary patterns.



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**Co-Create**

CO-CREATE is an EU funded project (2018 – 2023) that aims at preventing overweight and obesity in adolescents. The project will provide a model for how to involve young people and the range of relevant stakeholders by explicitly politicizing the issue of obesity, by providing specific obesity-related policy proposals, and by designing and testing advocacy tools and strategies for implementation and evaluation.

For more information: https://www.fhi.no/en/studies/co-create/.

## CO-CREATE

*Eradication of NCDs*

### Assessment of added value

CO-CREATE aims to reduce childhood obesity and its co-morbidities by working with adolescents, to create, inform and disseminate obesity-preventive evidence-based policies. The project applies a systems approach to provide a better understanding of how factors associated with obesity interact at various levels. The project focus on adolescence as the specific target group, a crucial age with increasing autonomy and the next generation of adults, parents and policymakers, and thus important agents for change. The project will contribute to the evidence and infrastructure for local and national policy changes to make healthy choices the easiest, most appealing, and preferred choices for adolescents across Europe, thus reducing the burden of obesity and related non-communicable diseases, both now and in the future.

### Assessment of challenges

Progress beyond the state of the art and expected potential impact need to be demonstrated. This includes the socio-economic impact and the wider societal implications of the project.

### Prospects for development

Applying large-scale datasets, policy monitoring tools, novel analytical approaches and youth involvement will provide new efficient strategies, tools and programmes for promoting sustainable and healthy dietary behaviours and lifestyles. The generated knowledge and innovative tools for assessing actual policy implementation, strategies for empowering adolescents; and strategies for identifying, implementing and monitoring relevant policy programmes are applicable to stakeholders involved in the European efforts to tackle childhood obesity.



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## Conclusion

"There are several levels which need to be taken into consideration to future-proof our food system. This includes inclusiveness to nourish 512 million persons and allow them to make the right choices. Education needs to facilitate persons with lower incomes to make informed choices and the system has to empower people by the use of new technologies (sensors, early warning systems). Furthermore, maintaining diversity is important. **The system has to provide room for breakthroughs allowing academic freedom**, long-term funding and allow people to think differently (science inside)" Louise Fresco, President of Wageningen University and Research (European Commission, 2018).

A **transition towards healthy, sustainable and personalised nutrition** is one of the leverage points towards a future proof food system and beyond that would contribute towards a significant reduction of costs associated with obesity and malnutrition. **Such a transition needs to happen across all groups within society to contribute towards mitigation of inequalities**. There are however significant barriers to achieve such goal. On the short-term, shifting to healthy and sustainable diets may have a negative impact on certain businesses in the food chain and on the competitiveness of the EU economy, therefore research into trade-offs and new business models is key. Furthermore, as **healthy diets and sustainable diets are not necessarily the same**, inter- and trans-disciplinary research is needed to look into dietary recommendations that take both into account as well as how to translate this into behavioural interventions. **The more vulnerable groups in society are often those associated with unhealthy diets**, which in turn have a negative impact on life expectations and professional development, thus increasing their vulnerability. R&I therefore need a **comprehensive approach to understand how to support all citizens to be able to adopt and afford healthy and sustainable diets**. Further knowledge on human health and the tools available to measure and to influence an adequate nutrition and healthy habits will enable the pathway towards personalized, or even precision, nutrition and medicine. This could help overcome the current barrier of represented by a lack of personalised nutritional recommendations, which reduces the impact of current efforts made to promote consumers' behavioural changes and healthy and sustainable choices. New policy and technological developments, as well as medical breakthroughs have brought the achievement of the foreseen goal a little closer – though significant research and investments into the relation between nutrition and health are still required to fully meet the objectives the EU has subscribed to.

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# Food Safety Systems of the Future

**Current mega-trends affecting food security such as climate change, global demographic increase of the population, rapid urbanization and agricultural pollution are also representing a threat to the safety of the EU food systems. Farmers, producers, processors, distributors, regulators, and policy makers worldwide will have to face a new set of demands to address those challenges in order to guarantee food safety and quality standards.**

**Scientific advances in rapid and more accurate food analysis, genome sequencing, big data management, and modelling can launch a new era of advanced risk assessment, risk management, traceability, and authenticity of foods. These technical solutions will mitigate some challenges but also create new ones, which will require further research, development, and innovation actions. The EU has the opportunity to become the global leader in setting standards for implementing rapid, robust, inexpensive, unambiguous and sustainable risk assessments, establishing a comprehensive and resilient food safety system for the future.**



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## Societal, economic & environmental needs

Mega-trends such as global demographic increase and simultaneous ageing population in highly industrialised countries; climate change; rapid urbanisation; globalisation of markets, soil degradation; depletion of oceans; increasing water scarcity; and loss of biodiversity - among others - are affecting food security. They also pose great **challenges to the respect of EU high standards on food safety for farmers, producers, processors, distributors, regulators, policy makers, suppliers and Hotel-Restaurant-Café (HoReCa) services**. To make sure the EU systems become sustainable and healthy while maintaining their safety standards, new and long-standing health, economic and environmental challenges need to be duly addressed (King et al., 2017).

Food safety is a **crucial component of the EU systems of tomorrow.** Society needs a reliable and robust food environment where food is not only available, affordable, nutritious, and environmentally sustainable, but also safe. Food safety is a **joint responsibility of all the actors across the food value chain** including public authorities, food and drink industries and consumers, and **collaboration among stakeholders is necessary at the local, national and EU level** in order to make food systems safe and trusted. The application of recent findings from food science in the field of additives, pesticides and antibiotics to food products through new technologic processes has eroded EU citizens' trust in the food systems, as **technological improvements are perceived to potentially compromise the health of consumers for the sake of economic efficiency** (EFSA, 2019). Research and Innovation (R&I) is needed to build consumer trust and communicate efficiently the commitment of all EU agri-food actors to the highest food safety standards. Some of the most pressing issues include achieving an effective, transparent communication on how risk analysis and risk management are carried out in EU food systems; a common understanding on how to address challenges such the shelf life of food products; food packaging; front-of-packaging labelling and the reduction of food waste, which all interlink with consumer behaviour; an agreed strategy on the reduction of animal testing for risk assessments without compromising the health of consumers; and a roadmap to achieve traceability and authenticity in (globalised) supply chains.

According to the World Health Organisation (WHO**), 600 million people fall ill and 420,000 die globally every year after eating contaminated food** (WHO, 2020). Thus, the economic impact of food-borne diseases and food spoilage in terms of productivity, medical expenses (Jaffee et al., 2019) and proliferation of food waste should not be underestimated. The current EU risk assessment and risk management model is seen as one of the most robust systems worldwide. However, **such a food safety system should be flexible and resilient** enough to accommodate the latest scientific developments. To this extent, food science and technology are continuously evolving and new



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methodologies in 'omic' sciences, digitalisation, food analysis, and mathematical modelling bring new tools that could be adapted, developed, and implemented to adjust and improve the EU food safety systems for the future (Eisenbrand, 2015).

The environmental sustainability of food systems is a fundamental component of food safety. Agricultural pollution, decreasing soil health, diffusion of transboundary pests and diseases, spread/increase of antibiotic resistance in animals, water resources depletion caused by over-consumption, resource scarcity, proliferation of food waste, and loss of biodiversity are increasingly concerning by-products of the agri-food systems that have a negative impact on food safety (EFSA, 2020). Several adaptive crops, processing practices and technologies are emerging that allow to tackle these challenges and increase the environmental sustainability of EU food systems, yet **a rigorous scientific base is needed to make sure that all innovations guarantee a real added value to the safety of food systems**. These factors must be considered together in the development of new tools and policies in the area of food safety, and more R&I is needed **to understand the possible trade-offs emerging from the application of different solutions**.

### R&I action required

The Outcome Report of FOOD 2030 Pathways Workshop 'Future Research & Innovation Needs in view of the transition to sustainable, healthy, safe and inclusive food systems', organised by the European Commission 4 March 2020, presents a list of number of R&I actions suggested by experts and stakeholders from different segments of the value chain (European Commission, 2020c). Some of the identified R&I actions are aimed to the area of food safety regulatory science, promoting the introduction of health and environmental sustainability parameters in the context of risk assessments; suggesting mechanisms to anticipate the emergence of risks from the development of new technologies, processes, and ingredients but also from better analytical tools; and prescribing the implementation of better systems to track authenticity and traceability of products, including through well-developed early warning systems.

- **Apply Responsible Research Innovation (RRI) to safety risk management**. An unifying principle across the actions suggested is the need to apply a Responsible Research Innovation (RRI) approach to food safety management, for instance by taking into account the perception of risk and the management of uncertainty of citizens with regard to food purchase and consumption choices (Renn, 2009). To this end, it is crucial to involve citizens in the development of risk management systems and elaborate transparent communication



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processes at the local, national and EU level to provide consumers with the necessary tools to make informed decisions, so-called 'Risk Governance' (Renn, 2009).

- **Develop new analytical tools for faster and more accurate analysis of foods and processes**. Technological developments are producing instruments that allow for more in-depth analyses of the potential impacts of chemical processes and food products on the human health and the environment. Parallelly, the European Food Safety Authority (EFSA) is working on horizontal topics relevant for risk assessment such as 'multiple exposure to chemicals', 'accumulative effects', 'interpretation of epidemiological studies', or 'reduction of animal testing' to produce new evidence grounded on a solid scientific base and with more attention to animal welfare and the sustainability of EU systems (EFSA, 2019).

Based on the analysis carried out, there seems to be a high level of alignment between the R&I actions proposed in the area of food safety in the European Commission Workshop on Pathway areas; EFSA priorities; and the possible R&I breakthroughs identified by the FIT4FOOD2030 project.

*Barriers to systemic change*

Food safety is an area of research in continuous development, and a major challenge is the need for actors in the public (e.g. policy makers, researchers), and private sector (e.g. laboratories, companies, technology suppliers) to **consistently regulate/comply and implement technological innovations**. Despite the impressive progress made in recent year by food science and technology that have enabled the EU safety systems and regulations to be one of the reliable in the world, **further research will be needed in the areas of testing, implementation and scaling up of new technologic discoveries**.

A remarkable social barrier to the objective to improve EU food safety standards is the **decreasing trust of consumers in the risk assessment system** in place. An example comes from the European Citizens' Initiative on glyphosate lodged in 2017 (Stop glyphosate, 2017), which gathered more than one million citizen signature to oppose the renewal of the approval for ten years (2017-2027) to use the active principle of glyphosate to produce fertilisers. The citizen initiative was sparkled by the patent divergence between the risk assessments produced by, on the one side, the International Agency for Research on Cancer (IARC) – a body of the World Health Organisation – which found that glyphosate is probably cancerogenic for humans and, on the other side, that of the European Food Safety Authority (EFSA) and the European Chemicals Agency (ECA), which approved the renewal of the authorisation (European Parliamentary Research Service, 2018). **More transparency is needed** on the criteria chosen for the risk assessments produced by the EU, as well as a better communication of



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the role of the stakeholders involved in the process, in particularly of industry actors, so as to avert any potential doubt of existing conflicts of interest (Bozzini, 2017).

**Decreasing levels of R&I investments** in EU Member States constitute another important barrier, linked to the perception that high EU standards guarantee a sufficient protection without the need for an injection of considerable resource. However, as food safety is a domain requiring constant improvements and update, awareness should be raised on the need to provide continuous investments to sustain the EU R&I efforts.

An enabling regulatory environment is key to make sure that food safety standards are harmonised and implemented consistently in the framework of globalised food chains. However, **gaps and discrepancies still exist with regard to regulatory frameworks between different EU Member States, and between the EU and global trade partners.** Such a lack of harmonisation represents a threat to the competitiveness of EU food products and risks to undermine the remarkable efforts made so far to guarantee safe, healthy and sustainable food products to all EU consumers.

The EU's interest in striking **trade deals with international partners** may also play out as a potential obstacle to the strengthening of EU safety systems. As the EU has some of the more advanced regulations on food safety in the world, some concerns have arisen that, in the course of the negotiations with the US over a new transatlantic trade deal, it may be persuaded to allow more US-grown genetically modified crops into Europe, to open up its market to chlorinated chicken, and to weaken regulation in order to allow pesticide residues in agricultural goods exported from the US (European Parliament, 2020). On the very opposite side of the spectrum, voices from the developing world have argued that the high stringency of EU safety standards prevent new entry into the EU market, drives less productive firms away, and discourages existing exporters from Africa and elsewhere from expanding their market base (Kareem et al., 2015). Therefore, in view of the new foreseen Partnership with Africa, the EU may be tempted to lower its standards in order to allow access to its market to African exports in exchange for a preferential trade deal (DW, 2018).

