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Towards sustainable food systems: an analysis of EU policy measures setting environmental sustainability requirements

Current status and assessment of impacts

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Contents

Abstract

The current challenges affecting the EU food system call for an urgent shift towards more sustainability. As set out by the Commission Farm to Fork Strategy, the path to achieve such an ambitious goal should promote policy coherence at EU and national level, mainstream sustainability in food-related policies and strengthen the resilience of food systems. In this report, we focus on provisions setting requirements to improve the sustainability of food products. This report was carried out to better understand the environmental impacts of such provisions and their evolution over time, as well as their coverage in terms of actors and environmental impacts of the EU food system.

Available data show that the environmental impacts of the EU food system are increasing and current trends are expected to be maintained. An analysis of existing EU policies suggests that there is a complex and fragmented policy landscape in the EU and in the Member States, which can act as a barrier to more systemic and transformative approaches to the governance of food systems. A focus on food waste highlights the lack of monitoring in current initiatives, hindering the efficacy of the plan, as well as an incoherent uptake of initiatives across the EU. The relevant actors are involved in existing policy initiatives in an heterogeneous way resulting in environmental impacts not being addressed consistently along the entire supply chain. Furthermore, the environmental impacts of the EU food system are not addressed horizontally and consistently across existing legislation.

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1 Introduction

This Chapter introduces the policy context and background (Section 1.1) as well an overview on the environmental impacts of the EU food system (Section 1.2).

1.1 Policy context and background

The **Farm to Fork Strategy** (F2F Strategy; (European Commission, 2020a)), adopted in May 2020 by the European Commission, aims at comprehensively addressing the challenges of sustainable food systems. The F2F Strategy recognises the inextricable links between healthy people, healthy societies and a healthy planet. All citizens and operators across value chains, in the EU and elsewhere, should benefit from a just transition. This strategy is also central to the Commission's European Green Deal[1] and wider agenda to achieve the United Nations' Sustainable Development Goals (SDGs).

The F2F Strategy indicates that a **system approach** is needed. It recognises that the food system is characterized by strong interrelations between supply chains, consumption patterns, ecosystems, our health, and planetary boundaries. It also sets a direction of travel bringing together various sectoral policies that affect food production, processing, distribution and consumption, and refocusing all action on the transition to sustainability, to move towards a fair, healthy and environmentally-friendly food system. A transition to a sustainable food system thus requires a shift in perspective and a recognition of the interlinkages among different elements, dimensions, and related policies. This also poses complex methodological challenges to the analysis, which will need to cover the different sectors, actors and sustainability dimensions involved.

The **environmental dimension** has a central role in the Strategy. The stated EU's goals are to '*reduce the environmental and climate footprint of the EU food system and strengthen its resilience, ensure food security in the face of climate change and biodiversity loss and lead a global transition towards competitive sustainability from farm to fork and tapping into new opportunities*' (European Commission, 2020a)). The Strategy further notes that ensuring that the whole food chain has a neutral or positive environmental impact requires the adoption of a comprehensive perspective, '*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'*.

Within this context, the present report aims to **contribute to the analysis of sustainability transition** by providing further **insights on the environmental dimension**, and in particular on the contribution of policy measures setting **requirements to foster food sustainability**. The study focuses on the environmental impacts of the food system, mapping them to the different stages of the food chain and providing an analysis of the relevant policy initiatives which are currently in place such as sectorial policies, policies addressed to food waste, voluntary instruments.

Our analysis also aims at contributing to **sound evidence informed policymaking**. As stated by the better regulation guidelines and associated toolbox, the main Commission regulatory framework (European Commission, 2021a), political decisions should indeed be informed by the best available evidence throughout the policy cycle.

In this context, our findings are relevant in various respects. First, as the actual objectives of the analysis are related to a **key policy question**. The Farm to Fork Strategy is at the heart of the European Green Deal that strives to transform the EU into a modern, resource-efficient and competitive economy. Second, from a methodological perspective, the complexity of the issue at stake implies a number of challenges. Integrated, systemic perspectives are needed that account for all sustainability dimensions (economic, environmental, social including health) across all stages in the food system, taking into account all relevant actors involved as well different policy sectors. Having

[1] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en.

in mind the complexity of the systems and the interdisciplinary analysis needed, an **appropriate methodological mix** has to be designed, backed up by desk research and expert advice. Third, our analysis builds a **comprehensive picture** which is available to integrate the evidence base to inform the decisions of the policymakers. Last but not least, the present exercise aims at contributing to the **debate on the improvement of regulatory quality**. In the academic debate on the better regulation agenda[2] scholars call for transparency on data, assumptions and methodology, and for a balanced implementation of qualitative and quantitative methods. The present analysis can be regarded as a concrete example of designing a pragmatic but sound methodology to address key policy questions. In addition, the very debate on the better regulation often seems to be confined within the academic fields of political science, public administration, and law. In practice, scientists from many other scientific fields are often deeply involved in in providing evidence in support to policy - such as the environmental scientists carrying out analysis of ex ante impact assessment, policy implementation, ex post policy evaluation. This research can also contribute to **bridging the gap between different scientific communities** which are involved in promoting evidence informed policymaking. The inclusion of such missing perspectives is of crucial importance for learning and further improvement of regulation quality.

1.2 Environmental impacts of the EU food system

The long-term viability and resilience of the food system is subject to various challenges. These relate to various developments taking place in the EU and globally – such as climate change, biodiversity loss, overfishing, unfair income distribution, food poverty, poor working conditions, unhealthy diet composition, waste, food insecurity, concentration of market power.

Several actors play a relevant role in the EU food system; their actions affect the sustainability both of its single parts and of the whole system. They can be categorised in the following groups: input producers; primary producers (from agriculture, aquaculture and fisheries); food and drink manufacturers; packaging manufacturers; logistic actors; retailers; food services (public/private); household consumers; finance actors and international trade actors. In addition to those directly involved in food chain activities, governments and civil society are also important, as they set the wider policy and societal context (adapted from European Environment Agency, 2017; further details on the role of actors on the sustainability of the EU food system are reported in Annex 1).

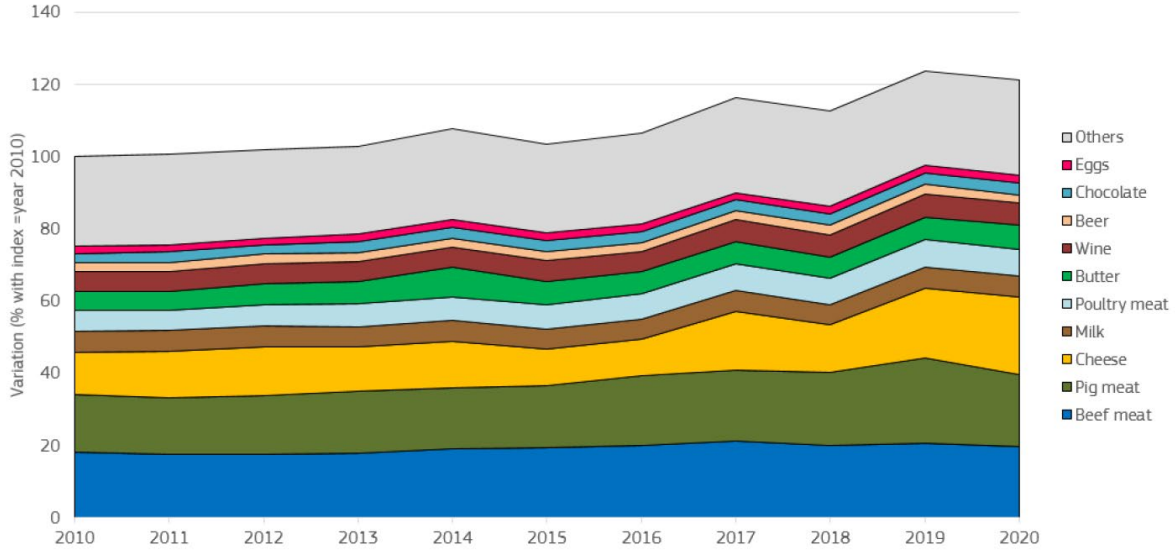
Climate change has reduced food security and affected water security (Calvin *et al.*, 2023). These challenges threaten the long-term viability and resilience of the food system in reducing its future capacity to face, respond and adapt to disturbances and shocks (Smith *et al.*, 2019; UNFSS, 2021). Even if recent crises showed that the current food system can be rather resilient in responding to various shocks, they have also exposed its vulnerabilities. The food system, particularly during the COVID-19 pandemic, showed a good capacity to face disturbances, to respond and adjust the production processes, distribution and logistics. However, it also emerged that its capacity to withstand and adapt to disturbances varies widely across its various components, regions, and over time (e.g., with respect to poverty and hunger of vulnerable groups, loss of income and livelihoods, shift to unhealthy diets, increased food insecurity in developing countries) (Deconinck, Avery and Jackson, 2020; Di Marcantonio, Solano-Hermosilla and Ciaian, 2022; McDermott and Swinnen, 2022).

The **limits of the Earth's ecosystems** in relation to biodiversity and climate have already been exceeded (Rockström *et al.*, 2009; Steffen *et al.*, 2015). Global food consumption is expected to add 1°C to warming by 2100; this increase is mainly driven by foods that are high sources of methane, such as meat, dairy and rice (Ivanovich *et al.*, 2023). The environmental impacts of EU food consumption have increased in the period 2010 to 2020 by 20% (Sala and Sanyé-Mengual, 2023b) (Figure 1). In 2020, with food representing around 45% of the environmental impacts of EU

[2] For a review see (Listorti et al., 2019).

consumption, the EU food system alone transgresses several planetary boundaries[3], including climate change (3.5 times), particulate matter (6 times) or freshwater ecotoxicity (5 times) (European Commission - Joint Research Centre, 2022a; Sala and Sanyé-Mengual, 2023a). Similarly, the biogeochemical flows of the nitrogen and phosphorus cycles have surpassed the planetary boundaries by 3.3 and 2 times (European Environment Agency, 2020). This seriously compromises the long-term viability and resilience of the food system regarding its environmental foundations.

Figure 1. Main impacts across the environmental dimension of EU food consumption. Impacts are expressed as single weighted score. Variation for 2010-2020 timeframe (% with index = year 2010)



Source: (Sala et al., 2023).

Food systems contribute and are vulnerable to ongoing climate and environmental changes that threaten their sustainability. The food system strongly depends on the environment and on the climate, probably much more than any other sector. Food systems benefit from stable and non-extreme climates, from fertile soils, irrigation and from the contribution of pollinators. However, the food system has also significant impacts on the environment, from biodiversity loss, water depletion and pollution, to climate change.

Climate change will further increase pressures on ecosystem services that support food systems with negative effects on air, soil and water quality and direct impacts on yields (Bezner Kerr *et al.*, 2022). The food system is responsible for 30% of greenhouse gas (GHG) emissions in Europe (Crippa *et al.*, 2021). Moreover, the **biodiversity** footprint due to EU food consumption (including impacts embedded in trade) is driven by meat products and agricultural land use (Crenna, Sinkko and Sala, 2019; Sala and Sanyé-Mengual, 2023a). Agriculture is in fact among the dominant sectors driving **land degradation** due to land use changes and to unsustainable land management practices (Olsson *et al.*, 2019). Between 2000 and 2018, artificial surfaces in Europe have increased by 7.1%, while arable land and permanent crops have decreased (Struhal *et al.*, 2011). According to projections until 2030 (Struhal *et al.*, 2011) land take and fragmentation are projected to increase. It has been estimated that 59% of total **water use**[4] in Europe, in 2017, was allocated to agriculture (European Environment Agency, 2021c). Water scarcity is an ever-growing concern. Per capita, freshwater

[3] The assessment is performed at a per capita level, with Planetary Boundaries allocated equally among the global population.

[4] Data for Europe for 2017 show that 64% of total water abstraction was from rivers and 24 % from groundwater (European Environment Agency, 2021c).

availability has been decreasing across Europe between 1990 and 2017, with a reduction of 64% in Spain (European Environment Agency, 2021c). Chemical inputs have helped to boost agricultural productivity; however, the discharge of large quantities of nutrients, agrochemicals, organic matter, sediments and saline into water bodies "affects billions of people and generates annual costs exceeding billions of dollars" (FAO, 2018a). Land use and climate change are direct drivers of biodiversity loss, with food systems being one of the main pressures (Bongaarts, 2019). The loss of diversity of local varieties and breeds of domesticated plants and animals is taking place at a rapid pace, causing agroecosystems to be less resilient against future climate change, pests and pathogens (Bongaarts, 2019). In Europe, the number and variety of species on farmland are declining: a decrease of more than 30% has been estimated for populations of farmland birds and grassland butterflies since 1990 (European Court of Auditors, 2020). An increase in food production, e.g., from the conversion of semi-natural habitats, could cause a further decline in farmland biodiversity (Jeanneret *et al.*, 2021).

Similarly, concerning **overfishing**, trends for 2003-2020 indicate a reduction in the average fishing mortality ratio and an increase in biomass of stocks in the North east Atlantic over the period (STECF, 2022). On the other hand, overfishing remains an issue for many stocks and further efforts are still needed (FAO, 2022b). Some methods of fishing, such as bottom trawling, also cause significant damages to the seabed and have negative impacts on sensitive species (European Commission, 2021e)[5]. Fishing activities also have a major role in macroplastic release into the oceans[6]. A reduction in the environmental and climate impacts of fishing and aquaculture has ecosystem, food security and climate neutrality implications. As stated in the CINEA report (EC *et al.*, 2022), EU fisheries can be resilient to climate change and participate in climate mitigation and adaptation but only when sustainably managed in line with Maximum Sustainable Yield (MSY) principles of the CFP, to grant healthy and replenished fishing stocks. However, even healthy stocks that are properly managed may not be resilient in the long-term. Indeed, changes or shocks on one species can imply cascading effects on other species, with unforeseen and non-linear responses, impacting the biomass of stocks and ecosystem structure and function. For example, fishing mortality can combine with the effects of climate change and magnify the negative impacts on stock reproduction (Bastardie *et al.*, 2022, 2023). Aquaculture, a growing sector given the increase in seafood demand, raises issues related to the use of non-therapeutic antimicrobials (DeWeerdt, 2020; Schar *et al.*, 2020), to the effluents from fish farms to the possibility of the spreading of parasites, to the impacts of escapees on wild populations[7].