*Enablers for transformation*

An RRI approach is needed to enable the shaping EU food safety systems of the future including through coordinated action in the domains of technological innovation, policy development, civil society participation, as well as public and private investment. Many technologies are under development but **require appropriate applications and adaptive regulatory frameworks**, as in the case of the ongoing process of substitution of medical testing with other reliable testing methods. A



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revolution of **analytical tools providing rapid and more accurate, but also less expensive assessments** is undergoing and has the potential to create the context for a qualitative shift in food analysis.

Opportunities also lie in **increased citizen and consumer engagement**, through transparent communication and dialogue on the importance of food safety and the transformative potential it has to improve current food systems in the sense of health and sustainability.

The current policy developments at the European level reflect an **increasing level of political priority attributed to the issue of food safety**. Therefore, the current context offers promising prospects for R&I actions aimed at improving the EU food safety systems of tomorrow. While public initiative is fundamental to give impulse to the uptake of innovations in food safety, **private funding will also be needed** for the development and implementation of the incoming research findings and services on the market. The promotion and **diffusion of Public-Private Partnerships** aimed at multi-stakeholders' collaboration in this area can act as enabler for a quicker uptake of innovations.

### Potential for sustainable social and economic breakthroughs

Through previous project activities, the FIT4FOOD2030 project identified several potential R&I breakthrough areas that are discussed in Deliverable 4.1 'Report on inventory of R&I breakthroughs' (FIT4FOOD2030, 2018) and D4.4 'Report on instruments for the identification of R&I breakthroughs for the future' (FIT4FOOD2030, 2020). Other proposed breakthrough areas related to food safety include 'Logistics, new systems', 'A novel approach to biotechnology', 'Information and Communication Technologies (ICT) applied to food systems', 'Food industry 4.0 – Novel and efficient food processing', and 'Sustainable packaging'. Other domains related to this topic have a more pronounced focus on the environmental and social dimension of food safety, including 'The new approach of primary food production and distribution', and 'An engaged and healthy consumer' with foresees crucial actions in the field of education and awareness building to empower consumers to make informed decisions. It is reasonable to think that new technological innovations potentially implemented in the food systems – included novel food processing and novel foods – will require a thorough research related to essential food safety aspects and respect of requirements.

*Social breakthroughs*

**Active citizenship and consumer engagement**. EU public authorities and agri-food private actors have an opportunity to build consumer trust by investing in highlighting the role of citizens in ensuring food safety in EU food systems. Challenges related to microbiological and chemical hazard; antimicrobial resistance and allergies; new consumer trends associated with unhealthy and unsustainable diets; and



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the negative effects of climate changes call for proactive adaptation measures, including stepping up the use of digital tools to improve the traceability of items in the food systems, and a better use of Big Data (Aung and Chang, 2014). Particularly relevant research areas are identified in the report by the Science Advice for Policy by European Academies (SAPEA), which acknowledges: "Consumers being particularly resistant towards hi-tech innovations, such as genetically modified foods, animal cloning, nutrigenomics, food irradiation, nanotechnology and synthetic biology, and to some extent functional foods, novel food processes and any perception of unnaturalness" (SAPEA, 2020). A fundamental step is to empower citizens to form informed opinions about the risks associated with a given food product, chemical additives, or plant protection products by enhancing the transparency of the EU risk assessment procedures. Although the current process is extensive and involves the mandatory participation of stakeholders from all across the food chain in a dual approval procedure of any new substance at the EU and Member States level, citizens still perceive the process as potentially biased due to an alleged risk of conflict of interests between public institutions and the involvement of chemical substance manufacturers involved in the process. For instance, it is common that risk assessors from EFSA and ECHA base part of their assessment on the dangers related to new chemical active substances on unpublished papers from industry actors, in line with the idea that the manufacturer has to prove that its active substance meets the cut-off criteria (European Parliamentary Research Service, 2017). However, as the principles regulating risk assessment procedures are often not clear to the majority of EU citizens, perceived lack of transparency can often lead public opinion to firmly oppose decisions perceived as opaque, even when these are based on large scientific evidence. New transdisciplinary approaches such as Risk Governance (Renn, 2009), including a wide participation of agri-food actors across the value chain, as well as investments in digital literacy for workers and consumers, will also be needed to ensure a full exploitation of the potential of the digital revolution with respect to the improvement of EU food safety systems.

*Economic breakthroughs*

**Public-Private Partnerships (PPPs) for Safe Food and Drinks**. R&I action is needed towards the establishment of a pre-competitive framework allowing collaboration, experimentation and knowledge exchanges between different stakeholders. Collaboration formats such as PPPs, international partnerships, Living Labs, pilot projects working on prototype innovations, and joint implementation of experimental activities designed by SMEs and start-ups should be investigated as a promising way for public authorities to pursue public objectives while exploiting the full potential of essential agri-food actors. Some research domains where PPPs could prove particularly fruitful include genome sequencing applications in the food systems – which allows a better surveillance and monitoring of pathogens; the metagenomics, transcriptomics and proteomics – which can provide



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further information on pathogens and foodborne diseases; food analysis – mainly in the area of chromatography and mass spectroscopy that allows for rapid, cheaper and more accurate characterisation of chemicals in complex matrices; hazard characterisation through biomarkers and better mathematical modelling of obtained data; novel technologies in processing – which can provide safe foods whilst maintaining the highest sensorial and nutritional quality; food packaging – based on smart and bio-degradable solutions enhancing the life of food products.

### Impacts & Co-benefits

Establishing EU food systems that guarantee the good health of EU citizens, high life expectancy a mitigation of the impacts of climate change has the potential to **allow the EU to accelerate its path towards safe, healthy and sustainable food systems**. Effective food control systems are essential to protect the health of EU consumers. They are also vital in enabling Member States to **assure safety and quality of food products for international trade and to verify that imported food products meet national requirements**. R&I actions aimed at improving food safety will also have positive spill-overs on the environmental sustainability of production and consumption; the fight against food fraud; joint efforts towards improvements in the quality of food products, respect of different tastes and individual tastes; the fight against food waste proliferation; and the promotion of a circular business model.

The involvement of several actors with different interests across the food value chain – which is required to design impactful food safety measures and regulations – will have a **positive impact on consumer trust and will have positive consequences on the interaction of these actors in other domains of the food chain**, including the joint efforts towards designing health and personalised nutrition advices; the shift towards plant-based, sustainable diets; the uptake of microbiome science; and the design of urban food systems well-equipped to serve EU citizens.

While it is difficult to predict the exact impact of R&I actions in the food systems area in the absence of dedicated risk assessment and cost-benefit analyses, some innovative techniques such as better mathematical/predicting modelling, management of Big Data; a better monitoring system of the production, processing, delivery and consumption processes show potential for good returns in investments. Positive social impacts include  a decreased of food-borne disease; a decrease in food waste production based on the reduction of detrimental factors such as microbial spoilage, mould development, oxidation of fats, pests; an improved traceability of products; minimisation of the use of animal testing due to the use of alternative predictive methods; more cost-effective strategies to



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guarantee the respect of food safety standard; an increase of overall consumer trust in the EU food safety systems.

## Policy alignment

*Alignment with EU policy frameworks*

Protection of food safety in the EU is articulated through a specific focus on the impact of food on human health; the animal welfare; and protection of green resources, with a special focus on setting international phytosanitary and quality standards for plants and plant products. Dating from 2003, EU cross-cutting food safety regulations centre on the concept of traceability both of inputs (e.g. animal feed) and of outputs (e.g. primary production, processing, storage, transport and retail sale). **The EU has agreed standards to ensure food hygiene, animal health and welfare, and plant health and to control contamination from external substances, such as pesticides.** Rigorous checks are carried out at every stage, and imports (e.g. meat) from outside the EU are required to meet the same standards and go through the same checks as food produced within the EU.

The **FOOD2030 policy framework** directly addresses the issue of food safety, in particular through its first priority 'Nutrition for sustainable and healthy diets'. Food security and the attention to the protection of human health are heavily interlinked, establishing a close relation between the availability and affordability of nutritious food – e.g. key components of food security – with the protection of hygiene and purity standards during production, handling and distribution processes. The EU communication on the **European Green Deal** (European Commission, 2019) and **Farm to Fork strategy** include a special focus the environmental and social sustainability parameters which will define EU future-proof food systems (European Commission, 2020). The Farm to fork strategy, in particular, makes the establishing of safe, healthy and environmental food systems conditional to the design and implementation of R&I actions advances in food safety methodologies and policies. Among the latest developments in EU legislation, the **upcoming EU Chemical Strategy for Sustainability**, which is expected to be published in Autumn 2020 (European Commission, 2020) will represent a relevant step towards the establishment of harmonised risk assessment methodologies for the control of chemical additives to food products.

*Alignment with international policy frameworks*

Working to improve EU food systems resonate with existing commitments to several international frameworks. Among these, one is the **UN Sustainable Development Agenda**, which in SGDS 3, 4, 9, and 12 established targets related to the protection of public health, quality education, innovation in



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industry and infrastructure, and responsible consumption and production, which all closely relate to the issue of food safety. Another reference policy framework is the FAO and WHO-sponsored **Codex Alimentarius** (FAO and WHO, 2020). The Codex provides international food standards, guidelines, and codes of practice to be applied to international trade, and constitutes the basis for food safety standards on the international level.



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**SafeConsumE**

SafeConsumE is an interdisciplinary project (2017-22) funded under the European Commission Horizon 2020 R&I programme, with the aim to provide science-based and sustainable strategies for food authorities, market actors and the research community to help consumers mitigate risk, thus reducing the health burden from food-borne illness in Europe. The ambition of SafeConsume is to initiate a new and broader approach in future research, innovation, education and food safety policy, widening the space of opportunities for improving food safety.

For more information: https://safeconsume.eu/about/the-project.

## SAFECONSUME

*Improved consumer behaviour*

### Assessment of added value

In the framework of project activities, tools are to be developed for consumers to mitigate safety risks of handling, storing and consuming food products, including sensors, apps, innovative hygiene concepts, kitchen utensils. Furthermore, SafeConsumE develops communication strategies that effectively stimulate the adoption and market uptake of safer practices and tools/technologies, as well as education programmes increasing the skills and knowledge in food handling. Finally, SafeConsumE also stimulates dynamic, sustainable and inclusive policy models to support national and EU level initiatives. SafeConsumE is a particularly useful initiative due to its comprehensive outlook on the issue of food safety, which includes both a focus on consumer behaviour and an attention for the creation of regulatory frameworks that enable safe practices while respecting consumer individual choices.

### Assessment of challenges

SafeConsumE faces a number of systemic challenges, mainly based on the articulated web of EU and Member States regulations on food safety, that potentially hinder the chances to communicate clear, EU-wide messages on 'safe practices' and 'optimum consumer behaviour' to citizens. As legislation on front-of-packaging labelling; amount of nutrients and addictives per product; types of food products allowed or banned in supermarkets, etc. differs among Member States, SafeConsumE needs to carefully craft its communication efforts so that its messages are at the same time general enough to be useful for a large section of EU consumers, and specific enough to help in actually mitigating safety risks.

### Prospects for future development

SafeConsumE has adopted a promising approach that includes the development of a Risk Behavior Map and its translation into an Opportunity Map for different actors. This way, to each consumer behaviour currently contributing to food safety issues is associated an incentive for one or more actors in the agri-food chain to act to change it. This approach can be developed in the future investing in the development of new tools/technologies/products associated with the opportunities identified.



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**SensoGenic**

SensoGenic is a portable biosensor developed by an Israeli tech start-up with the support of a European Horizon2020 grant. The sensor reports back to consumers' portable device if any allergens are detected in a food product, thus empowering people suffering from allergy to safely eat anywhere and avoid reactions. SensoGenic's device uses patented nanotechnology to detect specific allergy-causing proteins at a level of 10 ppm (parts per million), considered the lowest adverse reaction level. Users get results on their smartphone via a dedicated app.

For more information: http://www.sensogenic.com/.

## SENSOGENIC

*New tools for risk assessment*

### Assessment of added value

The research for rapid, reliable, and affordable methods for detecting allergens has been long under development, however SensoGenic seems to have ground-breaking innovative potential for a number of reasons: 1) it is the only such device capable of detecting and identifying all the common allergens — milk, eggs, peanuts, tree nuts, wheat, soy, fish and shellfish — from a single food sample placed on a disposable pad and analyzed by the battery-operated biosensor unit; 2) its portability makes it very practical in all situations; 3) Sensogenic's business model foresees an affordable price for both the biosensor unit and the disposable testing pads.

### Assessment of challenges

SensoGenic can be more affordable and multipurpose as compared to other sensors on the market because it uses a unique formulation based on cellulose, an abundant and cheap natural polymer, to attract all allergenic proteins from the food sample. However, the full effectiveness of this method to sample and analyse food risks is yet to be validated, as the biosensor is still in beta testing. Reliability and durability of the biosensor will be essential features determining SensoGenic's potential success or failure to get established on the market.

### Prospects for development

Planned to be sold online and later in restaurant chains through global distribution partners, the biosensor unit (which does not require regulatory approval) will be priced at around $199 and the disposable testing pads at 95 cents apiece, in contrast to other biosensors on the market using $4 disposable capsules to detect the specific allergen with antibody-based chemistry. This could prove significant in the $27 billion food-allergen market.



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## Conclusion

Food safety and food security are interrelated. EU food safety systems seek to **strike a balance between guaranteeing a high level of public health, environmental and consumer protection, while at the same time providing a stable regulatory environment for actors in the food chain.** High food safety standards are important for maintaining consumer confidence in both EU domestic markets and export markets. High food safety, environmental and animal welfare standards thus allow Europe to compete on world markets where it is difficult to compete on price alone. For these reasons, **the EU seeks international recognition as the global leader in setting the standards for food safety.**

Today, EU citizens enjoy one of the highest levels of food safety in the world, but the past and recent crises linked to bovine spongiform encephalopathy (BSE), the Enterohaemorrhagic E. coli (EHEC) or the horsemeat scandal highlight **vulnerabilities that can compromise these high standards**. Also, new food safety challenges can emerge from the increasing complexity of the food chain, with negative impacts on the environment such as increased agricultural pollution and resource scarcity. These risk factors are known to **raise the likelihood of diet-related Non-Communicable Diseases (NCDs)** such as cardiovascular diseases, diabetes and cancer, costing the EU an estimated 196, 100 and 126 billion euros per year, respectively and accounting for 77% of the disease burden (EFSA, 2019). According to the WHO, 600 million people fall ill and 420,000 die globally every year after eating contaminated food (WHO, 2020). Resulting diminished resources within families, prolonged disability, reduced productivity and capital formation have negative implications for quality of life and the economy.

The current EU food systems are under threat and require the participation of all stakeholders (farmers, producers, processors, distributors, regulators, policy makers and consumers/citizens) to provide long-term sustainable solutions. Enabling technological advances bearing potential to support EU efforts include genome sequencing; food 'omic' technologies; new methods for food analysis; new tools for risk assessment; big data management; new traceability tools; methodologies for proving food authenticity and battling fraud; new approaches and tools for (predictive) risk management. However, **technological development alone will not suffice to ensure all EU citizens have access to safe food and EU food systems are perceived as reliable and trusted, allowing for co-benefits across the value chain.** Innovations in governance and regulatory practices will be needed to make sure that the latest findings from food science and technology are incorporated into novel foods and processes in full respect of human health, animal welfare and with minimal impact on the environment. Awareness building activities, education and training as well as public engagement will be needed to empower consumers, so as to be able to make informed decisions, handle and consume food products



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safely, and feel that they are central actors to the EU food systems. **Continued and sustained R&I investments from public and private actors are important to constantly adapt to the new safety challenges including the raise of new resistant pathogens and the negative impacts of climate change**. Public-Private Partnerships are promising formats for collaboration of different stakeholders bringing a diverse expertise to the solution of common problems.

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# Food Systems Africa

**Africa has the youngest and fastest growing population in the world, projected to reach 2.5 billion in 2050. In 2018, the continent was hosting 260 million undernourished people, a number projected to further increase due to the effects of climate change and the COVID-19 pandemic. The need to generate sufficient food, income and jobs to sustain Africa's people, while also avoiding putting further strain on the planet's over-stressed ecosystems, requires a radical transformation representing one of the biggest challenges of our time.**

**Although African countries are very diverse, some common issues include the sustainable transition towards new models of circular food economy, increased food safety, the promotion of healthy diets for all, the reduction of food loss and waste, and a more effective technology transfer to smallholder farmers. The EU-Africa partnership will be instrumental to face the challenges and seize the opportunities connected to the green transition, ensuring a shared commitment to food and nutrition security, natural resource stewardship, job creation and sustainable agri-food industry and markets.**



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## Societal, economic & environmental needs

The food and nutrition challenges and potential opportunities vary considerably across the African continent, as the 55 countries differ significantly in terms of economic and social development, culture, models of political governance, availability of natural resources, demography, ethnic cleavages, (colonial) history and religious beliefs. Overall, **hunger and malnutrition are still present on the continent** and are extreme constraints to the continent's prospects for development. The effects of the lockdown measures put in place to curb the Covid-19 pandemic, which has been producing disruptions to African food supply chains since March 2020, have the potential to dramatically increase the number of malnourished Africans if effective and sustainable measures are not implemented resolutely.

Africa faces a unique socio-demographic situation. Its **population is projected to increase to 2.5 billion by 2050,** while 805 million new people will join the labour market (UN, 2018). In spite of the rapid changes due to the urbanisation mega-trend, **the majority of the population will remain rural well into the 2040s**, with agriculture continuing to be the main provider of jobs. However, as African food workers' incomes remain generally low and **wealth is poorly distributed** across society, hunger is on the rise, as people experiencing severe food insecurity have passed from 18.1% of Africa's population in 2014 to 21.1% in 2018 (FAO, 2018). The scale of the societal challenges linked to poverty, malnutrition and diseases facing Africa is impressive: every year 60 million children are stunted, 375 million people face severe food insecurity, 100 million youth are not in school, and hospitals lack staff and equipment to treat malnutrition-related illnesses (Task Force on Rural Africa, 2020). Extreme ongoing climatic events add a further burden on Africa's development: severe flooding and extraordinary locust infestations in East Africa, together with the consequences of an extremely dry 2019 rain season in 14 countries across Eastern and Southern Africa, have pushed more than 45 million people on the brink of food emergencies (The New Humanitarian, 2019). **Political instability and violent conflicts** persisting in several areas – the Horn and Great Lakes regions, Cameroon, Chad and Nigeria are described as experiencing a 'crisis situation' (FAO, IFAD, UNICEF, WFP & WHO, 2020 p. 19) – both shape and add to the fragility of Africa's food systems by disrupting all the aspects of the value chain from input supply to consumption.

Due to the severe limitations linked to the lockdown measures prompted by the **Covid-19 pandemic**, **another 43 million of severely undernourished people in West Africa alone will need food assistance** (UN News Agency, 2020). Jobs and income related to the food import-export business, such as the horticulture industry in Kenya or the cocoa trade in Ghana and Ivory Coast, have been severely affected, leading to **lay-offs, general income reduction and cut spending on food and nutrition**



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(Hirvonen et al., 2020). Border closures and food export bans imposed by third countries at the beginning of the crisis also meant that some African countries were not able to import essential staples such as wheat and rice from Russia and Vietnam respectively, with Kenya reporting a 15% decrease in imported calories for instance (IFPRI, 2020). The crisis has an **important gender dimension,** as African women are invested with heavy responsibilities in both the agri-food chains and in children and home caretaking (Decker et al., 2020). While the unsustainability of Africa's food systems was already evident before Covid-19 hit – as the dramatic stagnation of progress towards the achievement of food-related SDGs confirms (SDG Centre for Africa, 2020) - **the pandemic has also showed the extreme volatility of food systems**, with millions of children only one school meal away from hunger; several countries at risk of food shortages; small and middle-size farms suffering from important workforce reductions; and poor households slipping into food insecurity due to missed wage income (IPES-Food, 2020).

While some of the Northern African countries and South Africa show development indicators comparable to those of medium industrialised countries in other parts of the world, **Sub-Saharan Africa is home to 32 nations among the poorest on the globe** (UN, 2018), with the continent's overall economic outlook expected to worsen due to the severe consequences of the Covid-19 pandemic. Agriculture employs the majority of Africa's labour force, with a vast percentage working in the informal economy. Many millions are subject to under-employment due to the seasonality of the harvesting process and low wages linked to work in family farms or small household enterprises. Although Africa as a whole has experienced robust economic growth since 2000, the rate has been very uneven across the continent, with Sub-Saharan Africa experiencing economic recession due to spikes in commodity prices between 2012 and 2016 (AUC and OECD, 2019). As a consequence of Africa's multi-speed economic development, as well as of the broad rural-to-urban migration trend, **millions of Africans live in African countries others than their countries of nationality** (UN, 2018). Rural migration is therefore a key factor in Africa's economic structure. If, on the one hand, it can increase the employment and education perspectives of migrants and benefit their countries of origin's economy through remittances, on the other hand it drains high numbers of productive resources and potential innovators from their communities, thus impoverishing their country of origin. (FAO, 2018).

**Lack of access to land, finance, markets, technologies, as well as technical and entrepreneurial skills** are important constraints to the development of a functional African agri-food industry and market. In many countries, use of agricultural inputs spanning from seed, to fertilisers and machines are extremely low in quantity and financially costly even compared to countries in developing Asia, with



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studies showing that the African agriculture sector (excluding North Africa) would necessitate 8 times more fertilisers and 6 times more seeds than it currently uses in order to feed the population by 2050 (McKinsey, 2019). The lack of investments in African agriculture production means that the crops grown are often of poor quality and have low nutrition values. Many seed varieties that are used and recycled multiple times are not resistent to adverse climate events, with agriculture being still largely dependent on increasingly unpredictable rainfalls. The issue of low post-harvest storage and processing capabilities leads to major revenue reductions due to food losses close to the farm and the related reduction in potential exports**.** The issue of food loss and waste is particularly compelling, as while hunger ravages a majority of African countries, as many as 48 million people could be fed every year with the food rescued from food loss in Sub-Saharan Africa only (Food Safety News, 2020**). Lack in processing skills** and an overall low quality of food products compared to the high quality of primary ingredients causes African food to be scarcely competitive in the global markets and **leads to food imports,** thus highly reducing the governments' potential for investments in local production and increasing **vulnerability to 'beggar-thy-neighbour' trade restrictive policies** devised by third countries (Bill & Melinda Gates Foundation, 2020). **The poor state of transport infrastructures and uncertain accessibility to markets** for primary producers and distributors – due to physical, regulatory, tariff and information barriers – **contribute to the relatively high cost of food** for African households, who spend up to 50% of their income on food purchase in countries like Uganda, Tanzania and Ghana, as opposed to 10% in the US (Financial Times, 2019). The establishment of a functioning financing system and the guarantee of smooth access to credit for small and medium enterprises are essential features to boost the growth of the local agri-food sector and support the African food systems transformation needed to close the poverty and nutrition gaps.

**Africa's food systems are among the world's most vulnerable**. Causes include limited adaptations measures take to the increasing negative impacts of climate change, heavy reliance on rainfed agricultural production, high climate variability, recurrent droughts and floods affecting both crops and livestock, and persistent low-income of a majority of actors from primary producers to consumers that limits the capacity to adapt (IPCC, 2019). Projected further increases in temperatures will produce disastrous effects, including a significant yield reduction of major crops – especially maze and wheat – and a reduction in both the density of suitable agriculture lands and the length of the growing season (Innes et al., 2015). Secondly, breeding and keeping livestock may prove increasingly difficult due to climate change-related effects such as land degradation, fragmentation of grazing areas, in-migration of non-pastoralists populations into grazing areas, limited access to water reserves and increased drought conditions (Rojas-Downing et al., 2017). Fisheries also risk suffering from the negative consequences from climate change, with studies showing that the annual landed value of fish in



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coastal African countries risk declining by 21% by 2050, resulting in a nearly 50% decline in jobs associated with fisheries and remarkable economic losses (Lam et al., 2012). Furthermore, climate change in interaction with other environmental and production factors could increase the intensity of the damage caused by pests, weeds and diseases. For instance, climate warming in highland Arabica coffee-producing areas may result in the coffee berry borer beatle becoming a serious threat in coffee-growing regions of Ethiopia, Kenya, Uganda, Rwanda, and Burundi, while temperature increases in highland banana-producing areas of Eastern Africa multiply the risk of altitudinal range expansion of the highly destructive burrowing nematode (Deutsch et at., 2018). FAO maintains that even the higher recurrence of plagues of locusts, such as those that have been ravaging East Africa in 2019 and 2020, may depend on climate volatility, as rising sea surface temperatures increase the frequency of storms and cyclones, thus creating favourable conditions for locust spread (Reuters, 2020). **As climate change adds further strain on the current state of food (un)security in Africa, resilience needs to be increased**. Ground-breaking innovations, including the use of big data to drive smarter farm-level decisions on water management and fertilizer use to deploying drought-resistant crop varieties, can prompt agri-food transformation and farmers' adaptation to climate change. Targeted investments and enabling policy environments are key factors to support green processes - such as agroecology and sustainable intensification- and the uptake of new technologies, as well as a significant transfer of environmental knowledge and smart job skills towards the least specialised sectors of the African agri-food workforce (Ehui and Klytchnikova, 2020).