The state of **animal welfare**[8] in the livestock sector in the EU is a relevant issue for food systems and their sustainability, and has implications which relate to the diffusion of diseases, the safety of food products, farm productivity and in turn agri-food income (Peyraud and MacLeod, 2020). Animal welfare also relates to ethical issues such as animal abuse, cruel practices and negative consequences of intensive selection and production.

Environmental crises and climate change are expected to have serious impacts on key elements of food security, such as food availability, food prices, household income, food safety, and in particular on nutrition of vulnerable groups (Bezner Kerr *et al.*, 2022). **The negative impacts of food production and consumption are persisting because of the difficulties in including negative**

[5] These issues are covered by the EU Common Fisheries Policy that aims at the conservation of fish stocks and the reduction of overfishing for long-term stable, secure and healthy food supply.. See section 6.2 for more details.

[6] Together with the Single Use Plastic Directive Directive 2019/904 to decrease plastic waste (European Commission, 2019b), the Zero Pollution Action Plan includes a target to improve water quality by reducing waste, plastic litter at sea (by 50%) and microplastics released into the environment (by 30%) (European Commission, 2021b).

[7] In the beginning of 2022, the EU adopted the Veterinary Medicinal Products Regulation, which, among others, provides a set of measures to limit the use of preventive antimicrobials (European Commission, 2019c). Many issues faced by aquaculture are also informed by EU strategic guidelines for aquaculture

[8] Animal welfare can be defined as "the physical and mental state of an animal in relation to the conditions in which it lives and dies" (OIE, 2021) https://ec.europa.eu/food/animals/animal-welfare_en

externalities in food prices (Godfray *et al.*, 2010; SAPEA, 2020). This creates market distortions which favour unsustainable food products and related operations.

Inefficiencies across the whole food supply chain result in the generation of food losses and waste. The resource use and environmental impact associated with food production are embedded within food waste happening along the supply chain (Horton *et al.*, 2019), and aggregate further negative impacts arising from waste management and loss of valuable nutrients (Scherhaufer *et al.*, 2018). As roughly 20% of food produced in the EU ends up wasted, the scale of the problem is apparent. Failing to address food system inefficiencies leading to waste generation will exacerbate environmental impacts and food insecurity (Stenmarck *et al.*, 2016; De Laurentiis *et al.*, 2021). Increasing urbanization, extreme weather events and financial and institutional crises might intensify the already worrying scale of the problem.

The incentives underpinning the current food system still focus primarily on economic aspects and do not consider the negative environmental, social and health externalities. Existing incentives often do not induce actors with the greatest potential to adopt sustainable production and consumption practices nor do they capture short- and long-term costs and benefits of externalities. This is manifested, among others, in the continued degradation of the environment, socio-economic inequities and health issues. Furthermore, there is no integrated approach to account for the trade-offs and interplay between different sustainability dimensions with respect to the internalisation of externalities (De Schutter, 2017; FAO, 2018a; Piñeiro *et al.*, 2020; Hendriks *et al.*, 2021).

The global dimension of food systems adds to the complexity (European Environment Agency, 2017). Current food systems are highly globalised due to growth of international food trade in recent years, international input sourcing, foreign direct investments and the development of complex and global food supply chain governance mechanisms. In addition, food systems are intertwined with other systems such as energy, finance, climate, health, technology and transport, which in turn influence the way food systems operate. The viability and resilience of food systems cannot be seen in isolation but as interdependent with other complex systems. Disruptions or shocks in any of these systems can have repercussions on the viability and resilience of food system locally and at global scale.

2 Goal and scope of this report

The present report aims to contribute to the analysis of **sustainability transition** by providing further insights on the **environmental dimension**, and in particular on the contribution given by policy measures setting **requirements to foster food sustainability**.

The **analysis is structured around the following research questions**:

- What are the environmental impacts and the related relevant activities of EU food systems?
- How might the environmental impacts of the EU food system evolve without further policy action?
- What are the effects on the environmental impacts of the food system of specific policy measures?
- What is the coverage of different types of policy measures in terms of actors of the food system and of environmental impacts?

The remainder of the report is organised these questions, as follows. Section 3 is dedicated to the presentation of the methodology of the analysis. Then, first, to ensure a system perspective, a detailed and comprehensive mapping of the environmental impacts to the relevant activities and to the policy initiatives is provided (Section 4). Section 5 is devoted to the current environmental impacts of the European food system and what can be expected if no further policy action is taken. Then, we analyse the effects on the environmental impacts of selected EU policy instruments (Section 6), including the relevant sectoral policies and policy measures related to food waste. The, their coverage of actors and environmental impacts of the food system is assessed (Section 7). The results are discussed and conclusions presented in Section 8.

3 Methodology

The term "food systems" refers to all the elements and activities related to producing and consuming food, and their effects, including economic, health, and environmental impacts. The analysis conducted in this report focuses on the environmental impacts. The analysis was completed in summer 2023 considering policy up to 2022.

The analysis of the effects of the different policies on a wide range of environmental impacts is extremely challenging due to several factors. These include the difficulty in finding evidence of causal benefits of the different policy initiatives on each environmental indicator, the challenge of categorizing complex policies (such as for example the Common Agricultural Policy or Common Fishery Policy), as well as the complex nature of the food system and the interrelation that exists between many of its components.

As a result, a mixed methods approach has been designed for the analysis:

- Based on a **literature review,** we first performed an analysis to map each environmental impact both to the relevant activities (hotspots) and to specific policy measures (section 3.1.1); then, we analysed existing evidence on the potential effects of different policy measures (section 3.1.2), with specific focus on sectoral policies (section 3.1.3) and food waste (section 3.1.4).
- We further analysed existing policy initiatives that are currently in place at EU level and that are relevant for the food system and for targeting the environmental objectives through **semi-automatic text mining** analysis of a dedicated EU policy database (Section 3.2).
- In addition, we analysed in detail the Code of Conduct, one of the most recent voluntary instruments that has been proposed at the EU level (Section 3.3).
- Finally, we interpreted the results to understand how the selected environmental impacts are dealt with in the EU current legislation.

These approaches are described more in detail in the sub sections that follow.

3.1 Literature review

A broad literature review was carried out. Data was collected and organized in relation to the current EU food system, its main environmental impacts, the actors involved, the main policies currently in place in the EU, how the environmental impacts are related to the main activities and practices of the food system and the areas of intervention. Further details are included in Annex 2.

3.1.1 Mapping of environmental impacts

The analysis of the environmental impacts is complex because the policies cover a wide range of actions and of aspects of the whole food system: from the manufacturing of input products until the final consumption of meals.

For this reason, an attempt has been made to spell out the relationship existing between the different environmental impacts (e.g., climate change, ozone depletion, land use and so on), the relevant activities related to each impact (e.g., energy consumption or fertilisation practices both emit greenhouse gases) and, finally, the related policy initiatives (e.g., initiatives related to energy and climate, to circular economy, or to organic production).

We thus carried out a literature analysis of how the selected environmental impacts are related to the food system and organized the outcomes in a set of relationships that exemplify and clarify all possible existing causal links. The main output of this analysis is a table that links each environmental impact to the related relevant activities (hotspots) along the supply chain and ultimately to the related policy initiatives.

3.1.2 Analysing the potential effect of policy measures

This literature review aims at providing an overview of the relevance and effectiveness of policy instruments to support sustainable food systems. The search focused on the following types of policy measures: 1) **voluntary measures**, 2) **due diligence** provisions, 3) regulatory instruments used to establish **requirements related to sustainability**, amongst others. Details can be found in Table 1.

Table 1. Type of policy measure and description, as considered in this study.

Policy measure	Description
Voluntary measures	Include codes of conduct or dissemination and education campaigns, which aim to support actors in undertaking sustainable choices in their businesses.
Due diligence	Include all those tools available to business operators to ensure that good practices with respect to the environment or social issues are taken into account in the productive process.
Regulatory instruments (mandatory)	Include all those legal instruments, such as rules and regulations, that mandate behaviours, standards or minimum requirements, impose a ban or limit, etc.

Source: Own elaboration

3.1.3 Main sectorial policies (CAP & CFP)

A scoping exercise on the available literature on the design and impact of EU policies such as the Common Agricultural Policy (CAP) (2014-2022)[9] and the Common Fisheries Policy (CFP) has been conducted, as these play an important role to support and incentivise the adoption of sustainable agricultural and food practices.

3.1.4 Food waste and waste generation

Food losses, food waste, and waste are generated across the food supply chain, from production to final consumption. Embedded within the material losses there are substantial environmental impacts, as well as social and economic costs. In particular, food waste hinders the efficient allocation of resources and the achievement of food security for all.

The environmental impacts of food waste and of waste generation have been at the attention of EU policy-makers, leading to a proposal of legally binding targets on July 5 2023[10].To analyse the effects of policies on food waste, a literature review has been carried out starting from documents from EU platforms (such as the EU Platform food loss and food waste hub[11]) and EU funded projects (such as REFRESH[12]); documents providing results from interventions to reduce food waste, both voluntary and mandatory, including policy instruments such as GPP or due diligence; extensive review on interventions to prevent food waste, building from Caldeira *et al.* (2019), Reynolds *et al.* (2019) and

[9] The CAP analysed in this report is that of 2014-2022, as the current CAP 2023-27 was under negotiation during the preparation of this study.

[10] https://environment.ec.europa.eu/publications/proposal-targeted-revision-(waste-framework-directive_en

[11] https://food.ec.europa.eu/safety/food-waste/eu-actions-against-food-waste/eu-platform-food-losses-and-food-waste_en

[12] REFRESH was an EU research project taking action against food waste. 26 partners from 12 European countries and China work towards the project's goal to contribute towards Sustainable Development Goal 12.3. https://eu-refresh.org/index.html

Stöckli *et al.* (2018). The outcomes of this literature review can be found in (Casonato *et al.*, 2023) and (Swannell *et al.*, 2023).

Regarding waste, besides consulting EEA waste management reports[13] and waste management statistics from EUROSTAT[14] focusing on municipal waste (for the consumption level or along the food supply chain), a particular analysis was carried out with regards to plastics, due to its relevance as packaging material in agricultural processes and food consumption. The review was done revising scientific literature in Scopus under the key words "Packaging waste" and "Food", and "Plastic waste" and "Food". Only findings within the scope of this research were analysed (e.g. excluding those works related to food contact regulations). Moreover, publications by knowledgeable organisations such as Plastics Europe[15] and ZeroWaste Europe[16] were also revised. The main initiatives targeting packaging reduction or better sorting are listed in Annex 3.

3.2 Semi- automatic text mining analysis of the EU policy measures

A dedicated EU policy database JRC (forthcoming) allowed to **analyse EU existing policy initiatives** that are relevant for the food system and for targeting the environmental objectives, to better understand how the environmental impacts are currently addressed and how actors of the food system are involved. Exploring the database allowed us to shed light on a wide, but not exhaustive, set of the current EU legislation. Several EU legal acts and preparatory documents relate to the EU food system or to some of its elements, and some of these include specific measures for addressing food sustainability. The database provides information related to the type of measures included in each policy initiative, the elements of the supply chain involved and details on the content of the specific measure.

It is important to underline that the analysis represents a pragmatic attempt to systematically assess the coherence of current policies in terms of coverage of environmental impacts and actors, combining a text mining approach with extensive expert validation.

A semi-automatic text mining approach has been used to identify EU relevant policies. The final set of policies relevant to EU food system has been discussed and validated by the relevant Commission's services. The database includes 142 legal acts adopted from 1993 until 2021 in force at the time of the query (February 2022), and 92 preparatory documents from 2014 to 2021. These documents were manually screened for relevant information. Concerning the legal acts, the database includes information related to the actors of the supply chain involved and the type of policy measures contained in the document; 333 specific policy measures have been identified (as one legal act can include more than one measure).

For the purpose of this report, all these 333 measures have been further analysed and the information attached to them has been enriched with focus on the environmental dimension.

First of all, we looked at the types of policy measure, and detected prescriptive legislation, labelling schemes, product labels, certification and accreditation, and audits more frequently than public investment, taxation, benchmarking, and education and training. These measures have been attributed, when possible, to one of the three main categories of policies highlighted in section 3.1: either voluntary, due diligence or regulatory instruments (mandatory).

Second, we analysed the dataset of EU policy measures with the goal of understanding how coherent the current legislative landscape governing the European food system is concerning the actors

[13] https://www.eea.europa.eu/themes/waste/waste-management
[14] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_statistics
[15] Plastics Europe is a European trade association, with centres in Brussels, Frankfurt, London, Madrid, Milan and Paris. https://plasticseurope.org/
[16] Zero Waste Europe is the European network of communities, local leaders, experts, and change agents working towards the elimination of waste in our society. https://zerowasteeurope.eu/

involved and the environmental impacts addressed. Each measure has been therefore associated to one or more of the actors of the food system (for a detailed description of the actors of the food system, refer to Annex 1).

Finally, on the basis of the research described in section 3.1.1, we have associated to each measure to the major environmental impacts that it aims to address. The combination of these pieces of information allows us to derive a preliminary assessment of how environmental impacts of the food systems are currently addressed.
In addition, the effects of the current EU policies on environmental impacts is substantiated through desk research on available literature and relevant examples (e.g., best practices) as presented in section 3.1. However, no substantial results were found in the available literature to link in a direct way the effects of the considered set of policies with specific environmental impacts.

The policies measures outlined here are not meant to represent an exhaustive list, however they provide a good overview of relevant policies and regulations related to sustainable food systems.

3.3 Analysis of the EU Code of Conduct on Responsible Food Business and Marketing Practices

Launched in July 2021, the EU Code of Conduct on Responsible Food Business and Marketing Practices is one of the first deliverables of the Farm to Fork Strategy (European Commission, 2020a), and a recent example of voluntary measures in the food system. This measure has been developed with EU associations and companies, as well as international organizations, NGOs, trade unions and trade associations. The pledges and achievements for the year 2022 have been collected and organized (based on those reported in the dedicated website[17], last consulted on 31 July 2022).

The signatories' companies report their pledges articulated in aspirational objectives (AO) and related targets, which are organized as follows:

- **AO1. Healthy, balanced and sustainable diets for all European consumers**. Aspirational targets: a) Improved food consumption patterns in the EU and b) A food environment that makes it easier to choose a healthy and sustainable diet.
- **AO2. Prevention and reduction of food loss and waste** (at consumer level, within internal operations, and across value chains) with the aspirational target to reach a 50% reduction of per capita food waste at the retail and consumer level by 2030, and reduce food losses along the food production and supply chains in the EU.
- **AO3. A climate neutral food chain in Europe by 2050**, targeting a 55% GHG emission reduction target in the EU food chain by 2030 (compared to 1900 levels).
- **AO4. An optimised circular and resource-efficient food chain in Europe**. Aspirational targets: a) Improved resource-efficiency within own operations, contributing to sustainable, efficient use and management of energy and natural resources in operations by 2030 b) Improved sustainability of food and drink packaging, striving for all packaging towards circularity by 2030.
- **AO5. Sustained, inclusive and sustainable economic growth, employment and decent work for all.** Aspirational targets: a) Improved resilience and competitiveness of companies operating at any point along the food value chain by 2030 b) Quality jobs, skilled workforce and safe and inclusive workplaces for all.
- **AO6. Sustainable value creation in the European food supply chain through partnership**. Aspirational targets: a) Improved resilience and competitiveness of companies operating at any

[17] https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy/sustainable-food-processing/code-conduct_en

point along the food value chain by 2030 b) Continued progress towards sustainable production, contributing to sustainable management and efficient use of natural resources by 2030 and improved animal welfare.

— **AO7. Sustainable sourcing in food supply chains**. Aspirational targets: a) Transformed commodity supply chains which do not contribute to deforestation, forest degradation and destruction of natural habitat and which preserve and protect high value ecosystems and biodiversity b) Improved social performance in (global) food supply chains.

It should be noted that that associations can represent companies with very different features and might commit to different types of pledges compared to individual companies:

— endorse the aspirational objectives set out in the Code (where applicable);

— promote and disseminate the Code with(in) their constituency/ies;

— encourage their members to align their sustainability actions and/or business practices to the aspirational objectives and targets of the Code and invite them, on a voluntary basis, to adhere to the Code, as appropriate;

— explore the possibility of developing sector-specific tools and resources in support of the Code;

— provide, on an annual basis, a report of their activities in support of the Code, which will be published on an open dedicated website;

— continue to engage in dialogue with other food chain/systems actors and EU and international policy-makers to forge (new) relationships, exchange good practices and discuss challenges encountered, learn from each other (studies, projects) and create better mutual understanding, and identify opportunities for collaboration and potential partnership.

Our analysis aims at assessing and mapping the commitments reported for the Code. The elements considered are the following:

— Analysis of signatories: type of signatory, sector, geographical scope;

— Analysis of companies' commitments;

— Mapping of companies commitments with environmental impact categories;

— Description of associations' commitments status.

4 What are the environmental impacts and the related relevant activities in EU food systems?

The analysis of the environmental impacts is complex because the policies cover a wide range of actions and aspects of the whole food system, from the manufacturing of input products until the final consumption of meals at home. For this reason, an attempt has been made to detail the relationship existing between identified main environmental impacts (e.g., climate change), the relevant activities related to each impact (e.g., energy consumption or fertilisation practices both emit greenhouse gases) and the policy initiatives targeting this impact (e.g., initiatives related to energy and climate, to circular economy or to organic production).

The set of these relationships is summarized in Table 2 and detailed in Annex 2.

Table 2. Mapping of the environmental impacts with the main hotspots along the supply chain and the related type of initiatives.

Environmental impact	**Relevant activities (hotspots) along the supply chain**	**Related policy initiatives**
Climate change	Land use and land use changes (incl. deforestation), energy consumption along the supply chain (incl. fertiliser production), fertilisation, animal effluent management (incl. enteric fermentation emissions and effluents management), transportation (incl. fuels for machinery)	Energy and climate, local production, organic production, animal farming, circular economy, deforestation, supporting plant-based diets, waste management, GPP
Ozone depletion	Transportation and refrigeration, fertilisation	Local production, technological improvements, fertilisation practices, GPP
Land use (incl. deforestation and soil health)	Farmland expansion, energy production and use along the supply chain, soil management practices (such as practices that increase soil fertility and quality and prevent soil degradation – e.g., increasing soil organic matter, implementing cover crops, crops rotation, no or minimum tillage)	Energy and climate, halting deforestation, organic production, fertilisation practices, supporting plant-based diets, GPP
Water use	Irrigation, processing	Supporting plant-based diets, circular economy, water management/conservation practices, GPP
Eutrophication	Fertilisation (incl. synthetic and organic fertilisers), animal farming, aquaculture	Fertilisation practices, organic production, animal effluent management and treatment, supporting plant-based diets
Ecotoxicity	Agrochemicals (pesticides and fertilisers)	Organic production, fertilisation practices, pesticides reduction practices, GPP, supporting plant-based diets
Particulate matter	Energy consumption along the supply chain (incl. machinery used in the fields), fertilisation, crop residues burning	Energy and climate, fertilisation practices, GPP, local production
'Resource minerals and metals	Agrochemicals, packaging	Synthetic fertilisers, organic production, GPP, reusable, recyclable and compostable packaging, bio-materials
Biodiversity loss	Land use changes, farming management (concerning biodiversity at farm level: species and genetic diversity of cultivated crops and animal breed, GMO; concerning biodiversity at higher levels: ecosystem preservation or improvement, wildlife protection, protection of flora and fauna), pesticides, fisheries management	Deforestation, sustainable fishing, organic products, pesticides reduction, GMO, seeds, GPP
Waste generation	Packaging	Reusable, recyclable and compostable packaging, circular economy, waste management, GPP
Food waste generation	Food consumption (incl. households, retail and food services), processing	GPP, consumer awareness campaigns
Biotic resources (overexploitation)	Fisheries and aquaculture, livestock feedstock	Sustainable fishing practices, animal farming, GPP

Source: Own elaboration

5 How might the environmental impacts of the EU food system evolve without further policy action?

Under the current situation, existing trends are expected to be maintained, leading to an increase of environmental impacts associated to the EU food system (European Environment Agency, 2021b). Furthermore, due to cascading effects, environmental impacts are expected to be further exacerbated by the increasing magnitude of the consequences of planetary crises, e.g. climate change, biodiversity loss, water stress (e.g., IPBES, 2021; Shukla et al., 2019).

More specifically, the analysis of selected EU policies (see section 3.2 and JRC, forthcoming) shows that legal acts, which are specific in their scope and fields of application, fail to capture the food system holistically and with a systemic perspective. In most of the cases, they instead have a sectorial perspective: they do not target all sustainability dimensions (environmental, economic, social including health), nor they cover all the identified elements that are considered necessary for sustainable food systems.

Despite the predominant sectorial nature, the analysis also shows that the EU is increasingly embracing an integrated sustainability perspective in the text of some of its policies, with the Farm to Fork strategy as the most comprehensive example addressing all sustainability elements.

Other policy documents adopting a more comprehensive approach to sustainability dimensions include the Regulation 2021/2115 on the Rules for the Common Agricultural Policy (CAP) Strategic Plans and, the Regulation 1380/2013 on the Common Fishery Policy (CFP). However, different product groups and their associated economic sectors are addressed separately - CAP and CFP for agriculture and fisheries, respectively – thus leading to different environmental aspects and stages addressed as well as uneven levels of strictness.

Even though some progress has been registered, policy efforts have not been enough to counteract the increasing environmental impacts of the EU food system. Historically, the CAP has targeted mainly the economic and environmental aspects of sustainability of EU agriculture and has focused on the primary sector. However, the CAP presents some shortcomings related to environmental sustainability and a lack of an integrated assessment behind the definition of CAP targets, which creates the possibility for conflicts between different objectives (Recanati *et al.*, 2019). It follows that a weak link exists between environmental objectives and the relative actions within the CAP (Solazzo *et al.*, 2016). For climate change, a modest decline in non-CO_2 emissions is expected in the EU agriculture sector[18], thus showing the need for further action (European Environment Agency, 2022a). Moreover, there is a mismatch between Ecological Focus Areas goals and the implemented actions, since the most effective measures for conserving biodiversity are barely selected by farmers (Sutherland *et al.*, 2016; Pe'er *et al.*, 2017). Another example are the discrepancies among regulations and directives in assigning funds for water savings to enable water use reduction within the CAP framework (European Environment Agency, 2019a, 2021b). Finally, social considerations are emerging: the Regulation on the Rules for the CAP Strategic Plans, for example, looks at resilient and economically sustainable food production for food security and agricultural diversity.

Regarding fisheries, the last monitoring of the CFP performance indicates that the overall status of fish stocks and biomass levels in the North-East Atlantic has improved since 2003 (STECF, 2022). Yet, some stocks are still overfished and/or outside safe biological limits (40% in 2016). In the Mediterranean and Black Sea, the situation is more challenging, with annual fishing mortality twice as high as the Maximum Sustainable Yield (MSY) for the entire 2003-2019 period. The Mediterranean can be considered a biodiversity hotspot, yet largely degraded: only 6% of all the assessed stocks for the area are below or at MSY level (European Environment Agency, 2019c). Hence, CFP measures for

[18] If currently planned additional measures are implemented, a 6% reduction is expected highlighting the need for further action to reduce non-CO_2 emissions in the agriculture sector.

the Mediterranean have not yet contributed to improving the poor situation of stocks (European Environment Agency, 2019c).

Finally, both the CAP and the CFP are disputed in their success in delivering sustainability objectives (SAPEA, 2020). At this regard, to reinforce the possibilities to successfully reach its sustainability targets, the new CAP 2023-27 aims at being fairer, greener and more performance-based. It is built around ten key objectives encompassing social, environmental and economic goals. These objectives will be the basis upon which EU countries design their CAP strategic plans. In particular, a new "no backsliding" principle is applied on environment and climate ambition, which should be equal or higher compared to previous programming periods, and national CAP strategic plans are also bound to uptake the updates of climate and environmental legislation.

An improvement in the environmental sustainability of food production is expected to come from the Nature Restoration Law recently adopted by the European Commission as an important action to face climate and biodiversity crises, threatening long-term food security (IPBES, 2021). Maintaining agroecosystems in good condition means enhancing self-reproduction or self-restoration capabilities of processes and functions that are the basis of food production. A regenerative, non-depleting and non-destructive use of natural resources is essential to guarantee the right to food of current and future generations. Sustainable soil management and the restoration of degraded land is critical and is targeted by multiple European Green Deal ambitions through efficient nutrient management, including carbon sequestration to offset climate change (Common Agricultural Policy), reducing pesticide residue levels (Farm to Fork and Zero Pollution Action Plan), and reduced soil sealing and organic waste cycles (Circular Economy Action Plan).

The current legislative context might not meet the needs to counteract global environmental crises – such as climate change or biodiversity loss – which in turn have a crucial effect on the ecosystem sustaining food production. This jeopardizes the resilience of the global and EU food systems. EU policies related to food systems 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 (Biondi *et al.*, 2019; Emiliani *et al.*, 2020). Market support measures and direct payments for increasing competitiveness dominate over health and sustainability measures (Elinder, 2005; Birt *et al.*, 2017).

Due to persisting current trends, with no further actions, the EU food system is expected to remain highly resource intensive: current practices will continue to maintain or slightly decrease the high use of chemical inputs and machineries, all having effects on many environmental impacts (mainly resource minerals and use, eutrophication, ecotoxicity, particulate matter and ozone depletion). Intensive agriculture has in turn effects on the surrounding environment, namely on biodiversity.

The current EU food system is leaking various environmental impacts at the international level, for example through the delocalization of agricultural production to third countries with lower sustainability standards, leading to increasing impacts related to GHG emissions and land-use. An increase in trade could lead to increasing the environmental impacts on land use and deforestation, with consequences on other specific environmental impacts related to trade (e.g., climate change, ozone depletion) or to regional impacts that would be delocalized to third countries (e.g., land use, water use). Delocalization of impacts to third countries occurs also for fisheries for which, even though agreements are signed, regulations are not respected by EU vessels operating in non-EU waters and illegal activities also occur (Seto, 2015; Okafor-Yarwood and Belhabib, 2020).

Reduced food waste along the supply chain resulting from on-going initiatives (i.e., EU proposal for legally binding targets to be set by 2023) may have positive benefits on the other environmental impacts as food production would be reduced to satisfy the same demand. However, waste generation, in relation to food processing and packaging both for trade and for consumers, may be expected to increase.

6 What are the effects on the environmental impacts of the food system of specific policy measures?

This section includes the results of the analysis of the scientific and grey literature to look for the effects of different types of policy measures on environmental impacts (section 6.1). We found scarce literature that analysed the cause-effect relationship of the selected policy instruments to the effects on the sustainability of the food system in general. Therefore, to better understand the environmental impacts of the food system, we looked at the existing policy initiatives currently in place at the EU level for the food system (section 6.2); then, we focused on specific legislation such as the CAP and CFP (which are of relevance for the impacts of the agricultural and marine sectors, section 6.3) and to the Code of Conduct (a recent example of voluntary measures in the food system, section 6.4). Finally we carried out a more accurate analysis of the policies governing food waste and their effects (section 6.5). The most relevant findings are outlined below.

6.1 Results from the literature review

In the review on policy instruments for sustainable food consumption by Ammann *et al.* (2023), only two scientific papers are found that deal with regulatory instruments, whilst most of the scientific literature reviewed focuses on information-based instruments, such as labels or information campaigns.

As for the regulatory instruments, "command-and-control" regulations can be associated systematically with reductions in air pollutant emissions; however, for this to happen, sound implementation and control structures are necessary (Steinebach, 2022). Another example is the one of harmful pesticides that have been banned from the market thanks to stringent procedures in the past decades (e.g., Phillips McDougall, 2018). The EU's re-registration process (directive 91/414) has led to the removal of over half of the crop protection active ingredients (293 out of 499) of commercial significance. Another example of the application of regulatory instruments is provided by Denmark. Since the early 1990s, this country has reduced its nitrogen balance by 56% and its phosphorus balance by 58%, although its agricultural production has continued to increase over this period. Policy makers used a mix of instruments, including targets for reductions of nitrogen and phosphorus discharges, fertiliser accounting systems, nitrogen quota systems to regulate the use of fertilisers, bans on manure application on bare fields, fertiliser taxes for non-agricultural uses, taxes on phosphorus content in feed, as well as agri-environmental schemes and advisory services (OECD, 2019).