### R&I action required

Transforming African food systems while simultaneously supporting their sustainable development is complex. R&I is required in different ways. There is a **need to gain more knowledge on the food systems in African cities**, which are characterized by the decoupling of citizens and food production, rapid growth of urban population, and changing rural-urban linkages due to migration. The lifestyle and diets in urban settings are changing from typical African lifestyles and diets towards more industrialised lifestyles and diets (Mbogori and Mucherah 2019). **The revival of African diets with traditional foods might be the key to ensure more resource efficiency and circularity** in the value chain production.

- **R&I for African food cities**. African cities are growing rapidly, with each one facing its own challenges with food security and climate change. There is no uniform solution to deal with food security, economic development and climate change challenges, but it is important to share knowledge on how these challenges are faced in different circumstances. A number of



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African cities have already connected to the Milan Urban Food Policy Pact (MUFPP) to tacgle the issue of food insecurity. In the 3rd African Forum of MUFPP, delegates from 18 African cities agreed that there is an urgent need to strengthen local governance of food systems to facilitate collaboration between municipal departments and agencies; increase stakeholders' participation; and develop a disaster risk reduction strategy (Task Force Rural Africa, 2020). This urges for capacity building on food systems and climate risk at administrative levels beyond the national level. Rapid urbanization is a burden for Africa'metropolitan areas. The Task Force Rural Africa- an expert group created by the European Commission to provide expertise, advice and possible recommendations on enhancing the role of the EU agri-food and agro-industrial sector in the sustainable economic development of Africa - emphasizes the need for a prominent role of the so-called secondary cities for African territorial cohesion. The concept of secondary cities relates to the observation that urban population growth is best addressed when spread across different cities instead of few metropolises only, so as to avoid major issues such as insufficient housing, difficult access to food, traffic congestion, unemployment, etc. (World Economic Forum, 2019b). Secondary cities of a smaller size can increase the social and economic cohesion of a country as they play an important role as administrative areas, service centers, as well as places of socio-economic exchanges, which are key elements of the food system. Secondary cities are gateways to rural areas and vital for the outward orientation of rural economy including small-scale and subsistence farming (Task Force Rural Africa, 2020).

- **Food systems approach in Africa-EU collaboration**. The Task Force Rural Africa also indicates that both Africa and the EU have a profound mutual interest in working together to create stable and prosperous societies and economies, which can only be effectively explored if the connections between the economic, the political and the food systems of Africa and Europe are known. African governments' strategies for economic prosperity and food security have long been focused on improvement of agricultural productivity rather than on adopting a comprehensive approach to all elements of the food systems. Evidence has shown that a narrow focus on productivity is insufficient. Other bottlenecks must be addressed, such as the complex, polluting and expensive mechanisms regulating the transport and distribution of food; the degradation of perishable food due to a lack of cooling transport and storage capabilities; lack of infrastructure; traffic congestion in urban areas, etc. Moreover, food system thinking can also identify possible lock-ins of consumers and food producers, e.g. situations where actors do not consider alternative ways to acquire or produce food in spite of these being available to them. Public institutions should invest in building both food actors'



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competences and awareness of food systems, so that consumers may be able to opt for more sustainable ways to acquire food (including self-producing methods) and small-scale producers should be assisted to sell their produce at local or regional markets. Evidence from several African countries has shown that agricultural commercialisation provides opportunities to improve diets and nutrition. However, evaluation studies have shown that an increase in agricultural production and increased income do not necessarily translate into improved nutritional outcomes (Christiaensen and Demery eds., 2018). The food system perspective must help identify which additional R&I actions and interventions are needed taking into account the specificities of different contexts and variety of challenges affecting Africa's food systems.

- **Delivering safe, nutritious, affordable and available food for sustainable African diets.** Recent studies have shown the presence of pathogens in food products in different countries in Africa, such as polycyclic aromatic hydrocarbons in a number of Sub-Saharan Africa countries (Ingenbleek et al., 2019) and the occurrence of pesticide residues in Benin, Cameroon, Mali and Nigeria (Ingenbleek et al. 2019b). In particular, soils are one of the key factors of crop production and healthy soils are needed to ensure food security in the long run (Rojas et al., 2016). The "exposome" measurement framework is a useful tool to safeguard current and future generations from the increasing number of chemicals polluting our environment. The "exposome" concept captures the diversity and range of exposures to synthetic chemicals, dietary constituents, psychosocial stressors, and physical factors, as well as their corresponding biological responses (Vermeulen et al., 2020). Besides food safety, broder health concerns are linked to changing African diets. Science shows that undernutrition and overnutrition are closely related to the health of microbiota in the body (Blanton et al., 2016). Understanding the role of the microbiota in their pathogenesis is indispensable to be able to devise adequate interventions to mitigate these health challenges (Wilson et al., 2020). Recent research on human microbiome and nutrition in Africa has been featuring intervention trials in childhood undernutrition and exploration of the effects of urbanisation on the rising incidences of diseases typically related to Western diets, like several types of cancer, cardiovascular, diabetes etc. (Wilson et al., 2020). Studies have found a direct relation between specific dietary patterns, impacts on health and incidences of diseases, but more research on causality is needed before specific microbes, or groups of microbes, can be used therapeutically. Once the results of the studies on microbiota will have provided solid scientific evidence, tailored dietary guidelines for healthy diets could be issued. The adoption of food strategies aimed at diversifying diets has social, cultural, economic, and environmental



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benefits. Preserving biodiversity, including through agricultural innovations, like hybrid seeds and biofortification, is key to human health and wellbeing. The diversification of cropping systems and diets has a positive impact not only on human health,but it also yields other benefits including fostering healthier ecosystems (Dwivedi et al., 2017). Creating an environment for dietary diversification in Africa may enable behavioral change interventions for consumers, which can in turn induce more nutrition-sensitive agriculture through shifts in food demand. Several case studies on the impact of diversified farming systems on dietary diversity from different geographical locations and faming systems have been published over the years (Waha et al., 2018). More research is needed to unlock the expertise needed to harnass the benefits of diversified farming systems and how they can lead to dietary diversity. For example, more research is needed into the impacts and strategies to scale up Nutrition-Sensitive Agriculture approaches, in which diversified agriculture production is combined with nutritional and health interventions (FAO, 2017).

- **Sustainable packaging to improve circularity**. In the transition towards healthier diets and safe food for all in Africa, the environmental aspects need more attention and require additional R&I action. A more efficient use of resources as well as the reduction of food loss and waste are promising opportunities to support the food system changes (FAO, 2019). Local initiatives in the stages of the value chain exist as pointed out by a review study on food loss and waste in Sub-saharan Africa (Sheahan and Barrett, 2017), but more evidence is needed for upscaling across the continent. The food packaging industry has been growing in Africa as a consequence of the increase in agricultural production, the steady growth in food commodities (more processed food types and more intensified food processes), increasing food demand of a growing population, increasing wealth and increases of other types of food outlets such as supermarkets and restaurants. The transition towards sustainable packaging in Africa may come either from improving traditional technologies or importing technologies which are already mainstream elsewhere but are not yet diffused in Africa.

- **Urgent action to reduce post-harvest food loss and food waste**. In a recent study, FAO confirmed that food loss in African food systems is significant and losses close to the farm are the highest in the world (FAO, 2019). The reduction of post-harvest loss in Sub-Saharan Africa is largely regarded as a more effective strategy compared to attemps at further increasing agricultural productivity, and would also produce important co-benefits such as improving food security and food safety, reducing resource consumption and increasing profits in the value chain (Sheehan and Barrett, 2017). While the scale of the problem of food waste and



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loss in Africa is well known, there is little empirical evidence on the rates of post-harvest food loss in Sub-Saharan Africa. More research on causal effects of post-harvest loss through the food system is required so that remedies to avoid it can be implemented in a cost-efficient way.

- **Improvement of resource efficiency to maximise returns and adapt to the effects of climate change**. No real food systems transformation is possible without considerable improvements in resource efficiency. In many locations in Africa, water resources are scarce or are becoming scarcer due to climate change. Since agriculture is the main use of water resources, amounting up to 70% of freshwater worldwide and 80% in Africa (UNESCO, 2020), new efficient irrigation technologies such as drip and sprinkler irrigation can lead to improved water use efficiency. Soil management in Africa needs considerable improvements, including through a thorough application of the principles of agroecology, and with the use of organic and inorganic fertilizers and pesticides. Agricultural yields per hectare, as well as water managemnt efficiency are projected to increase significantly should agroecology principles should be duly implemented (Williams, 2015). An essential pre-condition to reduce waste and excessive resource use by African citizens is to understand the psychological factors driving food choices. Howevere, there is currently little empirical evidence because trial studies are limited (Odeyemi et al., 2018). Consumers have often little knowledge and awareness of food safety issues such as the presence of pesticide residues in food, hygienic norms to prepare food and sanitise machinery, etc.), as well as little nutrition literacy, including availability of information on what constitutes a healthy diets and the role of some important micro-nutrients such as vitamins (Oyeyinka et al. 2017). Research is required to investigate how nutrition information is received in emerging economies with a special attention to the urban and rural poor (Mandle et al. 2015).

*Barriers to systemic change*

Transforming African food systems and supporting their sustainable development is complex due to the many trade-offs existing between food security, economic prosperity and health. Developing **efficient infrastructure** is crucial to realize economic growth, improve Africa`s living standards and meet the UN SDGs (AfDB, 2020). The African Development Bank has established the Africa Infrastructure Development Index (AIDI) to monitor and evaluate the development of infrastructure networks with regard to the domains of transports, energy, ICT and water & sanitation. Electrification is essential to facilitate the green transition and harness the benefits of available digital solutions, however only 33% of rural dwellers dispose of electricity and only 1% of Africa's population has



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permanent access to Internet (African Development Bank, 2020). Improvements in transport infrastructure are particularly crucial in Africa (Emeana et al., 2020). Harnessing the full potential of Africa's agricultures requires the **sustainable development of a capillary network of paved roads** (EURACTIV, 2016). Remarkable improvements in the ICT infrastructure have already taken place as compared to the the 1990s, however considerable **investments for continental coverages of ICT networks are still required to meet Africa`s agri-food needs** (AfDB, 2020). Mobile phones are common in Africa since 2000s in both urban and the rural areas, and agricultural production has already benefited from the innovation potential associated with those, as shown by the case of farmers in Tanzania who have improved agricultural production and their livelihoods with the access to information through their mobile phone (Fureholt et al., 2011). However, while digital platforms enabling a variety of food purchase choices are fairly common to all consumers in High-Income Countries (HIC), such platforms are absent or still under development in many places in Africa. The main reason is the **limited access to internet and virtual marketplaces**. While a majority of Africans owns a mobile phone, **unlimited access to internet is still a** privilege belonging to a small share of the higher educated, affluent and urban population.

**Africa's urban population largely lacks in knowledge of food safety norms, as well as of the components of healthy & nutritious diets due to a disconnection of cities from the agricultural production**. This adds up to the burden of undernutrition and contributes to the **rising phenomena of malnutrition and overnutrition**.