Similarly, but more related to consumer preferences, (Panzone *et al.*, 2011) found that quantity control instruments (e.g., a ban or removal of the most polluting alternative) performed better than did price incentives and labelling in promoting sustainable food consumption. However, (Panzone *et al.*, 2011) also underline that good results may be achieved when combining different policy instruments.

A recent analysis on the linkages between policies, productivity, and environmental sustainability (Lankoski and Thiem, 2020) shows that countries achieve high sustainable productivity if agricultural support payments are either not coupled to production or if such payments have environmental constraints attached. Thus, again pointing to a main regulatory approach, that can then be coupled to other market-based policies.

In a modelling exercise, a restriction on livestock densities at EU NUTS2 level was found to have positive results with respect to reduction of nitrogen surplus, the reduction of greenhouse gases, the improvement of clean water, and an increase in biodiversity (Latka *et al.*, 2018). However, these results do not consider the potential rebound effect with a consequent decrease in EU production of meat and the relative increase of imports to satisfy the market demand – which also highlights the need to address environmental change together with dietary changes (social and health dimension).

A policy only implemented by the EU could lead to environmental leakage in other countries through the change of trade flows.

In another modelling exercise, using CAPRI to simulate the effects of specific policies, results show that by combing the targets of the Farm to Fork and of the biodiversity strategies, a significant reduction of GHG emissions may be delivered (28.4% reduction by 2030 compared to the baseline, details are in the report) (Barreiro-Hurle *et al.*, 2021). This would be achieved by regulatory instruments, such as reducing the use of pesticides and the use of nutrients, combined with an increase of land under organic farming and of agricultural land under high-diversity landscapes figures.

The literature on agricultural related policies points out a general failure at addressing environmental sustainability (DeBoe, 2020; OECD, 2021). In particular they point out that coupled agricultural support policies[19] often encourage farmers to expand production, to use more fertiliser and other inputs, and/or to expand agricultural land use, leading thus to negative environmental impacts. By contrast, relatively less coupled payments, such as those based on historical entitlements, do not encourage intensification or an expansion of agricultural land use and are therefore less harmful to the environment (Henderson and Lankoski, 2019; OECD, 2019). On the other hand, (DeBoe, 2020) also points out that there is limited evidence that existing mandatory constraints successfully mitigate negative environmental impacts of agriculture (such as impacts on water pollution or on biodiversity). This suggests that the design of mandatory constraints could be improved to deliver better environmental performance.

Interesting findings emerge if the perspective of the literature review is changed, switching from looking for the types of policy instruments to the *object* of such policies. For example, what emerges from the analysis carried out in the context of the FIT4FOOD2030[20] project, is that policies in the EU associated with 'nutrition and health', mainly on food safety, malnutrition and obesity, are significantly more prevalent, while policies on 'circularity and resource efficiency', 'climate and sustainability' and 'innovation and communities' are less present (Biondi *et al.*, 2019). Results of the FIT4FOOD2030 project are based on the analysis of an extended database that was built merging information from 460 policies related to food and food systems (up to March 2019), 179 implemented at EU level, the rest at MSs level. From the same analysis, it also emerges that there are differences between the groups targeted (consumers, food industry, fisheries, agriculture, R&I) by different types of policies (regulations, food and agricultural standards, information and labelling measures, etc.) and the level at which these policies are adopted (EU or Member State). For example, EU policies consist for more than 50% of regulations mainly addressing farmers, import/export companies, public authorities and fisheries. National policies target primarily the food industry followed by farmers and "others" actors, and consist of regulations and research and R&I instruments.

Taken together, all these insights suggest a complex and fragmented policy landscape in the EU and in Member States, which can act as a barrier to more systemic and transformative approaches to the governance of food systems. A recent EEA report notes that, while there are some synergies between the goals of the CAP, CFP and F2F strategy, policies that influence the EU food system, the overall EU food policy mix "sends mixed signals because of incoherencies between policy goals" (European Environment Agency, 2023). The overall EU food system is characterised by different approaches at Union, national and sectoral levels vis-à-vis sustainability aspects (Biondi *et al.*, 2019). Where sustainability aspects are addressed at those different levels, they lack a common approach and are not always comprehensive. With the current approach, EU legislation mainly deals with food-related issues by looking at one or more actors and/or one or more parts of the food system, however, not in

[19] Coupled support measures such as import tariffs or output and input subsidies
[20] More information on the project is available at https://fit4food2030.eu/theproject/aims-objectives/

a holistic and systemic way. In a similar way, when sustainability is addressed, not all aspects are considered at the same time and the same level.

Historically, the Union policies regulating the functioning of different parts of the food system (such as the Common Agricultural Policy, the Common Fisheries Policy, and legislation on food safety, the environment, health, research and innovation, trade and competition amongst others), have developed sectorally. Moreover, they have mainly been elaborated in an ad-hoc fashion and may result disconnected from each other, rather than governed under a coherent and integrated framework. Instead, policies that address the interconnectedness of different sectors of the food system and integrate them with a systemic approach (whole-of-food system transformation) are necessary (European Economic and Social Committee, 2017a; iPES Food, 2019; HLPE, 2020).The literature has extensively criticized the fragmentation of food policies and governance by underlying its inconsistencies, overlaps and gaps, thus calling for more coherence (Sonnino, Faus and Maggio, 2014; Slade, Baldwin and Budget, 2016). Since food systems comprise many subsystems that cut across boundaries between policy sectors, jurisdictions, geographical and temporal scales, and involve different actors (e.g., (Hospes and Brons, 2016)) a degree of fragmentation is conceivable. However, conflicting objectives and lack of harmonization can result in inconsistent governance (Termeer *et al.*, 2018).

Policies interact among them causing synergies and trade-offs (OECD, 2021). Fragmentation and a silo approach to policymaking cannot account for these interactions, neither capitalising on positive linkages nor addressing existing trade-offs. Some examples of challenges emerging from silo thinking include, for instance, biomass competition in agri-food and bio-economy policies (Muscat *et al.*, 2020). For this reason, integration across policy domains and nexus policymaking, as well as acknowledging complexity and uncertainty due to multiple scales and sectors, can be fit for navigating the governance of multifaceted food systems and kick-start transformative change (Smith *et al.*, 2016; Candel and Pereira, 2017; Recanati *et al.*, 2019; Muscat *et al.*, 2020).

6.2 Analysis of current EU policy measures

The semi-automatic text mining analysis of the EU policy database (see section 3.2) provided some insights by type of measure: voluntary measure, due diligence initiative or mandatory requirement. The complete list of the EU policy measures that have been analysed is compiled in JRC (forthcoming).

Within the whole set of policy measures included in the EU policy database we selected 21 measures that can be representative of **voluntary measures**. The measures collected were awareness campaign (11 measures), code of good practices (8 measures) and covenants (1 measure). Only five measures addressed two or more categories of actors of the supply chain. The presence of several measures on fertilizers and pesticides is reflected in the type of actors involved, mainly input producers and primary producers. Eight measures dealt with seed varieties or basic vegetative propagation material and the corresponding accepted practices for their maintenance. These measures are directed towards input providers and relate to environmental impacts on biodiversity. Another measure (code of good practice) deals with accepted practices for the maintenance of the variety and is targeted at input providers and MS authorities. Two measures dealt with information campaigns targeted at primary producers concerning good practices related to the use of fertilizers. One measure dealt with information campaigns targeted at primary producers concerning good practices related to water use. Four measures (awareness campaigns) address consumers regarding issues of waste generation, GMOs and pesticides. There is one awareness campaign directed at input providers and primary producers for a catalogue of plant species and GMOs. There is one partnership agreement (covenant) on sustainable fisheries addressing traders. There is one code of conduct for MS authorities for the application of food and feed law, rules on animal health and welfare, plant health and plant protection products. One awareness campaign is dedicated to the CAP and the dissemination of its contents among primary producers and consumers. Two overarching awareness

campaigns were included, dealing respectively with organic products and with the setting up of the European Clean Air Forum. These two measures involve all the actors of the food system.

From the entire dataset of EU policies, we selected 8 measures that could be associated with due **diligence initiatives**. Due diligence is currently a voluntary initiative taken on by a company or implemented through legislation. An example is the Non-financial Reporting Directive (Directive 2014/95/EU) which introduces disclosure requirements on environmental and social indicators from certain businesses, namely those with more than 500 employees. In the analysis for the group of measures falling under due diligence, 8 measures relevant for the environmental impacts were selected from the database of EU policy initiatives. Analysis shows that the current coverage of environmental impacts by these measures focuses on agricultural primary production (e.g. impacts of eutrophication due to fertilizers or ecotoxicity due to chemicals use) and to a less extent on biodiversity and land use (organic products). Water use and waste generation are also addressed. Of the analysed measures, six measures target one actor only, while the remaining two measures target four and five actors. Actors involved are predominantly from the input providers and primary producers sector, even though other actors are represented, with the exception of MS and EU authorities.

From the database of EU policy measures, we selected 45 policy initiatives, relevant with respect to the environment that can relate to some extent to **mandatory requirements**. Among these policy initiatives (a policy initiative may include more than one specific measure) we identified 34 specific measures falling under prescriptive legislation and 11 specific measures falling under mandatory requirements. The high number of policy measures considered is related to the fact that it is in fact possible to affirm that any legislative prescription translates, at the end, in respecting some sort of limit, or minimum requirement, set by the law. The analysis of these policy measures supports the analysis policies related to minimum requirements.

6.3 A focus on sectoral policies: design, environmental impacts and challenges

The analysis of policies addressing EU food production was supported by specific focus on the CAP and CFP. In a recent report, the EEA (European Environment Agency, 2023) considers that: “the EU policy mix governing Europe's food system is characterised by gaps and inconsistencies that limit its transformative potential [...]”.

There is growing consensus on the need to set common directions towards sustainability for the whole food system, bringing together various sectorial policies and coordinating and aligning actions. In fact, historically, the Union policies regulating the functioning of different parts of the food system (such as the common agricultural policy (CAP), the common fisheries policy (CFP), and legislation on food safety, the environment, health, research and innovation, trade and competition amongst others), have developed sectorally. Moreover, they have mainly been elaborated in an ad-hoc fashion and result thus disconnected from each other, rather than governed under a coherent and integrated framework. Instead, many authors and institutions emphasise the need for policies that address the interconnectedness of different sectors of the food system and integrate them with a systemic approach (whole-of-food system transformation) (European Economic and Social Committee, 2017b; iPES Food, 2019; De Schutter, Jacobs and Clément, 2020; Galli *et al.*, 2020; HLPE, 2020; European Environment Agency, 2023).

Common Agricultural Policy (CAP)

The Common Agricultural Policy (CAP) has progressively introduced environmental sustainability goals over the last decades and has been repeatedly reformed in the attempt to tackle environmental issues (European Commission, no date). The introduction of environmental goals started in 1993 with the introduction of agri-environmental measures, while greening payments have been implemented starting in 2015 (Recanati *et al.*, 2019; Salvan *et al.*, 2022). The CAP 2014-2020 (Regulation (EU) 1307/2013, Regulation (EU) 1308/2013 Regulation (EU) 1305/2013, Regulation (EU) 1306/2013)

addressed environmental concerns through Pillar I, which enforces direct payments and market measures, and Pillar II which incentivizes and remunerates farmers voluntary practices that go beyond the mandatory requirements (Recanati *et al.*, 2019).

Despite these efforts, EU agriculture remained one of the major drivers of negative impacts on the environment, as analysed in Section 4. For this reason, the coherence and the efficacy of the environmental policy integration into the CAP has been extensively debated in the scientific literature (Erjavec and Erjavec, 2015; Salvan *et al.*, 2022). For instance, the greening measures were found to be not particularly effective for GHGs emissions abatement (Solazzo *et al.*, 2016) and had a neutral and negligible impacts on biodiversity (Pe'er *et al.*, 2014). This might be associated with a lack of integration between policy objectives and actions, as in the case of the Ecological Focus Areas (EFA) options among which the most beneficial for the environment were barely selected and implemented by farmers (Pe'er *et al.*, 2017). Indeed, although some of CAP instruments and measures (e.g., the Natura 2000 measures) made significant contribution to the conservation of semi-natural farmland habitat and their species, the overall biodiversity monitoring indicates that these measures did not counteract the pressure on biodiversity from agriculture (EC, 2019). The CAP environmental commitment resulted also fragmented and disharmonized with the other EU environmental policies (Recanati *et al.*, 2019) as in the case of the integration of the EU water policy objectives with the CAP, which resulted only partially successful (European Court of Auditors, 2014).

In addition to the intrinsic discrepancies between CAP objectives and actions, and the incoherence with other environmental policies, the call for incorporating the nutritional and health aspects has been also in the spotlight of the policy debate for decades (Elinder, 2003; Hawkes, 2007). Indeed, the failure in supporting the increase in production of fruit and vegetables compared to other sectors (Recanati *et al.*, 2019) resulted in higher affordability for foods with high saturated fat content than fruit and vegetables (Faculty of Public Health, 2007).

To align with the EGD objectives, the new CAP (2023-2027) in place from January 2023 (Regulation (EU) 2021/2115, Regulation (EU) 2021/2116, Regulation (EU) 2021/2117) aims to overcome these challenges by improving the coherence with other EU polices to address environmental and climate objectives and proposing from one hand a new system of 'conditionality' and from the others a complementary tool of voluntary measures for farmers (EC, 2019[21]). Indeed, the new CAP architecture replaces the Cross Compliance schemes with two mechanisms: the Statutory Management Requirements (SMR) and the Good Agricultural and Environmental conditions (GAEC), an additional set of land maintenance conditions that farmers must respect to receive the CAP support. To higher the ambition beyond conditionality, the reform envisages voluntary measures in Pillar I such as the Eco-schemes, which substitute the previous greening payments, and the Agri-environment-climate Measures (AECM) in Pillar II.

Although the possible outcomes of CAP reform are promising, some doubts emerged on the efficacy of production-oriented mechanisms in the form of payments per hectare and number of livestock heads which remained unchanged. The same mechanisms contributed to the agricultural intensification in Europe (Pe'er *et al.*, 2017), which represents one of the major causes of biodiversity loss and ecosystem degradation (EEA, 2019), and could hamper the CAP in place to achieve the biodiversity objectives set by EGD and Biodiversity Strategy. In addition, while new indicators were introduced to evaluate agricultural impacts on biodiversity, a comprehensive monitoring framework

[21] https://agriculture.ec.europa.eu/system/files/2021-01/cap-post-2020-environ-benefits-simplification_en_0.pdf

that, for instance, accounts also for freshwater and insects' species could help to halt negative trends (European Court of Auditors, 2020; Cuadros-Casanova *et al.*, 2023).

Further, Eco-schemes could represent a powerful tool to achieve climate mitigation objectives with fixed budget allocation for climate-friendly measures (Guyomard *et al.*, 2020), however, their level of ambition depends on the national strategic plans implemented by Member States, highlighting the need of a review of strategic plans by the Commission (Pe'er *et al.*, 2022).

Finally, food systems impacts outside Europe should be considered too. Indeed, results from the analysis of (Barreiro-Hurle *et al.*, 2021) based on CAPRI model, illustrate that the change in production patterns and fertilizers use could lead to a reduction of emissions in the agricultural sector, however, more than half of them is leaked to the rest of the world causing an increase of emissions in non-EU regions.

Hence, while if and how the new CAP reform could achieve its climatic and environmental ambitions is still uncertain, adopting a systemic approach that minimize trade-offs among objectives and contribute to the selection of measures that promote synergies, remains urgent (Pe'er *et al.*, 2022). This requires linking social, environmental, food and agricultural policies integrating stakeholders' perspectives (Candel and Pereira, 2017; Recanati *et al.*, 2019) while considering possible spillover effects of environmental impacts. This approach requires recognizing the structural interdependencies between food and other sectors (Sonnino, Faus and Maggio, 2014) and understanding how the current policies instruments address the environmental impacts and target the key actors of the food systems. This could allow identifying barriers and lock-ins of the current sectorial legislation and identify transition pathways towards a more integrated and systemic food and agricultural policy.

Common Fisheries Policy (CFP)

The current Common Fisheries Policy (CFP), reformed in 2013 (Regulation 1380/2013), regulates the conservation of marine biological resources and the management and control of fisheries and fleets exploiting them. The aim of this policy is to ensure the long-term environmental sustainability of fishing and aquaculture activities and their management, consistently with the achievement of economic, social and employment benefits, and contributing to available food supplies. At the stakeholders' level, the CFP sees the involvement of Member States in fisheries management, to bring forward regional considerations. A control, inspection and enforcement system supports the policy objectives.

According to the CFP, sustainability is to be achieved through conservation measures established based on the best available scientific advice; a precautionary approach to fisheries management (i.e., the absence of adequate scientific is no ground for not taking appropriate management measures); ensuring the maximum sustainable yield[22] (MSY); and the collection of scientific data. Commitment to these principles is also foreseen in international agreements[23].

Specific aims related to environmental impacts include the elimination of the practice of discards through the reduction of unwanted catches and landing obligations; adjusting the fishing capacity of

[22] The maximum sustainable yield, MSY, is a measurable and science-based principle defined as the highest theoretical equilibrium yield that can be continuously taken from a stock under current average environmental conditions without significantly affecting its reproduction; an ecosystem-based approach to fisheries management to reduce the negative impacts of fishing activities and aquaculture on the marine ecosystem and avoid the degradation of the marine environment.

[23] Sustainable Fisheries Partnership Agreements (SFPAs) provide financial and technical support in exchange for fishing rights of surplus stocks. Under the SFPAs, fishing is restricted to agreed target species and priority is given to local artisanal fleets, banning discards, and targeting underexploited stocks that the coastal states cannot capture.

the fleets to avoid resources overexploitation; developing sustainable aquaculture activities for food security; coherence with the Union environmental legislation.

Concerning coherence, Article 11 of the CFP allows Member States to adopt conservation measures not affecting fishing vessels of other MSs or issue joint recommendations for the Commission to act when other MSs have direct management interests. The conservation measures of Article 11 are in fulfilment of obligations under the Habitats Directive and Birds Directive (the legal basis of the Natura 2000 ecological network of protected areas) and Marine Strategy Framework Directive (MSFD). They serve as a basis to implement environmental legislation.

In the years since the last reform, the CFP has achieved concrete results in rebuilding fish stocks. From the five stocks fished at sustainable levels in 2009, the number increased to 60 in 2022 (European Commission, 2023). According to the last monitoring of the CFP performance (STECF, 2022), the overall status of fish stocks and biomass levels in the North-East Atlantic (both EU and non-EU waters) has improved since 2003. Overexploitation of fully assessed stocks lowered from 70% to 28% in 2020 (however, some stocks are still overfished and/or outside safe biological limits).

However, despite the ambitions of the policy and the tools offered for sustainable management of fisheries and aquaculture, the CFP has not reached a full implementation of its policy's objectives. Fishing activities remain a source of seabed disturbances, bycatch of sensitive species, impacts on marine food webs, and pollution and overfishing remain a challenge (PEW, 2021). Moreover, fisheries activities pose challenges to overall biodiversity as incidental catches are a source of population decline and extinction risks for vulnerable species (sharks, turtles, marine mammals, seabirds) (Lewison *et al.*, 2011; Burgess *et al.*, 2018).

Many ongoing challenges for sustainable fisheries and aquaculture management regard implementation and governance, for example, on the implementation of MSY, landing obligations, the strengthening of the ecosystem-based approach, and the contribution to EU Environmental legislation. Data collection is also a challenge to CFP monitoring and enforcement, for example, as it concerns the impacts of specific activities (like fishing recreational activities) (European Commission, 2021).

Despite the precautionary and best scientific advice principles embraced by the CFP, scientific advice is taken as the baseline for negotiations to maximise fishing quotas, rather than as the maximum threshold not to cross, rendering the recovery of fish stocks slow and non-homogeneous. Where the MSY is applied, stocks have begun to recover. Nevertheless, in the Mediterranean and Black Sea, where fisheries management is mainly based on technical measures or input controls (European Environment Agency, 2022c), overfishing is ongoing and improvements are slow, with average fishing pressure twice as high as the MSY for the entire 2003-2019 period and most stocks are fished outside biologically sustainable limits (FAO, 2022b; STECF, 2022). Slow decreases in overexploitation and fishing pressures are present since 2012, more substantial for some priority species, however, there are also increases in pressure for some commercially important stocks. Biomass levels are also slow in recovering (FAO, 2022). In the Baltic, since 2019, the status of many stocks has been deteriorating (European Commission, 2023).

Oftentimes, total allowable catches (TACs) are set above the scientific advice (Carpenter *et al.*, 2016; Bastardie *et al.*, 2022, 2023) and there is not full accountability and transparency when setting them (Belschner *et al.*, 2019) and exemptions are granted, impairing stock recovery. The failure of properly implementing the tool can lead to replicating existing patterns of resources exploitation rather than favouring more sustainable fishing activities, invalidating the effect on reduction of overfishing. These circumstances also suggest decision-making influenced by national and economic interest rather than sustainability concerns (Belschner *et al.*, 2019).

Landing obligations have been fully in force since 2019. However, levels of unwanted catches remain high in certain areas (e.g., between 20-30% in the Greater North Sea, Celtic Sea and Bay of Biscay and the Iberian coast) (European Commission, 2023). Moreover, exemptions to landing obligations have flourished and become institutionalised, resulting in discards and increasing challenges and

delays for control and enforcement (Stockhausen, 2019). Control and enforcement of landing obligations remain inadequate – e.g., inspections can only monitor compliance at the time (European Commission, 2023). This approach again might suggest a prioritisation of short-term objectives *vis à vis* long-term biodiversity conservation goals.

There is also the issue of horizontal coherence with other policies addressing the conservation of marine resources. As outlined in its objectives, the CFP aims to protect ecosystem health in accordance to UE environmental law (for instance, to grant "Good Environmental Status", in alignment with the MFD, and to adopt an ecosystem-based approach, aligning with the Biodiversity Directive and the European Green Deal).

Delivering these objectives requires institutional coordination, common implementation, and reduced fragmentation in maritime activities and sectors (Raakjaer et al., 2014). However, the implementation of ecosystem-based approaches is limited, as current conservation measures mainly focus on single-species fisheries management and commercial species (EC *et al.*, 2022).

6.4 The Code of Conduct

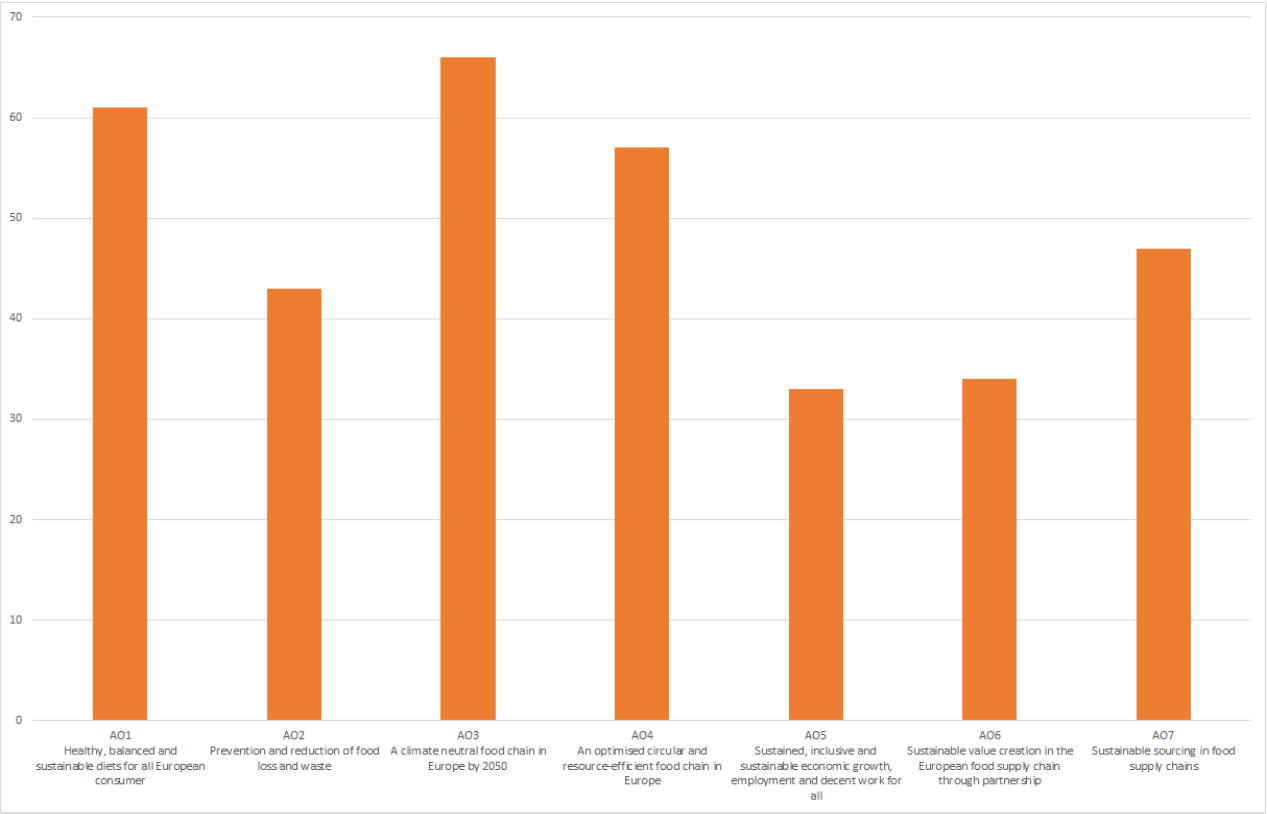
One of the most recent voluntary instruments that has been proposed at the EU level is the Code of Conduct on Responsible Food Business and Marketing Practices (European Commission, 2021c) (see Section 3.3). The Code allows signatories to submit both new and existing (undertaken prior to the launch of the Code of Conduct) commitments. As illustrated in the related EC report (European Commission, 2022d), only 11% of commitments are reported as new, while 50% were already existing (the remaining 39% of commitments was not specified).

Most of the signatories of the Code are multinational corporations. Regarding national associations/companies, the majority is from Spain, Italy, and United Kingdom. Companies that signed the Code are distributed along the supply chain as follows: 39 food manufacturers, 2 primary production, 1 food service, 19 food retailers, 5 input providers and 3 traders. This shows the very heterogeneous uptake of the code among the actors of the supply chain, highlighting the very marginal involvement of primary production stakeholders. Considering the size of signatory companies, majority (91%) are large companies (more than 250 employees) (European Commission, 2022d).

Figure 2 illustrates the number of actions by aspirational objective. The AOs with more actions are: AO3, AO1 and AO4. Many companies set as main target of their action to reduce GHG emissions from their operations, including renewable energy use (AO3). Other common commitments are represent by:

- using more healthy ingredients and a healthier food composition (AO1);
- using more sustainable material for packaging (AO4);
- reducing food waste across the supply chain (AO2);
- improving working conditions, focusing on social inclusion (AO5);
- more cooperation with partners (AO6);
- using food coming from more sustainable sources (AO7).

Figure 2. Number of actions by aspirational objective.