Since the 1970s, agricultural cooperatives have been introduced in Africa to rationalise farmers' productivity and improve their income by collectively buying inputs, acquiring information on production technologies and marketing techniques, selling stocks of products (Sifa, 2014), and sharing risks (Navarra and Franchini, 2017). Unfortunately, **the introduction of agricultural cooperatives has rarely been associated with real improvements in agricultural efficiency due to poor management practices**, although successful examples exist, as in the case of the dairy sector in Kenya and the coffee sector in Ethiopia and cotton sector in Mali (Sifa, 2014).The position of agricultural cooperatives is further complicated by the growing phenomenon of economic migrants moving from rural areas to urban centres in search of jobs (UN, 2018), with a considerable percentage of workers joining the informal economy and in particular informal food markets. Given their uncertain status, these workers do not always qualify for membership in organised cooperatives, which at the same weakens both informal workers'negotiation power vis-a'-vis the state and cooperatives' representativity of the vulnerable groups (Meagher, 2019).



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Both long-standing and recent violent conflicts due to political, economic, cultural or religious disputes still ravage the African continent (Reliefweb, 2020). **Persisting violent conflicts undermine efforts to establish sustainable food systems**. Agri-food actors at the local, national and continental level in Africa – as well as global actors with stakes in the region – all have **specific sets of interests apt to generate tensions whenever they collide**. At present time, **very few mechanisms for the management of controversies exist.** While some progress on issues such as improving water management & sanitation or better redistributing wealth can be achieved at the African level under the current constraints, in the long run it is essential to establish continental mechanisms to mediate between different positions and mainstream shared interests. **More R&I action is needed to make sure that actors across all levels understand their interconnectedness in the food value chain**, and how their own interests are best pursued by working together in the establishment of sustainable food systems.

For decades, African economic development policies have emphasized the need for improvements in agricultural productivity without considering other important aspects of functioning food systems, while **agricultural, nutrition and health policies have only been pursued through sectorial and fragmented approaches**. Recently, economic development policies in African countries have been broadened so as to cover more policy sectors, but **a comprehensive food systems approach is still to be adopted.** Most African countries are classified as low- and middle- income countries with a significant share of subsistence farmers. **Without any access to credit markets, investments are risky** (Mago and Hofisi, 2016). **Many smallholders are trapped in a vicious circle** where they either largely consume their own produce with little surplus to sell at local markets, or they produce and sell all of their produce at a low price to traders who supply food to urban centers. In both ways, there is hardly any opportunity to save money to invest and grow their agri-business. The power of traders or food processing companies has to be revisited, for instance by well-established agricultural cooperatives.

*Enablers for transformation*

Administrative authorities at the local, regional, national and international levels have the opportunity to facilitate the transformation of food systems through their **policy strategies, regulations, education of consumers, concession of credit and investments**. Public administrations have the opportunity to **influence markets through green public procurements and audits**, although they have to strengthen the enforcement of the rule of law and avoid mismanagement of public funds. Technological innovations, as well as changes in behaviours related to land use and dietary choices, can be promoted through targeted actions coordinated by public authorities. **The uptake of technological innovations has to be reinforced while also ensuring more transparency** across the food chain, so that economic,



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environmental, health and social consequences of specific production, consumption and business choices are traceable throughout the food system (World Economic Forum, 2019). Tech companies such as Microsoft with the Microsoft4Afrika initiative (Microsoft, 2020) or Yara International - a multinational fertilizer and crop nutrition producer (EURACTIV, 2020) - can be enlisted to deliver **educational programmes aimed at inspiring young and educated women and men to start their own agri-business**. This allows to strengthen the rural-urban linkages and address food security issues the vulnerable urban population. However, increasing the diffusion and cover of diffusion of internet is a key pre-conditions for such initiatives to be widely impactful.

Knowledge of safe and healthy food/diets could be included in primary and secondary school curricula. **FAO assists African universities incorporating training in nutrition education** (FAO, 2020). NGOs such as Africare, as well as local community organizations, and agricultural cooperatives have the potential to play a crucial role to **increase African consumers' awareness of safe, healthy and sustainable food** (Nisbett et al., 2017). This would open up opportunities for community and producer organisations, which can promote the availability of safe food and healthy and sustainable diets. In urban areas, initiatives like community gardening are useful to educate older people on how to grow vegetables, fruits and other crops and increase the social cohesion in urban communities (IOL, 2017).

An increase in the **uptake of the food systems approach** at national, regional and local level, starting with a clear vision from the Africa Union**, can be facilitated through with a renewed EU-Africa Partnership** in the changing policy landscape. This partnership should integrate the UN Agenda for Development including thematic priorities such as agriculture, nutrition & health and job creation, the UNFCC recommendations for sustainable land management practices, the African Union commitments on food waste, etc. Africa would benefit from a **reduction of intra-continental trade restrictions** which increase transaction costs and produce negative trade-offs on public spending in social services. Intra-regional economic liberalization would result in long-term economic growth, trade, poverty reduction and employment. The **African Continental Free Trade Area (AfCFTA)** entered into force in 2019 may prove especially crucial to help Africa address the current trade challenges in the context of global trade restrictions due to the COVID-19 pandemic crisis (The World Bank, 2020).

### Potential for sustainable social and economic breakthroughs

*Social breakthroughs*

**Adoption of territorial approach to food systems governance. I**n many African countries, strategies for agri-food development policy have long been focusing on farm modernisation and farming practices, rather than on the whole value chain. As a result, in spite of the central role of agriculture



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in African economy and in millions of households' livelihoods, countries have usually relied on fragmented, sectorial approaches to food systems governance. This has involved the neglection of fundamental aspects of agri-food ecosystem management, such as regulating land property rights, taxation, labour law, exports, as well as investments in infrastructures, technical skills, access to finance for farmers, logistics, manufacturing, and services. Addressing current food systems governance issues is also relevant to facilitate the transition towards healthier lifestyles and nutritious diets. Most of African traditional diets are very healthy – featuring leafy greens and colourful fruits, beans, whole grains, spices, fish and minimal consumption of red meat. However, a high number of governments in African countries have long welcomed the short-term investments of multinational agri-food companies promoting 'Western' diets rich in meat and sugar as well as alcoholic beverages, over the long-term preservation of their citizens' health. Questionable policy choices have allowed for decades of massive advertisement and barely regulated marketing practices contributing to the current phenomenon of the triple burden of undernutrition, malnutrition and overnutrition (Reuters, 2017). Looking at the future, the transformation of Africa's food systems can be promoted through a comprehensive set of actions aimed at building synergies between the rural and urban networks, between the public sector providing public goods and the private sector creating jobs, between the ambition to boost competitiveness and growth and the need to ensure the right to nutritious food for all. To this end, participation of a wide range of actors in the dialogue on food systems transformation needs to be secured, especially through affirmative action directed at raising awareness on food systems and building professional competences for vulnerable groups such as small farmers, youth and women associations, so as to redress power imbalances across the value chain and achieve more just and sustainable outcomes.

**Integration of climate action into public policies, private projects and awareness campaigns**. Public authorities, companies and households are starting to take action to change African agri-food chains from farm to fork. Programmes aimed at transferring a wide range of technical skills in sectors such as integrated land, soil and water management; biodiversity conservation; waste reuse, cold storage of post-harvest produce, etc. are currently developed by international organisations and philanthropic donors (OnePlanet, 2020) but need further integration and follow-up in national as well as pan-African strategies. Small farmers and – where relevant – agricultural extension agents mediating between research and farmers need to be trained on sustainable agriculture, reduction of post-harvest losses and efficient use of pesticides. Synergies between food security, climate interventions and economic returns can be explored, for example through the promotion of healthy diets based on traditional recipes, the reduction and reuse of food loss and waste, and the transfer of agroecology skills for a more resilient and profitable agriculture (Task Force on Rural Africa, 2020).



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**Nutrition-Sensitive Agriculture (NSA).** NSA is an approach that seeks to ensure the production of a variety of affordable, nutritious and safe foods, respectful of cultural traditions, in adequate quantity and quality to meet the dietary requirements of populations in a sustainable manner. The recognition that addressing nutrition requires taking action at all stages of the food chain has led to a broader focus on agriculture which encompasses the entire food systems (FAO Committee on Agriculture, 2016). Switching to NSA in Africa would contribute to improving health outcomes, through for example, production of diverse, safe and nutrient-rich food, income generation that can facilitate access to health services, through reducing contamination of water sources, and through the application of labour-saving technologies. However, to be enacted in Africa, NSA necessitates taking action to address input quality, production, post-harvest handling, processing, retailing and consumption. To faciliate this, it is essential to promote an enabling environment, inclunding policies that facilitate access to inputs and support extension services for production of nutritious foods, incentives and regulations to encourage initial adoption of sustainable practices (e.g. payments for environmental services, ecolabels and certification systems), as well as adoption of sectoral and cross-sectoral frameworks and approaches for crops, livestock, forestry, fisheries and aquaculture that will facilitate the transition to more sustainable and diverse production systems (FAO, 2017).

*Economic breakthroughs*

**Investments in climate-smart physical and digital infrastructures.** Robust investments in Africa's water and sanitary systems, as well as in the expansion of the paved road network and an increased availability of agri-food machines and processing facilities would increase Africans' quality of life together with the food systems' productivity. The transformation of food systems needs to be guided by data and advanced analytics to better understand trade-offs between potential actions, yet research, information and technology gaps are still hindering data gathering efforts. Public policies that enhance returns and promote digital services among poor farmers can be used to trigger private sector investments, which in turn can be channeled to provide farmers with better access to knowledge, markets and funding. Initiatives incentivising private investments towards climate-smart agriculture adaptation tools also bear strong potential for impact. For instance, public-private partnerships can provide incentives for business to contribute to infrastructure-building in exchange for a share of the returns harnessed through the green transition. By improving its markets and promoting better functioning value chains, Africa can stimulate private investments while also increasing its food systems'inclusiveness and sustainability. Public authorities can leverage private funding to achieve development impact, for example by offering support in scaling up existing efforts to improve agro-processing and reducing food loss and waste, producing research on smart packaging and green fertilisers, designing responsible marketing and circular business models (Task Force on



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Rural Africa, 2020). A progressive reorientation of the agri-food business towards local and regional markets would allow for a better connection between producers and consumers, fairer prices paid to local producers and more predictable price variations, as well as shorter and more resilient supply chains and reduced transaction and transport costs (OECD, FAO & UNCDF, 2016).

### Impacts & Co-benefits

The successful implementation of the interventions and strategies mentioned above would have multiple benefits towards the establishment of sustainable food systems in Africa. A generalized **improvement in the levels of food and nutrition security** on the continent would be the most evident positive impact of such transition, with important spillovers on the environment and the economy such **as increased resource efficiency, mitigation of climate risk and increased economic prosperity**.

City authorities can prove key actors in mitigating the vulnerability of urban dwellers in accessing nutritious food due to the increasing effects of climate change. African cities are expanding their responsibilities with regard to food production, processing, distribution, preparation and disposal. Policy interventions and planning processes related to the development of cities can create **opportunities to feed cities better in terms of sufficient and nutrient-rich food**. Initiatives like the 'city to city' collaboration and South-South and Triangular Cooperation (SSTC) bring together all actors in the food system, including consumers, producers, processors, traders and retailers, and government to **build new skills and opportunities through innovative exchanges and projects** (FAO, 2020b). In addition, knowledge and experiences on sustainable food production, efficient water and energy use can be exchanged and best practices explored by the stakeholders of the food systems.

In Africa, food safety improvements in production, processing, transport and storage will have multiple benefits for the population. **African diets will become safer and healthier, with increasing opportunities to export agricultural produce** within Africa or to the EU and other partner importers. The African Food Safety Network (AFoSaN) stakeholders contribute to supporting the goals of the African Continental Free Trade Area (AfCFTA), which include economic growth, trade, job creation and poverty alleviation (World Bank, 2020). Moreover, the AfCFTA stimulates the elimination of non-tariff barriers and harmonization of regulatory measures (AFoSaN, 2020), which would lead to **less volatile food prices and accelerate agricultural growth in Africa** (van Berkum et al., 2017).

The promotion of Nutrition-Sensitive Agriculture has the potential to improve the food and nutrition security of millions of Africans, thus leading **to longer lives, increased dietary quality, and availability of income** (Ruet and al., 2018). Collaboration between nutritionists and agronomists has resulted in



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tools that can make the development of agriculture more nutrition-sensitive (Timler and al., 2020). Effective implementation and upscaling of nutrition-sensitive agriculture requires a more holistic approach and cooperation with other sectors in the value chain and food systems.

In the past, the reduction of food waste and loss was narrowly regarded as an enabler for increased agricultural productivity (Sheehan and Barrett, 2017). It has now been established, however that **reducing food loss and waste would produce multiple benefits such as improved food security** due to increased food availability; **improved food safety** due to better storage and transportation facilities; **reduced resource waste** including fertilisers, pesticides etc.; and **increased profits** in the value chain due to increased exports. Food waste reduction can then be associated with **improved health and a positive impact on the reduction of the triple burden of undernutrition, malnutrition and overnutrition** (van den Bos Verma et al., 2020). Furthermore, food waste significantly contributes to climate change through greenhouse gas (GHG) emissions. Methane emissions from landfills are the largest source of GHG emissions in the waste sector in the African context (Farming First, 2020). Therefore, **tackling food waste and loss is one of the most effective strategies to address climate** change. Additionally, climate adaptation for smallholders can be realized by stimulating diversified farming systems, so that smallholders reduce the environmental footprint of their agricultural processes.

## Policy alignment

*Alignment with EU policy frameworks*

R&I cooperation with Africa on food nutrition and security is a long-standing priority for the EU. The **2007 Joint Africa-EU Strategy** emphasised the importance of food security and science cooperation to ensure socio-economic growth and sustainable development in Africa (AU and EU, 2007). The African Union-EU Summit in Tripoli, in 2010, established the creation of a **High-Level Policy Dialogue on Science, Technology and Innovation**, which published a roadmap towards the establishment of a **Partnership on Food and Nutrition Security and Sustainable Agriculture (FNSSA)** in 2016. Key goals of the FNSSA partnership include boosting the impact of African Union-EU joint research at local level by addressing the entire value-chain; strengthening capacity-building (human, research infrastructures and institutional); focusing on demonstration projects and pilot actions to bring research and innovation results to the users; increasing production of high quality food with appropriate inputs; enhancing income growth and promoting rural development (AU and EU, 2016). To support the work of FNSSA, the EU has set up two different funding instruments: the **African Union Research Grants**, funded by the EU and managed by the African Union Commission to reinforce



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African R&I; and **Horizon 2020 projects** (Horizon Europe projects from 2021 onwards). Horizon 2020 projects dealing with R&I in Africa are grouped under the dedicated call "Sustainable food security" and aim to create international partnerships with a strong focus on multi-stakeholder action, identification of showcases and breakthroughs, and impact. **LEAP-Agri** (the "Long-Term EU-Africa Partnership on FNSSA") is the flagship Horizon 2020 initiative worth 27,6 million EUR, a network of 30 EU-African partners from ministries, funding agencies, research centres and technology platforms aimed at identifying FNSSA priorities and award funding through R&I project calls (LEAP-Agri, 2018). While DG Research and Innovation is the main responsible for Horizon 2020, DG EuropeAid also supports FNSSA through the robust 300 million EUR project **DeSIRA** ("Development of Smart Innovation through Research in Agriculture"), which seeks to contribute to climate-relevant, productive and sustainable transformation of agriculture and food systems in low and middle-incomes countries in Africa, Asia and Latin America (Capacity4Dev, 2019).

Following the establishment of the **Africa-Europe Alliance for Sustainable Investments and Jobs** in September 2018, **a Task Force Rural Africa** was created to provide advice on how to accelerate impact through better coordination with existing initiatives, identify strategies to promote and prioritise agricultural policy and regulatory reform in African countries and facilitate EU responsible private investments in African agriculture and agribusiness (European Commission, 2018). Responsible investments in Africa have been funded since 2017 through the **EU External Investment Plan**, worth 44 million EUR (European Commission, 2019). Partnership with Africa on food security and fight against climate change also features the European Commission's 2020 **EU-Africa Strategy**, where agri-food diplomacy can find its way in the international collaboration between Europe and Africa against the background of a global geopolitical arena characterised by rising tensions and competition from the US, China and Brazil (European Commission, 2020). The 2020 **EU Farm to Fork Strategy** also references the partnership with Africa as an example of the Green Alliances on sustainable food systems that the EU intends to establish in bilateral, regional and multilateral fora, thus confirming the high degree of political relevance awarded to this pathway area (European Commission, 2020b).

*Alignment with international policy frameworks*

EU R&I action in support of Africa's food system transformation is consistent with a large number of commitments on the international level. International cooperation was foreseen as an important component of the 2003 **Comprehensive Africa Agriculture Development Programme (CAADP)**, which has indeed received direct support from the EU DeSIRA initiative in recent years (ASARECA, 2018). Building on the commitments on sustainable development and fight against climate change expressed by the African Union through the 2014 **Malabo Declaration**, the EU has repeatedly highlighted how



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cooperation on food security and against climate change is aligned with Africa's objectives and also consistent with UN-sponsored framework such as the **Paris Agreement on Climate Change** and the **UN Sustainable Development Agenda** (European Commission, 2017). Supporting Africa's food systems transformation would directly contribute to meeting SDG2 (zero hunger), SDG3 (good health and well-being), SDG12 (Responsible Consumption and Production), as well as SDG 13 (climate action). Indirectly, the Africa-EU Partnership can also promote positive action towards the achievement of the socio-economic targets encompassed in SDGs 1, 5, 8, 9, 10, 11, 16 – which are linked to the renaissance of rural territories, and SDGs 6 and 15, which refer to the viability and sustainability of African eco-systems.



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**MUMM**


Mumm is an online platform in Egypt connecting talented homebased cooks with hungry professionals to give them access to wholesome fresh homemade food. The homemade food is cooked by local and refugee women. Mumm works with home chefs that prepare the meals. All food is prepared in pre-approved kitchens with strict hygiene and safety checks. Then the order is delivered to the consumer's location. The types of dishes that can be ordered include single dishes, family meals or frozen meals. The single dishes are portion controlled, well balanced, clean and healthy meals.

For more information:
https://www.getmumm.com/ .

## MUMM

*E-commerce*

### Assessment of added value

Mumm assists people who do not have time to prepare food themselves or are not able to do so due to specific health conditions. Additionally, Mumm inspires citizens to develop their own cooking and entrepreneurial skills by becoming chefs who sell meals via the Mumm platform. The platform attention to food safety standards, size of portions served, balance of nutrients in each meal, as well as on-time delivery provides opportunities to reduce contamination concerns, prevent over-consumption and malnutrition, and reduce risks to produce excessive waste.

### Assessment of challenges

As Mumm mainly targets middle- and high-income households, its services are hardly affordable for low income families. The system of pre-checked kitchens may prove very challenging to check kitchens located in remote rural areas, therefore hindering the diffusion of the platform besides urban areas. Furthermore, while the production of food 'on demand' can contribute to the reduction of waste from the consumer side, chefs need to acquire relevant production skills so as to assess which is the correct quantity of meals to be prepared in order to waste any unsold portion. Finally, in case the sale of single dishes will emerge as Mumm's prevalent business model – as it is the case for other platforms already existing – there may be a risk that the packaging requiredwill actually increase the production of waste instead of reducing it.

### Prospects for future development

Initiatives such as Mumm can target the promotion of traditional African diets, so that African consumers can be encouraged to shift towards safe, healthy and sustainable diets rich in vitamins, vegetables and fruits and refrain from unhealthy eating patterns high in saturated fats and sugar. However, for the large diffusion and success of such initiatives there are at least two pre-requisites: a significant improvement in the ICT networkd and market of internet services, allowing an increasing number of cheft and consumers to connect through the app; and an increase in the income available to the average African household, allowing for a lifestyles that include the option to purchase food from caterers.



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**UgandMicro-Gardening Initiative & Abalimi Bezekhaya**

Micro-gardening is the intensive cultivation of a wide range of vegetables, roots and tubers, and herbs in small spaces, such as balconies, patios and rooftops. Modern micro-gardening makes use of containers such as plastic lined wooden crates, custom-built tables and even old car tyres. It integrates horticulture production techniques with environmentally friendly technologies suited to cities, such as rainwater harvesting and household waste management.

Community gardens utilize either individual or shared plots on private or public land while producing fruit, vegetables, and plants.

For more information: https://www.climatecolab.org/contests/2016/land-use-agriculture-forestry-livestock/c/proposal/1331576 & http://abalimibezekhaya.org.za/about/community-gardens/.

## MICRO-GARDENING & COMMUNITY GARDENS

*Reduction of food insecurity*

### Assessment of added value

Micro-gardening allows low-income urban families to meet their needs for vitamins, minerals and plant protein by providing direct access to fresh, nutritious vegetables every day. Mirgro-gardens also offer a source of extra income from the sale of small surpluses for subsistance farmers. Micro-gardens can be easily fertilized with organic leftovers taken directly from household waste, thus contributing to the circularity of food systems and to valorisation of waste. Micro-gardening initiatives can be found in countries in West and East Africa. In South and East Africa, a similar initiative is the use of community gardens, where public communities are used to grow vegetables and other nutritious foods. Community gardens have an additional social benefit in that they stimulate the social cohesion of the communities.

### Assessment of challenges

The main issue related to such initiatives is the competition over urban space to be allocated to micro & community gardens. As the main garden users are low-income citizens, strong organisation is necessary to make a case for the public interest inherent to the establishment of gardens against the privatisation of lots by powerful actors. Public authorities need to carry out careful cost-benefit, as well as impact assessments to determine the extent of the positive impacts of such initiative on urban citizens' food and nutrition security in the short and long term.

### Prospects for development

Micro gardening and community gardens have been successfully introduced by FAO in Dakar (Senegal) and Cape Town (South Africa) in the 1990s and have expanded to other major cities in African countries like Gabon, Namibia, Niger, Senegal, Rwanda, Uganda, and on other continents. These initiatives has been adopted by the Milan Urban Food Policy Pact (MUFPP) to exchange knowledge and best practices across different regions of the world. The MUFPP has recently developed a monitoring framework to assess member cities'progress towards achieving sustainable food systems, which includes references to micro- and community- gardens.



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## Conclusion

**Africa is on a path of rapid demographic, social, political and economic transformation**. While by 2050 the population on the continent will increase by 150% up to 2.4 billion with more than a half under 25 years old, five of the world's ten fastest growing economies are already to be found among sub-Saharan Africa countries (AFD, 2019). Mega-trends affecting the food systems include the **rapid process of urbanisation and consequent shifts in food demand**; the **triple burden of the co-existence of undernutrition, overnutrition and micronutrient deficiency** due to the lack of access to or knowledge of healthy diets; a progressive **shift in the labour force from farming to non-farm jobs** mirroring rural-to-urban migration flows; and **rising competition over farmland** due to the increasingly devastating effects of desertification and climate change and expansion of latifundia.

The way the many social, economic and environmental challenges currently affecting the food systems will shape the future of Africa will depend on many internal and external factors including **fluctuations in world food prices** and the extent of the **diffusion of income growth** for urban and rural households. The progress and pace of Africa's food systems transformation needs to be accelerated by policy decisions creating **enabling regulatory environments**; **public and private investments** prompting a vast uptake of available technologies; and i**nnovative processes steering the re-design of inclusive food value chains** which will value decent livelihoods of workers and producers, the health and nutrition of consumers, and the protection of the environment.

Cooperation on R&I for sustainable agriculture from economic, social and environmental perspectives is a central topic in the agenda of the **EU-Africa Partnership**. Europe can play a significant role in **reducing the vulnerability of smallholder farmers** by leveraging more private investments, supporting governmental initiatives and programmes that **encourage sustainability and innovation** in the agricultural sector, and **empowering women and youth** in the food systems.

Since 2017, **the EU has pledged** through the 'Development smart innovation through research in agriculture' (DeSIRA) initiative **more than € 270 million to better link R&I action with national programmes** for a climate-relevant transformation of Africa's agriculture and food systems. The EU's commitment to global partnerships in a peaceful and multilateral governance system has been renewed by the European Commission presided by President von der Leyen. She made cooperation with Africa a cornerstone of political guidelines published at the beginning of her mandate in December 2019 (von der Leyen, 2019), and chose the African Union headquarters in Addis Ababa as the location for her first visit outside Europe to highlight the 'pivotal' significance given to EU-Africa cooperation (POLITICO, 2019).



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Cooperation between Africa and Europe can help both sides to achieve their objectives to meet the UN SDG goals more effectively and efficiently than if they work in isolation from each other. However, more attention is required to **address several systemic and structural challenges** that tend to limit the continents' ability to participate in transformative R&I action and benefit from the cooperation with the EU. To ameliorate this situation, resources need to be leveraged and geared towards **strengthening the capacity of African political institutions and research centres** to become effective and genuine partners of their EU counterparts in the transition towards sustainable food systems that work for the environment and for all.