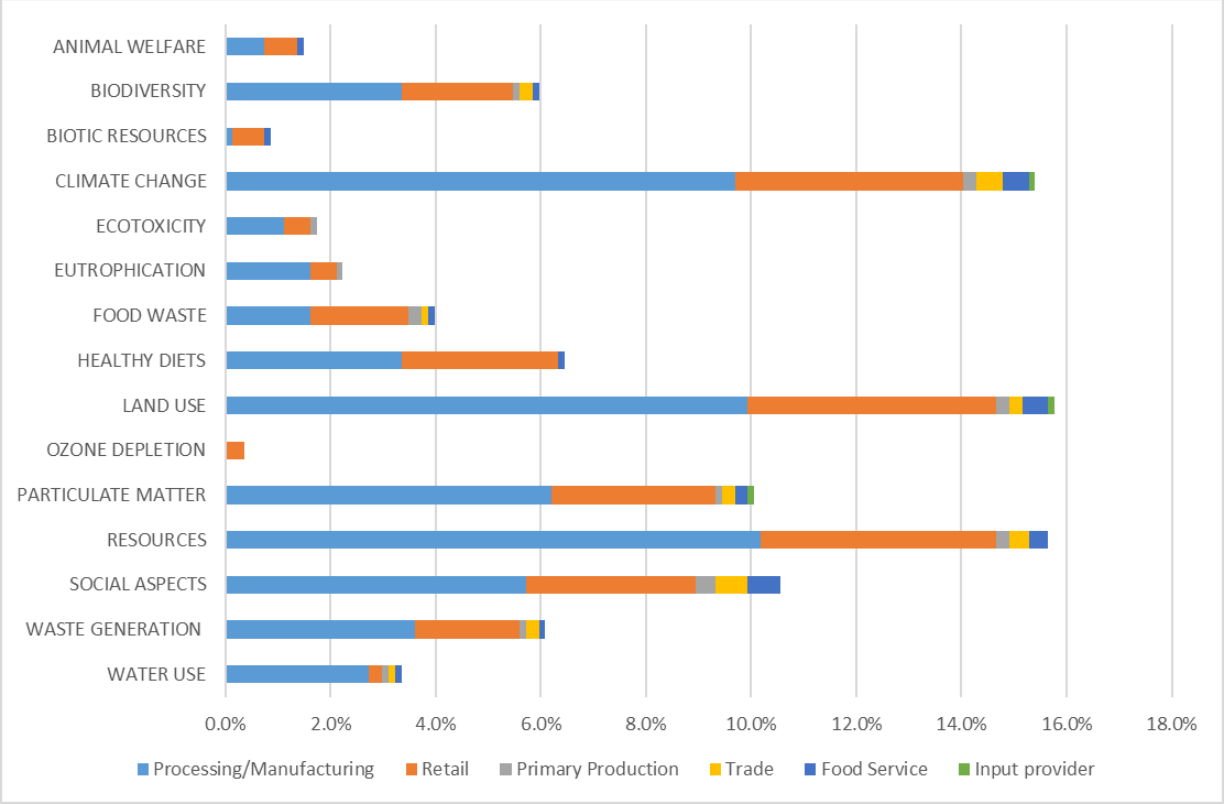


Source: (European Commission, 2021d).

Furthermore, each action adopted by companies was mapped to one or more of the relevant environmental impacts (as in Table 2). Three additional categories were considered in this analysis, in addition to the environmental ones: healthy diet, social aspects and animal welfare.

Figure 3 shows the mapping according to the involved actor (input provider, primary production, processing/manufacturing, retail, trade, food service). Regarding the impact categories, land use, climate change and resources are the ones mostly affected by companies' actions. This is related to the main goal of almost all companies to cut their greenhouse gas emissions and to the fact that many of them are involved in other initiatives targeting GHG reduction.

Figure 3. Mapping of actions and impacts in Code of Conduct according to the different stakeholders involved (companies only).



Source: Own elaboration.

Regarding the associations that signed the Code, most of them belong to the primary production and processing sectors. Furthermore, they are mostly EU-wide associations (45), while there are only eight national associations (from Spain, Italy and the Netherlands) and three international associations. As previously mentioned, the commitments made by associations mostly concerned the promotion and dissemination of the Code among their members. According to (European Commission, 2022d), more than half of the associations that submitted a report in 2022 explicitly referred to all commitments made in the pledge, while (26%) referred to some of the commitments made.

6.5 Initiatives on food waste and waste generation

An overview of the various actions in EU MSs with respect to food waste, derived from extensive literature review, is presented in Table 3. Across the EU, there are many different types of instruments currently in use; however, many of these do not foresee monitoring, thus hindering the efficacy of the plan. Also, food waste is not addressed in a coherent way across the EU, and many countries do not have any plan in place at all.

The reviewed actions are divided into voluntary agreements and strategies at the national level focused on food waste prevention (if the level of action is different, for example regional, then it is indicated in the table). In addition, possible monitoring information and the main target are also indicated in the table. The information was retrieved from the EU Food Loss and Waste Prevention hub[24], and the activities reported within the EU Platform on Food Losses and Food Waste[25].

[24] https://ec.europa.eu/food/safety/food_waste/eu-food-loss-waste-prevention-hub/resources

[25] https://food.ec.europa.eu/safety/food-waste/eu-actions-against-food-waste/eu-platform-food-losses-and-food-waste_en

Table 3. Overview of actions at national level in EU MSs

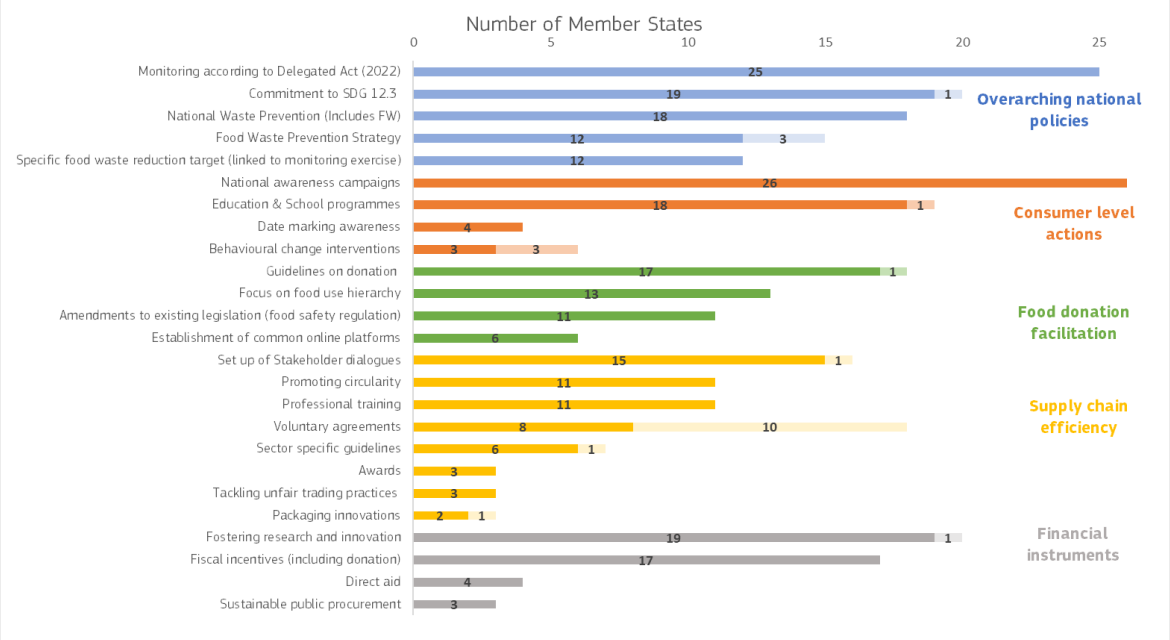
Country	Voluntary Agreement	National Prevention Strategy	Monitoring figures available	Targets
Austria	yes	yes	yes	Reduction of avoidable food waste along the food supply chain. 50% reduction of avoidable food waste in the retail sector, outside home catering and households by 2030
Belgium	regional level agreements	yes (regional)	yes	Flanders: Reduce food waste by 30% by 2025 Wallonia: Reduce food losses and food waste across the food supply chain by 30% by 2025 Brussels region: Reduce household waste by 40% & canteen waste by 40% by 2020
Bulgaria	no	yes	no	No
Croatia	no	yes	yes	National target: reduce food waste by 50% by 2030
Cyprus	NA	NA	NA	NA
Czech Republic	no	yes	no	In 2022 started the development of data collection and monitoring methodology
Denmark	yes	yes	yes	Danish food business operators along the entire food value chain commit themselves to monitor and reduce their food waste by 50 % by 2030 through the voluntary agreement
Estonia	no	yes	yes	SDG 12.3
Finland	yes	yes	yes	Finland aims to reduce food waste by 50% by 2030. A voluntary commitment signed by relevant public authorities and actors of the food industry includes relevant targets to reduce food waste
France	yes	yes	yes	The law sets the objective to halve food waste by 2025 for the retail and collective catering sectors, and by 2030 for the other sectors (compared to 2015).
Germany	yes	yes	yes	Indicative targets of reducing food waste by 30 % by 2025 and by 50 % by 2030 at retail and consumer levels
Greece	yes	NA	NA	NA
Hungary	yes	yes	yes	NA
Ireland	yes	yes	yes	SDG 12.3
Italy	yes	yes	no	NA
Latvia	no	yes	yes	Target to reduce food waste by 30% by 2025 and to reach a 50% reduction by 2030 (as compared to the 2022 baseline)
Lithuania	no	yes	yes	SDG 12.3
Luxembourg	no	yes	yes	SDG 12.3
Malta	NA	yes	NA	NA
Netherlands	yes	yes	yes	SDG 12.3
Poland	no	yes	yes	Future adoption of SDG 12.3
Portugal	yes	yes	NA	SDG 12.3
Romania	no	yes	NA	SDG 12.3
Slovakia	no	yes	NA	The goal of the Slovak Republic is to prevent the generation of food losses and food waste along the whole food supply chain - from primary production to the final consumer.
Slovenia	no	yes	yes	Targets are mentioned but not set in the forthcoming prevention program
Spain	no	yes	NA	It aims to reduce the generation of food waste throughout the food chain by 2030, as follows: 50% reduction at household and retail

Country	Voluntary Agreement	National Prevention Strategy	Monitoring figures available	Targets
				level and 20% in the production and other stages of the food supply chain.
Sweden	yes	yes	yes	From 2020 to 2025, the total amount of food waste should be reduced by at least 20% by weight per capita. By 2025, an increased share of the food production should reach retailers and consumers.

Source: Own elaboration

The main typologies of actions undertaken through the national prevention programs are listed in Figure 4. Most plans include awareness raising for the general population (often including clarification on date marking), facilitation of redistribution actions (through the publication of sector-specific guidelines or through dedicated legislation, promoting stakeholder dialogues. Education programs in primary and secondary schools are also widely used to increase the knowledge and skills of the younger generations. 17 MSs have already undertaken efforts in monitoring, as it will become mandatory from 2022.

Figure 4. Typologies of actions undertaken under National Prevention Programs.



Footnote and source: (1) Except for the category "Monitoring according to Delegated Act (2022)" the total reference number is considered to be 28, as the Regions of Flanders and Wallonia were mapped separately. (2) In darker hue, the policies of which the implementation was clear (legislative documents or reports available) and in lighter hue, the number of policies for which implementation status was unclear but some evidence was found (i.e. on national website, programme webpages, or on EU Food Loss and Waste Prevention Hub). Adapted from De Laurentiis et al., (2023).

Most Member States, in some cases triggered by the Waste Framework directive implementation and by national policies on the circular economy, have set up national strategies for food waste prevention committing to reaching SDG 12.3, envisioning a reduction of food waste along the supply chain and 50% reduction at consumption and retail level (for CY and HE, no information has been found). There are some disparities among MSs regarding the monitoring of food waste quantities and implementations of prevention strategies: few countries (NL, DE, SE) have been addressing the food waste issue since several years, while others have just implemented targeted action and lack data. Prevention measures at national level can vary in the intervention logic, but most national plans include awareness raising and education programs in schools, while economic incentives are less

frequent. Legislative actions have been implemented in few MSs, mostly through amendments to the Hygiene Package regulation (HU, LT) or specific regulation introducing minimum requirements aimed at facilitating redistribution actions (FR, IT, CZ). Voluntary agreements, either as part of the National plans or as stakeholder platforms, have been set up in 14 MSs and in Norway and UK. The aim of these agreements is the coordination of reduction efforts along the food supply chain and the setting of common objectives, both qualitative and quantitative. These tools are used as alternative actions to traditional legislation and can be piloted with or without the support of specific regulatory actions (REFRESH, 2019). Furthermore, international alliances and networks aimed at capacity building and knowledge have been established in the last decade to catalyse public and private initiatives to reduce food waste.

Further legislative actions may be taken at MS level through amendments to regulations and national initiatives. Examples of such initiatives are legislation in France (Garot law) and Italy (Gadda law) establishing further guidelines to encourage and facilitate donation and redistribution (Czech Republic). The main mechanisms include tax incentives (exemption from VAT for redistributed food), amendment to hygiene regulation (Hungary), and introduction of minimum requirements for establishing a redistribution action.

In addition to the national prevention strategies, in 14 MSs and in Norway and UK, voluntary agreements have been arranged – either as part of a National prevention strategy or from stakeholder initiatives – to coordinate efforts to reduce food waste. Voluntary agreements in this context are defined as self-determined commitments or pacts with qualitative and quantitative objectives, developed by private entities and/or other stakeholders in consultation with their signatories. They are used as alternative courses of action to traditional legislation, can be piloted by government officials, businesses or other actors, and can be used in addition to, or independently from existing legislation (REFRESH, 2019).

Other initiatives are targeted to specific categories of actors, such as those adopted in Romania. Portugal and Ireland which involve mostly retailers, with the aim of developing guidance for donation initiatives and implementing prevention strategies.

The waste generation impact category is often connected with the circular economy. There are several initiatives and reports under the circular economy umbrella and SDG 12.5 targeting food and the connection with waste, mainly under a resources management perspective (improving the use of our resources by reducing the use while maximizing the use of waste), while more efforts should be made. There are different guidelines supporting packaging reduction as well as information questioning the effect of plastic packaging and food waste (as it could create more waste in certain food products). On sorting waste, the mandatory Deposit Return System (DSR) has been identified as an instrument bringing many benefits in terms of recycling rate (while not in prevention) but with some barriers to be applied widely in EU. The briefing paper "A European Refunding Scheme for drinks containers" from 2011 presents an overview on the pros and cons of the introduction of a Europe-wide mandatory deposit refund system.

Regarding food waste, there is scarce knowledge (due to lack of information available) on the actual effectiveness in reducing food waste of these voluntary approaches, as monitoring and evaluation is not widely carried out and that cause-effect links are hard to establish between the voluntary actions and quantities of food waste averted. Some initiatives in specific countries (e.g., United Kingdom, The Netherlands) show a high effectiveness. However, there is evidence showing that the presence of multi-stakeholder collaboration, both in private networks or public-private initiatives, has a positive influence to reach pursued goals (Eckert-Matzembacher et al., 2021; Szulecka et al., 2021; Bhattacharya & Fayezi, 2021).