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# Food Systems and Data

**The Twenty-first century has seen the expansion of the digital revolution to the agri-food sector, with the development of potentially transformative innovations such as advanced robotics, advanced sensors, digital twinning, the Internet of Things, augmented reality, Big Data, the blockchain technology and the Artificial Intelligence. New technologies have the potential to contribute to improve the safety and quality of food for EU consumers; foster a better management of natural resources; increase productivity while reducing the proliferation of food waste; and make life easier and more comfortable for food workers and consumers alike. The collection of data is at the core of the functioning and implementation of new technologies.**

**While increased connectivity and data gathering techniques allow for an unprecedented capacity to analyse elements that are key to establish future-proof EU food systems, a Responsible Research and Innovation (RRI) approach is needed to ensure that sensitive data is collected and managed in ways and with objectives that are in line with the protection of EU citizens and the respect of EU regulations.**



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## Societal, economic & environmental needs

**The digital revolution** is generating trends that are already **producing direct economic, social, environmental impac**ts. The rise of mobile applications and global social interconnectivity; the role of social media, the integration of new miniaturised sensors in many aspects of everyday life; the speed of new advanced robotics; new digital business models; and new traceability systems facilitated by the blockchain technology are just some examples of how the digital revolution is producing impact on EU citizens' lives that were unthinkable three decades ago, when private use of internet and mobile phones was not common (Venkataraman, 2019).

Due to its high level of complexity and interconnectedness, but also to deeply rooted traditions and practices, **food systems are traditionally slow in absorbing digital innovations**. However, the EU agri-food sector is now starting to embrace the digital revolution from farm to fork and beyond, affecting the way food is produced (precision agriculture, new sensors, prediction tools etc.), processed (robotics, monitoring, Internet of Things applied to the control of machinery), distributed (new digital business models, traceability systems, automatised transport) and consumed (e-commerce, importance of social media, opinion hubs, consumer interactions). While several changes are already underway, **Research and Innovation (R&I) is needed to regulate how to apply, improve, monitor, control, and validate the use of the data** enabling the functioning of technological innovations.

In comparison with other impact pathways, the use of data and the digitalisation of the food system is in itself a tool. As an instrument, it is neither inherently bad nor good. The extent of its impact depends on its use and implementation. **Big challenges are linked to the social impact of data collecting and use, ranging from the transparency of the collecting and management process to issues of privacy**. Making sure that a clear regulatory framework is established with regard to how and why data is collected, formatted, used, transformed, stocked, sold or shared and deleted will have a positive **impact on the trust EU consumers and other relevant stakeholders** have in EU food systems and new technologies applied to food products in general. The question of the uptake of new technologies also relates to the issue of capacity building and training. **The EU agri-food labour force needs dedicated skills transfer** to be able to operate the new devices being currently developed, as well as a clear **understanding of the limits and red lines to respect when managing sensible data**. Consumers, on the other hand, need **education and digital literacy** to be empowered **to make informed decisions** and harness the full potential of the digital revolution.



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The use of data has several implications and impacts for the growth and competitivity of the EU economy. While great opportunities to improve the efficiency of the food systems lie ahead, there are also **challenges related to costs of data management, applications development and testing, procedures related to regulate data ownership, data exchange and transparency of data**. Data owners are usually associated with large multinational companies which see in the collection and management of large datasets an edge to increase their competitiveness, however Small and Medium Enterprises representing the 99% of the EU agri-food market are constrained by the need to conduct their operations on global markets with only minimal resources available. The implementation of new business models in the digital era requires an in-depth understanding on how the digital market operates, its regulatory framework and the factors and forces at play. Such a complex and inter-related web of political, technological, social and economic relations has prompted the **creation of the concept of 'data economy'** (Opher et al., 2016), which, on the one side, offers high prospects for growth and monetisation, while on the other side, requires inclusive governance models and R&I actions to understand, monitor, regulate and validate the use of data.

**The environmental sustainability of EU food systems is closely linked to the acceleration of the data digitalisation process**. Addressing challenges such as the **reduction of greenhouse gas (GHG) emissions, reduction of food waste, increased resource efficiency or better traceability of foods requires digital tools** that can facilitate the transition to EU sustainable food systems. Examples of the transformational potential of digital technology for the protection of the environment are the use of predictive tools in agriculture through satellite data, which can reduce the use of water, pesticides, biocides and fertilisers; the automatised interaction of machines in a factory line through the Internet of Things, that allows for the maximisation of production and minimisation of food waste; the use of digital twins to improve the design of processes or delivery systems to model more efficient systems; or the provision of personalised nutrition advices to consumers to promote healthy and sustainable diets (FAO, 2020).

### R&I action required

The food sector is lagging behind in the uptake of digital technologies in comparison with other sectors. According to the 'Digital Transformation Scoreboard 2018' of the European Commission (European Commission, 2018), only about **58% of the interviewed food companies had the available resources, expertise or business intentions to invest in digital solutions** to improve the functioning of its business, a relatively low figure compared to the transport or chemical sectors. Thus, data management requires pre-competitive research of the involved actors in the agri-food value chain.



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The report 'Future Research & Innovation needs in view of the transition to sustainable, healthy, safe and inclusive food systems' from the FOOD 2030 Workshop hosted by the European Commission and held on 4 March 2020 outlines a number of R&I actions (European Commission, 2020) which have a transformative potential in the field of data application to the EU food systems. Three particularly relevant R&I actions are discussed below:

- **Develop a comprehensive analysis of the data economy in EU food systems**. The European Commission Communication 'A European Strategy for Data' (European Commission, 2020b) provides the basis for the EU to build a Single Market of data and a framework for the industrial and commercial uses of data. However more research is needed to understand the size of the market, opportunities and challenges related to the food systems, which present specific peculiarities as compared to other sectors of the EU economy where the uptake of digital innovations is already happening at a quick rate. An in-depth analysis of the interactions between the data economy and food systems should also allow for the identification of good practices and case studies that would provide more information on the critical success factors for agri-food tech start-ups, as well as the regulatory benchmarks for data management, and other critical issues that currently hinder the adoption of existing digital solutions.

- **Adopt a bottom-up approach to food data management**. Adopting an inclusive approach to digital innovation, based on the principles of co-design of legislation, supportive actions, monitoring frameworks and communication strategies will help the EU to boost an ecosystem that works for consumers and businesses. Participatory frameworks for collaboration should be designed not only between industry actors such as SMEs, start-ups, entrepreneurs, and large multinational actors but also through horizontal, multi-sector and multi-actor addressing issues such as transformation of business operations through responsible management of data; consumer education on the risks and opportunities related to digital innovations in food systems; knowledge transfers, digital literacy, and skills building. The social aspects of data collection and management should be addressed in a transparent and inclusive way, by highlighting the potential of the use of data in terms of economic growth but also by making sure that consumer protection plays a central role in shaping the policy environment regarding topics such as ownership of data, integrity, traceability, access and modification of personal information.



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- **Create a single e single marketplace of food and drink data.** Digital market places are platforms creating a venue for both buyers and sellers to transact over a product or a service. An EU food and drink digital market would allow to match the supply and the demand as it is already the case in other business sectors such as clothing, transports and housing. As the food digital market is only at the beginning of its development, it is barely regulated and still presents many barriers for SMEs and consumers. The purpose of a EU digital food and drink marketplace would be to aggregate all available resources, build up scale and thus be able to provide and sell food services and products all over Europe. While some smaller platforms already exist in Europe, there is still too much fragmentation and little alignment. A centralized digital marketplace would promote the exchange of information and best practices among agri-food actors with a higher focus on implementation, and taking into account possible trade-offs across different sectors of the EU value chain. To this end, multi-disciplinary research would be needed to accelerate the uptake of technological innovations across different food sectors.

*Barriers to systemic change*

The most pressing issues are the **ethical concerns regarding the treatment of data, and consumer reluctance and lack of trust in accepting and adopting innovations** using their personal data. Public authorities and private actors need to invest in building trust, competences and digital literacy for agri-food workers and consumers alike, so that **increased transparency and understanding of digital issue will stimulate more confidence in the food systems**. In order to overcome trust issues, a multi-actor approach to education, training and communication on agri-food digital matters should be adopted, so that relevant stakeholders do not perceive the digital revolution as a top-down process, but rather as a participatory process where workers and consumers play a central role.

**Political barriers** come from the **slow development of policy and legislatives processes** compared to the quick advancements of technology and the digital services offered on the market. Such gaps produce a **fragmented policy framework** that creates regulatory differences among regions and Member States and imbalances in competitiveness.

**Economic barriers** are mainly related to the structural features of global economy, that operates on **small margins for a majority of agri-food actors**, thus constraining the capacity to invest in digital technologies for SMEs and start-ups.

The most significant problem hindering tech innovation in the food systems is the **'chicken or egg' trap that prevents investment**: manufacturers wait until there is a demonstrated demand before they develop and commercialise tech products, but buyers wait to see the novel food product on the



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market before they demonstrate they will buy it. This risk coincides with the stage in the innovation process when public support usually ends creating a risk profile that is sometimes known as **'the Valley of Death' for agri-food tech innovations.**

*Enablers for transformation*

The most useful interventions to facilitate the uptake of technological innovations in the EU food systems are those that allow to **reduce market uncertainty without compromising freedom in consumer choice.** Therefore, policies aimed at increasing the demand for innovations, defining new functional requirement for food products and services or better articulating demand are promising initiatives to ensure the establishment of a functioning food digital market. **Participatory R&I is needed to design co-creative processes** where the final users can have a say in the development of food product and service applications. An enabling regulatory environment is essential to support market development and the uptake of innovations. It is therefore essential to streamline the initiatives already existing in Member States and **align investments in order to ensure a maximization of the results**. The high place digitalization occupies in political agendas across Europe can be exploited to create momentum for digital investments in the agri-food sector, which is still lagging behind as compared to others.

## Potential for sustainable social and economic breakthroughs

*Social breakthroughs*

**Smart and Precision Farming.** Digital technology allows to increase the quantity and quality of livestock and plant production, ensure increased food safety, better traceability, higher resource efficiency, detect food fraud, lower costs, and reduce the use of chemicals. Smart farming includes a variety of digital tools based on data collection with the aim of producing more efficiently in combination with improving the environmental sustainability of EU food systems. Smart Farming tools are based on precision sensors, robots, advanced machinery, the Internet of Things, data modelling and Artificial Intelligence. For instance, the management of animal and plant production using near real-time observations and measurements applying digital tools is considered Precision Farming. Precision Farming makes use of innovations such as sensors to follow soil data, irrigation, foliar growth, weed development or pest management. Data is collected through local sensors at farm level, via mobile apps, drone services or satellites. The data can be aimed to provide information at local level, thus giving smart access to farmers to critical information on farming, but can also be made globally available through web platforms and forecasts. Overall, these technologies can improve yield



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output, animal performance, food safety, and reduce farm inputs as fertilizers or pesticides, bringing higher profitability and sustainability to farms.

*Economic breakthroughs*

**Blockchain technology for safe, sustainable and competitive food value chains**. The blockchain technology will likely impact the way that food products are sourced, priced, and delivered. Blockchain technology stores data in blocks, in chronological order, in a way that does not allow for the alteration or deletion of data. Copies of the chain of blocks - hence the term blockchain - are distributed among the participants in the network. The blockchain technology has the potential to monitor social and environmental responsibility, improve provenance information, facilitate mobile payments, credits, and financing, decrease transaction fees, and facilitate real-time management of supply chain transactions in a secure and trustworthy way. Indeed, quick tracing of food products to their source will enhance food authenticity, transparency, and trust in the food value chain. New business models will emerge with a wider use of smart traceability technologies. Blockchain solutions can reduce market inefficiencies to create more value, including issues of over-purchase and over-production leading to the proliferation of food waste. New digital business models enabled by the blockchain technologies can potentially connect the food value chain to a new, digitally defined industry-performance standard. A main challenge to the full implementation of smart traceability technologies such as blockchain remains the complexity of the food systems. For a typical agricultural production site, implementing blockchain technology requires a customized system and streamlined practices for data entry. Agricultural products have various forms, storage methods, handling processes, and a variety of data recording methods. Therefore, implementing blockchain in scale requires a great effort of customization, and a relevant commitment of financial and human resources.