The Food waste reduction roadmap in the UK is an example of a successful initiative at country level of a voluntary agreement putting together efforts from various stakeholders, authorities and researchers. The Target-Measure-Act methodology proposed through this initiative has become a golden standard in the food waste prevention community. According to the latest figures from 2021,

the agreement involved 314 different stakeholders and resulted in a 27% food waste reduction since the baseline (2015). The Netherlands also presents a relevant example of successful voluntary initiative to curb food waste generation, by initiating the *Samen tegen voedselverspilling* foundation – which collects food system stakeholders, institutions, financing entities, and research institutions. De Visser-Amundsen (2021) provides an evaluation of a part of this initiative, specifically targeting food service operators through a challenge including various interventions and a recent study by Wageningen University has delivered some data on the progress made by retailers in reducing food waste (WUR, 2022); van Dooren et al. (2020) also provide an evaluation of an intervention carried out within the voluntary agreement addressing consumer behavior change. Other MSs have established voluntary agreements showing a good sign of engagement from stakeholders, but there is scarce information on the single initiatives' effects on reducing food waste.

There are few voluntary initiatives identified aiming to reduce food packaging in general or specifically plastics, while other voluntary initiatives aim at improving their sorting or recyclability. Some examples are the plastic pledges included in the Assessment report of the voluntary pledges under Annex III of the European Strategy for plastics in a Circular Economy. Still, monitoring of these actions are missing to understand their efficiency.

As of 2022, Member States have to report on food waste quantities occurring within their borders (delegated act 2019). The EU has issued guidance on methodology and quality of reporting data. Due to the timing of this reporting requirement, there is no evidence on this matter. Similarly, mandatory prevention targets set for food waste prevention are being assessed as part of other EU Commission initiative on Waste Framework restructuring. Many MS have adhered to SDG 12.3 as a prevention target. At the moment, monitoring is required at MS level, and not at FBO level. The food waste community relies a lot on the adage "what gets measured gets managed"; most voluntary initiatives and policy efforts rely on quantification as necessary condition to take action towards prevention (in the UK example, a "target – measure – act" programme developed as part of a route map to reducing food waste allowing businesses to better measure and report their actions[26]). Quantification efforts have increased in recent years, as the food waste issue has gained more attention, however there is still a lot of variability due to the heterogeneity of stakeholders and environments (Xue et al., 2017). Furthermore, implementation of the waste framework directive and application of the waste hierarchy to guide decision making is also argued to not be optimal, as argued by Teigiserova et al. (2020). They report the limitations of the requirements currently laid out in the Waste Framework directive, which fails to address the specificities of the food system, and call for an update of the waste hierarchy to account for the possibilities of circular economy and increased information sharing to maximize valorization and recovery. Redlinshofer et al. (2020) also propose a critique on current waste management requirements, which applies an approach which focuses on valorization or optimal recovery/disposal routes rather than prevention. The authors propose a "food approach to food waste" as opposed to the "waste approach to food waste" which is currently used.

A more recent study from Zero Waste Europe published in 2022 highlights that bottle recycling is the most advanced out of all the technologies, with countries in Europe that have DRS in place achieving a 96% Collection Rate on average and those without DRS reaching 48%. The report analyses to which extent PET has been used in circular manufacturing in recent years in EU and provides an evaluation of the current state of circularity and future scenarios, considering that beverage bottles account for 47% of overall PET demand in the EU. The report concludes that the PET system is currently not very circular and has a high level of leakage (approximately 75% of PET placed on the market), suggesting improving the situation with a further improvement in Collection Rates; and/or a move from coloured and opaque bottles to clear bottles.

[26] https://wrap.org.uk/resources/tool/food-waste-reduction-roadmap-toolkit

In addition, non-financial reporting can also be noted. Due-diligence can be a voluntary initiative taken on by a company or implemented through legislation, like the Non-financial Reporting Directive (Directive 2014/95/EU) which introduces disclosure requirements on environmental and social indicators from certain businesses, namely those with more than 500 employees. This legislation has been complemented after its inception with guidelines for reporting and is currently undergoing a revision process. To aid reporting of non-financial information, international standards are issued, such as the Global Reporting Initiative (GRI), where standards are used by large companies such as Coca Cola, Danone or Nestle. The GRI issues standards to measure and monitor indicators, including waste (and food waste), as shown in Standard 306[27] which lays down some principles for food manufacturers.

[27] GRI 306 – WASTE: 2020 https://www.globalreporting.org/standards/media/2573/gri-306-waste-2020.pdf

7 What is the coverage of different types of policy measures in terms of actors of the food system and of environmental impacts?

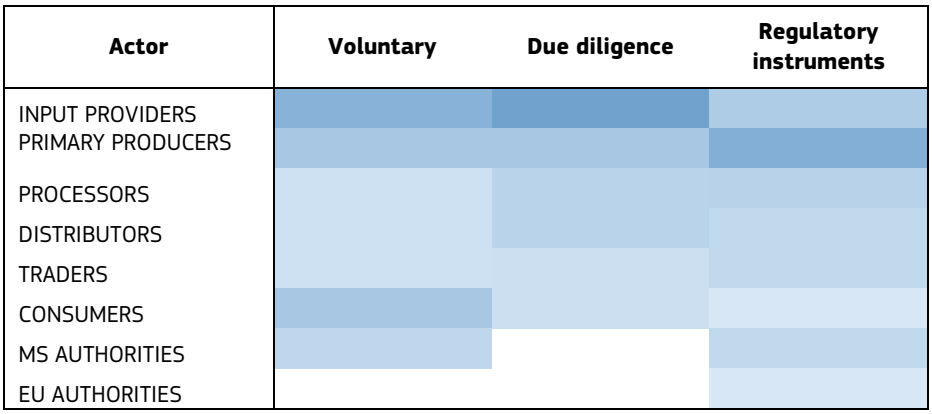
In this section, we aim at providing an overview of how different types of policy measures currently consider the actors of the EU food system as well as address specific environmental impacts. The analysis is based upon semi-automatic text mining (see section 3.2) of the relevant EU legislation, and taking as a first indication the number of relevant policy measures.

7.1 Actors of the EU food system

Results of this analysis aim at providing information on whether current initiatives are considering the actors of the supply chain in a consistent manner, as well as at highlighting possible current gaps. Several pieces of legislation already include measures to target the whole supply chain: from input providers to traders with non-EU countries. A supply chain perspective is aligned with the European Green Deal and associated ambitions shifting the focus from territorial approaches to value chains and the transboundary effects of EU consumption (Sanyé Mengual & Sala, 2022), which results also from a progressive integration of life cycle thinking into EU policy (Sala et al., 2021).

Based on semi-automatic text mining (see section 3.2 and JRC, forthcoming), we analysed how many EU policy measures target each class of actors. Results are summarised in Figure 5. Actors of the supply chain turn out to be involved by existing policy initiatives in a heterogeneous way. Few instruments target important groups of actors, such as food processors, distributors or traders, which all play an important role in shaping the choices of both producers and consumers. The introduction of the Code of Conduct may overcome this void, as most of its goals have been set by actors in the processing and distributing parts of the supply chain, even though it has to be noted that these actions all fall under voluntary measures. Also the highest number of instruments targeting consumers is concentrated under the voluntary set of measures.

Figure 5. Heatmap showing the involvement of actors in three types of policy initiatives in the analysed EU policy database.



Source: Own elaboration

Measures that do not target the entire chain focus predominantly upstream, on input providers (labelling, audits and prescriptive legislation) and primary producers (especially prescriptive legislation and labels). Traders are covered across different categories of policy measures, with the exception, for example, of education and information measures. Gaps and different approaches exist, in general, for processors, distributors, and consumers. For example, if we exclude umbrella initiatives, processors are not targeted by any of the identified measures belonging to hard rules and education and information, and only once by soft regulation, through benchmarking. Similarly, distributors are not addressed by education and information and soft regulation measures, and only once by prescriptive legislation. Finally, measures addressing consumers are not present in the form of hard and soft

regulation, and only as subsidies among economic instruments. Labels are the main instrument used to target consumers.

When we look at the policy fields addressed by the detected measures and how these relate to the food supply chain, coverage turns also out to be uneven. Measures in the field of environmental, consumers and health protection are overwhelmingly predominant and present for the whole supply chain. Moreover, measures belonging to the field of industrial policy and internal market are also present along the whole chain, although in lower numbers, similar to measures for agriculture (which target mainly primary producers, processors and distributors). Primary producers are also broadly targeted in the field of fisheries. However, for all other policy fields analysed, only a handful of measures are identified. This is the case, for example, of the social and science policy fields, with two and one measures detected respectively.

These findings have been acknowledged in a recent EEA report (European Environment Agency, 2023) where the analysis shows that consumers and other key actors are addressed in an uneven way. For example, "consumers are targeted with informational tools, such as labelling, while pricing instruments are hardly used". Policies and actions targeting food manufacturers and retailers are emerging, but are currently mainly voluntary, such as the Code of Conduct. Furthermore, actors involved in the Code of Conduct belong mainly to the processing and distribution parts of the supply chain, while traders and consumers (e.g., food services) are present in significantly minor numbers. The CAP, CFP and F2F strategy are targeted to a limited set of actors and operate within a specific area, without taking full advantage of potential synergies, or accounting for trade-offs across policy domains.

For each type of policy instruments, it is possible to observe that current measures target less than two actors on average; at maximum seven types of actors are targeted by the same measure, while the majority of measures deals with one actor only (Figure 6).

Figure 6. Number of actors that are targeted by each set of EU policy measures (for each set of measures, average, minimum and maximum are shown).

Source: Own elaboration

Similar conclusions derive from the analysis of the national measures in place in Member States (see JRC, forthcoming). The legal acts usually are sectorial, considering specific elements of the food system sustainability (e. g. food loss, food waste, animal welfare, GMO, plant protection products, sustainable consumption, healthy diets, etc.). There are examples of overarching national policies addressing the sustainability of food systems in an integrated manner (e.g., the National Food Strategy for Sweden, the Irish "Food Vision 2030", the Romanian multi-sectoral strategic framework

for the sustainable development of agri-food sector and rural development, etc.). However, the most comprehensive initiatives are mainly non-legislative documents, such as strategic plans, guidelines, programmes and resolutions. In a few cases, they are complemented also by legislative acts (for example in France and Sweden), but they are isolated cases. Additionally, there are many differences among countries; in some cases there are only sectorial legislations, regarding specific topics. All aspects of sustainability are rarely considered together, tackling the three dimensions (social, economic and environmental) at the same time. There are also countries without a proper national legislation in place, since they apply EU-level measures.

7.2 Environmental impacts of the food system

The environmental impacts of the EU food system are not addressed horizontally and consistently across existing legislation. Current measures are in part inducing actors to improve the sustainability of their practices for example with respect to eutrophication, ecotoxicity or land use (like in the directive on industrial pollution or the regulations on fertilizers[28], or the ongoing proposal for a Regulation on the Sustainable Use of Pesticides, or the ongoing proposal for deforestation-free products[29]), also considering a higher demand of consumers to buy more sustainable products. However, such effects are not enough to counteract increasing environmental impacts.

We have analysed the database of EU policy instruments currently in place (see section 3.2) to assess how environmental impacts are addressed. To do this end, we counted the number of times that each environmental impact is addressed by a policy instrument. Results are shown in the heatmap in Figure 7. All environmental impacts turn out to be covered in the voluntary set of policy instruments, particularly with regards to biodiversity and climate change. On the other hand, under the due diligence set, not all impacts are covered: climate change, ozone depletion, particulate matter, food waste and biotic resources arte in fact not reported. Finally, regulatory instruments are present for the considered impacts with the exception, once again, of food waste. Furthermore, the environmental impacts are not covered in an even way, but there is a predominance of policy instruments addressing for example ecotoxicity, biodiversity or biotic resources.

More in detail, exploring the complete set of policy measures included in the EU policy database, 21 measures were selected as voluntary. These measures have been classified into awareness campaign (11 measures), code of good practices (8 measures) and covenants (1 measure). Most measures deal with only one impact at the time, while only 7 measures target two or more environmental impacts. The environmental impacts covered in these voluntary measures are mainly related to biodiversity (because of the presence of several measures on plant and forest reproductive material), ecotoxicity and eutrophication (e.g., for fertilizers). Eventually, all impacts are covered at least once because of the presence of a few measures with broader scope (related to the CAP, organic products and clean air). Only five measures address two or more categories of actors of the supply chain. The presence of several measures on fertilizers and pesticides is reflected in the type of actors involved, mainly input producers and primary producers.

In the analysis for the group of measures falling under due diligence, 8 measures, relevant with respect to environmental impacts, were selected. The environmental impacts covered here are focused on regulating the use of chemical products, monitoring the production process of fruit plant propagating material, and controlling the production and distribution of fertilizers. There are then measures devoted to controlling organic products, the waste related to certain plastic products, the use of water. Overall, while six out of eight of the selected measures target only one actor of the food system, the remaining two measures target the whole food supply chain, with the exception of

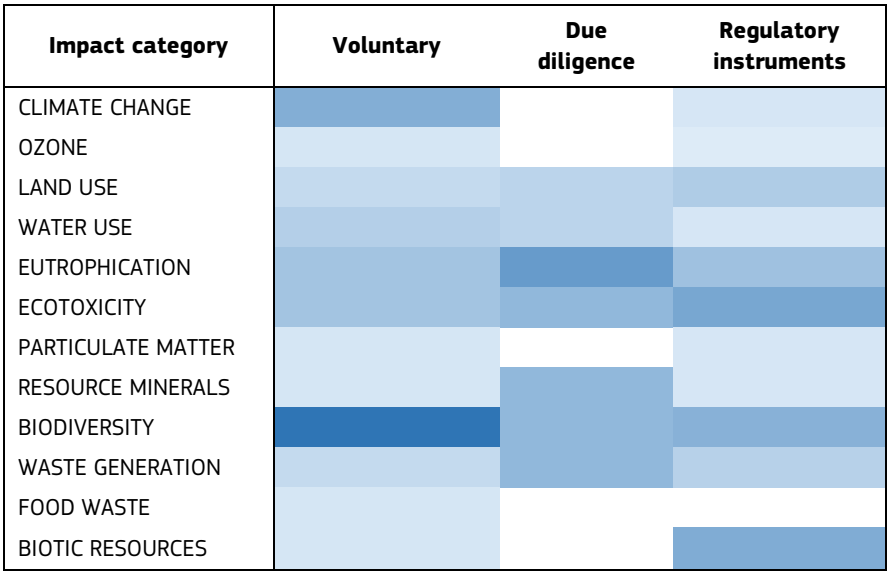
[28] Directive 2010/75/EU to prevent or reduce industrial emissions into air, water and land and to prevent the generation of waste. Regulation 2003/2003 and Regulation 2019/2009 on EU fertilizing products.