**The Physical Internet**. The digital revolution is also changing the logistics of food supply and distribution, with the aim to replace the currently unsustainable and too often inefficient global practices of how physical objects are moved, stored, supplied, and used. It draws inspiration from the digital internet to create a global logistical network with high interconnectivity, goods enclosed in smart, eco-friendly, and modular containers, and distributed multi-segmented intermodal transport. Such a smart but complex global system will be challenging to put in place but has large implications for the logistical dimensions of food systems. It requires technological breakthroughs in the design of infrastructure, container handling and transportation, supply chains modes as well as social innovations that transform the practices involved in, for instance, (online) shopping, food delivery and transportation.



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## Impacts & Co-benefits

The European Commission Communication "Building a European Data Economy" estimates that the overall value of this economy will be **worth €643 billion by 2020, representing 3.17% of the overall EU GDP** (European Commission, 2017). There is therefore a the clear economic opportunity to **increase the productivity and competitiveness of EU food and drink market, strengthening the EU's international role as a leading trade actor, opening a window for the creation of new jobs, attracting investments and sustainable business models.** As the implementation of a data economy will require a comprehensive regulatory framework for data collection and management, an important co-benefit will be the **creation of an advanced data regulation with clear benchmarks and fair** provisions related to the commercial use of food actors' sensitive data, which will contribute to the EU's overall efforts to take global leadership in citizen data protection. Digitalisation of the EU food systems will also produce an **optimisation of processes facilitating less use of resources** at the production, processing, distribution, retail and consumer level, thus producing a positive effect on environmental aspects such as a reduction of GHG emissions and of food loss and waste; a more efficient use of natural resources such as land and water, as well as of fertilisers and pesticides. The need to train the agri-food workforce in digital competences and data management will also allow for a **broad upskilling of EU workers, which will increase the overall EU industrial competitiveness**, while the need to educate consumers to make smart informed decisions will allow for **filling the digital literacy gap** with dedicated R&I actions to address the issue.

## Policy alignment

*Alignment with EU policy frameworks*

The digitalisation of EU food systems is a policy objective which is currently addressed through several horizontal initiatives at the European level. For example, the European Commission **FOOD2030 policy framework** acknowledges the relevance of digitalisation in adopting a 'whole food value chain' approach to food systems transformation. The FOOD2030 framework places digitalisation at the same level of open innovation, education and scaling-up initiatives as levers to accelerate the transition and create linkages with other policy areas and R&I actions (European Commission, 2017b).

Digitalisation and data management aspects relevant for food systems are also mentioned in the Communication on **the European Green Deal**, which states that "accessible and interoperable data are at the heart of data-driven innovation. This data, combined with digital infrastructure (e.g. supercomputers, cloud, ultra-fast networks) and artificial intelligence solutions, facilitate evidence-



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based decisions and expand the capacity to understand and tackle environmental challenges" (European Commission, 2019). The 2020 **EU Farm to Fork Strategy** is explicitly linked to an aim to accelerate the roll-out of fast broadband internet to rural areas. The aim is to make precision farming and the use of artificial intelligence mainstream, reducing costs for farmers and improving soil and water management to create a healthier environment. Data is central to the strategy. The EU will introduce legislation to convert its **Farm Accountancy Data Network** into the **Farm Sustainability Data Network**, in order to collect data on the Farm to Fork and Biodiversity Strategies' targets and collect key performance indicators for a better intelligence towards environmental sustainability (European Commission, 2020c. As part of the next long-term EU budget – the Multiannual Financial Framework – the Commission has proposed **Digital Europe**, a programme focused on building the strategic digital capacities of the EU and on facilitating the wide deployment of digital technologies. With a planned overall budget of €8.2 billion, it will shape and support the digital transformation of Europe's society and economy, including EU food systems (European Commission, 2020d). The programme will boost investments in supercomputing, artificial intelligence, cybersecurity, advanced digital skills, and ensuring a wide use of digital technologies across the economy and society, including through **Digital Innovation Hubs**. Digital Europe will complement other EU programmes, such as the proposed **Horizon Europe** programme for R&I, as well as the **Connecting Europe Facility** for digital infrastructure.

Other European partnerships, platforms and initiatives supported by EU institutions include: 1) The **European Innovation Partnership for Agricultural Productivity and Sustainability (EIP-AGRI),** promoted in 2012 to provide proposals and suggestions to ensure a steady supply of food, feed and biomaterials. Specific actors such as farmers, advisors, researchers, and businesses work together in multi-actor projects to find a solution for a specific issue or develop concrete opportunities (EIP-AGRI, 2019); 2) The European Technology Platforms (ETPs) launched in 2005 with the objective of identify the needs for an effective integration of strategically-focused, transnational, concerted research in the nutritional, food and consumer sciences and food chain management. The aim is to deliver innovative, novel and improved food products for, and to, national, regional and global markets in line with consumer needs and expectations (ETP, 2016); 3) The Knowledge and Innovation Community EIT Food, created in 2015 to increase European sustainable growth and competitiveness and reinforce the innovation capacity of EU member states. EIT Food is the first EU initiative to fully integrate all three sides of the Knowledge Triangle (higher education, research and business) plus a focus on consumer engagement to foster digital innovation in the food sector (EIT Food, 2018).



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*Alignment with international policy frameworks*

The digitalisation of EU food systems could help progress towards the achievement of **UN Sustainable Development Goals** such as Zero Hunger (SDG 2); Good Health and Well-Being (SDG 3); Quality Education (SDG 4); Industry, Innovation and Infrastructure (SDG 9); and Responsible Consumption and Production (SDG 12). While an international policy framework regulating digital innovation in food systems is yet to emerge, the UN Food and Drink Organisation (FAO) has taken several steps consistent with the EU ambitions and principles. One initiative is the development of a **Digital Services Portfolio** containing applications, databases and platforms to support the work on data and digitalisation in agriculture being carried out in countries around the world. These digital services increase access to useful data, information, maps and statistics (FAO, 2020b). Another initiative consists in the development of an **E-agriculture strategy**, a guideline on leveraging the advances in digital technologies to address some of the challenges faced in agriculture. Such strategy will also help to generate new revenue streams and improve the livelihoods of the rural community as well as ensure that the goals of the national agriculture master plan are achieved. The alignment of a future EU framework on digital innovation in the food systems with the FAO E-agriculture strategy prevent overlap of investments and research activities and will avoid that activities are implemented in isolation (FAO, 2020c).



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**S3 Agri-food Traceability and Big Data Partnership**


The European Commission launched in 2015 the S3 Agri-food T&BD Platform, a strategic alliance of regions and other entities that work together with the aim of contribute to the digitisation of the agrifood value chain through the adoption of digital technologies and the value creation from data. The Platform consists of five partnerships on: Consumer Involvement, High-tech Farming, Nutritional Ingredients, Smart Sensors for Agri-Food, and Traceability and Big Data. The Partnership In Traceability and Big Data funds and implement large EU R&I projects such as the ERA-NET ICT Agri-Food, DIVA, Track Growing Data, ICT Biochain, Regions4Food and SmartAgriHubs.

For more information:

https://www.traceabilityandbigdata.eu/.

## S3P AGRIFOOD T&BD

*Multi-actor collaboration for food systems transformation*

### Assessment of added value

The S3 Agri-food Traceability and Big Data Partnership provides a multi-actor approach to the development of digital innovations in the food systems at the EU regional. Its assets include a diverse network of 1,600 stakeholders including governments, ICT companies, agri-food businesses, knowledge agents, and civil society; a focus on building pilot projects in line with regional policies, so as to exploit synergies and avoid overlaps with existing programmes; and a close connection with the S3 platform established by the European Commission on Industry Modernisation, that allows the development of joint scale-up projects.

### Assessment of challenges

In order to be fully effective, the S3 Agri-food Partnership on Traceability and Big Data needs to be fully endorsed by regional authorities, including through the provision of financial and political commitment to digital agri-food innovation. The risk is that if public authorities' commitment vanishes, the transformative potential of the Partnership and its focus on smart specialisation will be reduced, with partners focusing on networking opportunities for business rather than on the implementation of innovative solutions.

### Prospects for future development

The future of the S3 Agri-food Partnership will be marked by its interaction with the European Digital Innovation Hubs (EDIHs), that will play an important part in the Digital Europe programme foreseen by the European Commission for the period 2021-27. With regard to S3 Agri-food Partnerhips, EDIHs can play an important role horizontally, by providing digitalisation support to all sectors, and vertically, by leading or taking part in processes of mobilising S3 Afri-food Partnership stakeholders towards digital innovation or by supporting the specialisation of regions in digital priorities strategically set.



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**Seebo**

Seebo is aiming to help manufacturers predict and prevent quality, yield, and waste losses. The company's process-based artificial intelligence is designed to solve process inefficiencies, revealing the hidden causes and recommending the right actions. With Seebo, manufacturers know why process inefficiencies happen, using Automated Root Cause Analysis; how to prevent process inefficiencies, using Predictive Recommendations; and when to act, using Proactive Alerts.

For more information: www.seebo.com.

## SEEBO

*Reduction of food waste*

### Assessment of added value

Seebo's approach can produce transformational impacts on businesses' food waste reduction efforts for four sets of reasons: 1) it addresses the hidden causes of food waste through an intelligent sensor that continuously reveals these hidden inefficiencies and informs the company staff on how to prevent them from occurring; 2) it is designed with a simple, intuitive interface, real-time alerts and best practices that can be quickly and effectively used to investigate and prevent production losses, without necessitating long and expensive training; 3) it continuously adapts to any changes in the production process of the company through intelligent data collection and use of algorithms to ensure that insights and recommendations remain relevant and actionable; 4) its technology is built to scale across multiple lines, and even multiple plants, with minimal effort.

### Assessment of challenges

The main challenge for Seebo is to be able to deliver on what it promises, notably on the capacity of its sensors and related algorithms to continuously adapt to the specificities of different companies' business models so as to be able to provide reliable recommendations on how to avoid food waste. With increasing popularity and success, it is expected that Seebo will be used by increasingly complex business with multiple production lines, which will present a remarkable testbed for Seebo's ambitions to transform the food systems.

### Prospects for development

Future developments for Seebo in the EU market are closely linked to the evolution of the policy landscape regarding food waste reduction efforts. With the European Commission mandating Member States to consistently measure their food waste levels (from 2020) and produce yearly reports to submit to the EU (from 2023), there is mounting pressure on private businesses to develop targets and design concrete actions to contribute to Europe-wide reduction efforts. Seebo, and similar innovative companies addressing food waste reduction and waste management, have an opportunity to gain visibility and a bigger market share as they provide services of increasing relevance in the EU political agenda.



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## Conclusion

The EU food systems are now entering in the digital revolution that has already been changing the lives of European citizens and the way business is done in several other industrial areas for a while. The rise of mobile phone applications, global internet connectivity, data processing, and diffusion of digital skills is inaugurating a **new era of technological solutions that can have an impact in a sector traditionally reluctant to open to innovations in production, processing, distribution, and consumption of foo**d. New technological advances in robotics, precision sensors, digital twinning, Internet of Things, big data, blockchain, and Artificial Intelligence are already changing the manufacturing and consumption ecosystems, with the **potential to produce great benefits on food security, protection of the environment, creation of jobs, and economic growth and competitiveness**.

The digital revolution is based on one fundamental assumption and pre-requisite: that **the collection and use of sensible data for commercial purposes is legally possible and technically viable**. This poses two sets of challenges. The first one is the **establishment of a regulatory frameworks that protects the privacy of consumers, as well as business secrecy and the public interest** by establishing clear rules on transparency of data collection and management, ownership, flows, and analysis, without compromising SME competitiveness. To this extent, it is necessary that **processes of digital governance are co-created with the participation of relevant actors** from all across the food value chain. The second one is the creation of a supporting environment for digital innovation and data sharing, including the **development of digital infrastructures, the transfer of skills and competences, and the market uptake of new technologies through financial and R&I investments and communication campaigns**.

Digital technologies offer unique opportunities for improving food production and trade, especially to smallholder farmers, and in helping to achieve the UN Sustainable Development Goals in order to future-proof EU food systems. However, as the sector is in its early stage of development, EU and Member States authorities need to guarantee a thorough monitoring, and deploy relevant and inclusive R&I action to harness the potential of the digital revolution without compromising citizen trust in the democratic governance.



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