[29] Proposal for a regulation on deforestation-free products, https://environment.ec.europa.eu/publications/proposal-regulation-deforestation-free-products_en

EU and MS authorities. The environmental impacts that are affected by these measures are mainly limited to those related to agricultural primary production and more specifically to eutrophication (because of fertilizers), ecotoxicity (chemicals), and to a less extent to biodiversity and land use (organic products). Water use and waste generation are also affected.

For the group of measures falling under regulatory instruments, 45 policy initiatives with relevance with respect to the environment were selected. Among these policies, the following specific measures were identified (a policy may include more than one specific measure): 34 falling under prescriptive legislation and 11 falling under mandatory requirements. Analysis shows that the current measures cover, albeit to a different extent, all the environmental impacts except for food waste, which is not addressed at all. Overall, environmental impacts are covered in an uneven way: while some impacts are referred to in many measures (such as eutrophication, ecotoxicity, biodiversity and biotic resources), others appear in a more limited number (climate change, particulate matter, water use etc.). On average, each measure covers a bit more than one impact, with a maximum of 4 impacts covered by one measure. On a similar level, if we look at the actors involved, we may see that on average each measure deals with a bit less than two actors, with a maximum of 7 actors. Input and primary producers are more represented.

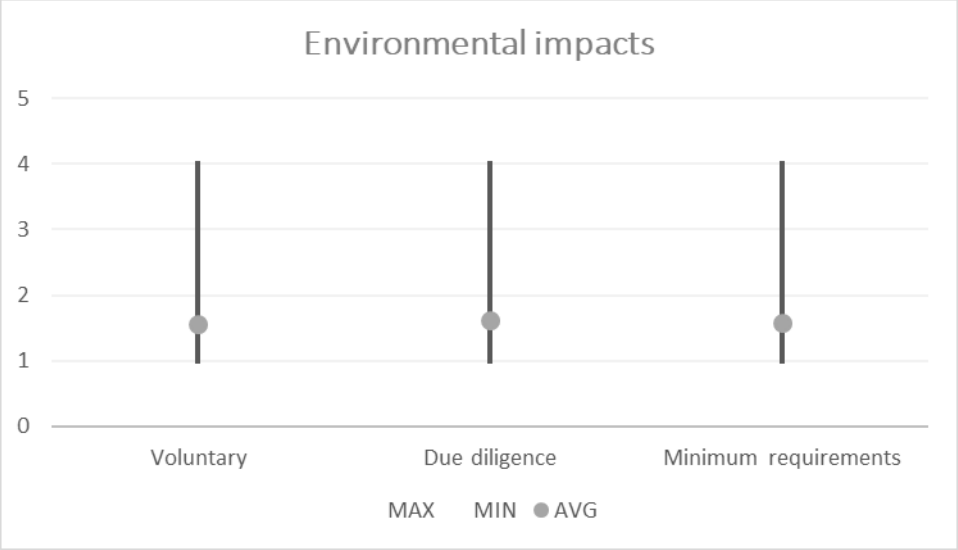
Figure 7. Heatmap showing how the policy initiatives in the analysed EU policy database address the selected environmental impacts.



Source: Own elaboration

Furthermore, for each set of measures, the number of environmental impacts that is addressed by each measure is slightly higher than one. It is thus possible to say that usually current measures focus just on one impact, while at the maximum four impacts are addressed by the same measure (Figure 8). This analysis shows that there is uneven coverage of aspects related to environmental impacts across EU policy measures, which might affect their coherence in addressing environmental impacts and actors. The current policy environment does not seem to be fit for purpose to address existing environmental challenges, which are expected to continue to increase in the future.

Figure 8. Number of environmental impacts that are addressed by each set of EU policy measures (for each set of measures, average, minimum and maximum are shown).



Source: Own elaboration

8 Conclusions

The present report aims to contribute to the analysis of sustainability transition by providing further insights on the environmental dimension, and in particular on the contribution given by policy measures setting requirements to foster food sustainability. The analysis is challenging as it needs to address different dimensions of sustainability, for all actors involved.

The report includes the results of the analysis carried out on the environmental impacts of the current EU food system and expected future trends. In addition, we present an analysis of the wide set of policies that is currently governing the EU food system. To this end we analysed a large, even though not exhaustive, policy database and performed more in-depth research on a few relevant sectors or specific policies, precisely the CAP and CFP, the recent Code of Conduct, and food waste.

Considering the complexity of the system and the interdisciplinary approach needed, simplification and a certain degree of pragmatism are required in the methodological choices. The complexity of the analysis required to combine different approaches and data sources, and to collect the available knowledge on the potential effects on environmental impacts. The assumptions made and limitations encountered are transparently presented and should be carefully taken into account for the interpretation of the results. Our research can also contribute to bridging the gap between different scientific communities which are involved in promoting evidence informed policymaking.

The analysis is structured around four main research questions.

What are the environmental impacts and the related relevant activities in EU food systems? An in-depth literature review was carried out to describe on one hand the environmental impacts of the activities of the current EU food system and on the other hand to identify the policy initiatives that are targeting each of these impacts. This analysis allows us to depict the most relevant relationships existing between impacts, activities and the related policies.

How might the environmental impacts of the EU food system evolve without further policy action? Current trends are expected to be maintained, leading to an increase of environmental impacts associated to the EU food system. Furthermore, due to cascading effects, environmental impacts are expected to be further exacerbated by the increasing impacts of climate change, biodiversity loss, or water stress. The current legislative context thus might not be suitable to counteract the global environmental crises. With no further actions, the EU food system will remain highly resource intensive, with the related consequences on the environment.

What are the effects on the environmental impacts of the food system of specific policy measures? The analysis of existing EU policies suggests that there is a complex and fragmented policy, which can act as a barrier to more systemic and transformative approaches to the governance of food systems. A focus on food waste highlights the lack of monitoring in current initiatives, hindering the efficacy of the plan, as well as an incoherent uptake of initiatives across the EU. An analysis of the pledges in the Code of Conduct reveals that focus is put on some specific environmental impacts only.

What is the coverage of different types of policy measures in terms of actors of the food system and of environmental impacts? The relevant actors are involved in existing policy initiatives in an heterogeneous way resulting in environmental impacts not being addressed consistently along the entire supply chain. Furthermore, the environmental impacts of the EU food system are not addressed horizontally and consistently across existing legislation. These findings have been acknowledged in a recent EEA report (European Environment Agency, 2023) where the analysis shows that consumers and other key actors are addressed in an uneven way.

Overall, as confirmed by the F2F strategy, there is then the need to move to a more systemic perspective (Westhoek *et al.*, 2016; Niles *et al.*, 2018). This is fundamental to achieve a long term transition towards sustainable food systems. In terms of stakeholders, a systemic approach means that actions and policies should make leverage of each actor, so that each can participate and

contribute in its own way to obtain the maximum for the complete system (Foley *et al.*, 2011). Similarly, approaching the food system in its entirety allows to account for interlinkages between all stages of food production and consumption, including food loss and waste. Hence, when it comes to sustainability, a systemic view allows considering the social, economic, and environmental causes and consequences of issues within the food system or affecting it, as well as their relations, feedback loops and possible solutions. At the same time, it enables the understanding of the impact to certain measures beyond their scope and across the entire system. All of this will aid the creation of comprehensive policies that maximise synergies and minimize trade-offs strengthening the Union commitment toward policy coherence for sustainability (Foley et al., 2011).

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List of abbreviations

AO	Aspirational objectives
BEMP	Best environmental management practices
BAT	Best available technologies
BREF	Best available technologies reference documents
CAP	Common Agricultural Policy
CFP	Common Fisheries Policy
CINEA	European Climate, Infrastructure and Environment Executive Agency
EEA	European Environment Agency
EMAS	Eco-Management and Audit Scheme
EU	European Union
F2F	Farm to Fork
FAO	Food and Agriculture Organization
GHG	Greenhouse gas
GMO	Genetically-modified organisms
GPP	Green Public Procurement
LULUC	Land use and land use changes
MPA	Marine protected area
MSFD	Marine Strategy Framework Directive
MSY	Maximum Sustainable Yield
SDG	Sustainable Development Goal
TAC	Total allowable catches

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Annexes

Annex 1. Actors of the food system

This annex details the role of the different actors of the EU food system on its sustainability.

Input producers

Primary production is sustained not only by natural capital, but also by many manufactured inputs that encompass synthetic fertilizers, pesticides, food animals' drugs and feed, but also farm and fishing equipment. The overall sustainability of the food system thus also depends on the inputs to the agriculture, aquaculture and fishery industries. All the above-mentioned manufactured inputs have enabled the intensification of agriculture, the expansion in livestock production and in the aquaculture and fishery sector meaning that it has been possible to increase productivity per unit of land or of equipment. This intensification of production has however led to considerable environmental impacts, reduced diversity and growing concerns among consumers about food quality (European Environment Agency, 2017)[30].

Food systems interact with non-food supply chains. Broader economic, social and natural environments shape and influence food systems and their production systems (FAO, 2021b). For example, there have been fears of an upcoming food crisis caused by Russia's invasion of Ukraine, not only because Ukraine and Russia combined make up 12% of global traded calories, but also because of the increase in energy prices and consequently of fertilizers (European Commission, 2022c; The Economist, 2022). Furthermore, commerce of input materials is restricted because of many bans that have been put in place: Russia for example is a producer of significant amounts of nutrients, like potash and phosphate, key ingredients in fertilisers[31].

Small-scale farmers typically face higher transaction costs than do large-scale enterprises. It is more difficult and costly for them to access high-quality inputs (especially feed) and technology.

Primary producers

Primary producers are intrinsically tied with the whole value chain as production practices are realized at the interface with nature. Furthermore, looking at the whole context of the food system, primary producers are subject to market pressures and often do not have the necessary agency for change.

Agriculture is the dominant sector driving land degradation due to unsustainable land management practices, contributing to GHG emissions, reduced carbon uptake rates and resource depletion (Shukla *et al.*, 2019; Bezner Kerr *et al.*, 2022). Recent data show that 30% of global anthropogenic GHG emissions originate from the world's food systems[32] (Crippa *et al.*, 2021). Primary production is the most relevant life cycle stage of food regarding most of the environmental impacts, such as land use, acidification, eutrophication, water use (Castellani, Fusi and Sala, 2017). Numerous agroecological farming practices[33] exist that could provide significant improvements on resource efficiency,

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[30] One of the actions included in the Farm to Fork is indeed a 20% reduction of fertilizers by 2030 (European Commission, 2020a). Policy to promote a sustainable use of pesticides has been launched in June 2002; https://ec.europa.eu/food/plants/pesticides/sustainable-use-pesticides_en#farm-to-fork-targets---progress; https://ec.europa.eu/food/system/files/2022-06/pesticides_sud_eval_2022_req_2022-305_en.pdf.

[31] https://www.bbc.com/news/business-60623941

[32] Out of 4.2 Gt CO_2-eq GHG emissions in Europe in 2015, 1.2 Gt CO_2-eq are from food systems. At global level, the largest contribution comes from agriculture and land use/land-use change activities, whilst the remaining are from supply chain activities such as retail (almost half due to refrigeration), transport, consumption, fuel production, waste management, industrial processes and packaging (Crippa *et al.*, 2021). Major sources of GHG gases are enteric fermentation and agricultural soils (42.5% and 39.4% respectively of t CO_2-eq in the EU27 in 2019) (Eurostat, 2021c).

[33] Agroecology farming practices include organic farming, agroforestry and mixed farming, and more in detail practices such as fertilizers and input management, perennial crops or cover crops, reduced tillage, crop rotation, changes in the management of livestock and many more (e.g. for the reduction of GHG related to different farming practices see (Niles *et al.*, 2018)).

biodiversity, soil health and strengthening systems' resilience and economic diversification (Wezel *et al.*, 2014; D'Annolfo *et al.*, 2017; HLPE, 2019; González de Molina, 2020). The performance of certified food (organic and with geographical indication) has been found to be in general higher than that of conventional food for a wide set of indicators, both social and environmental (Bellassen *et al.*, 2022). Species richness has been observed to be about 30% higher on land under organic farming with respect to conventional agriculture (Hayo M G van der Werf, Knudsen and Cederberg, 2020). However, even if organic farming usually has better environmental performances than conventional farming per unit of land, this may not be true per unit of output, given that yields may be lower (Seufert and Ramankutty, 2017; Meemken and Qaim, 2018). In 2020 organic area made up 9.1% of total EU agricultural land (+55.6% with respect to 2012 (Eurostat, 2020)), thus with significant potential of increase. The effects of scaling up organic farming are still not completely known (Seufert and Ramankutty, 2017), but can be relevant, notwithstanding the issues mentioned above, considering that land under organic practices is often marginal land[34].

Although the social dimension of sustainability is beyond the scope of this report, the current food systems also has negative impacts on society. The agricultural sector is an important source of livelihood and jobs, especially in low-income countries where more than two-thirds of all workers are employed in the agricultural sector (ILO, 2015). The sector is also prone to serious social problems, for instance, globally it accounts for 70% of the total child labour (ILO and UNICEF, 2021). Poor working conditions, exploitation of migrant and seasonal workers, unfair remuneration and low generational turnover are reported as most prominent social impacts in the sector, even though these aspects are poorly addressed in the literature (Desiderio *et al.*, 2021). For example, in the case of Italy, statistics place at about 180,000 the number of vulnerable workers subject to *caporalato*[35] or other forms of exploitation in the food sector for 2018-2020, with an increase of about 28% with respect to 2017 (FLAI and CGIL, 2021; SIT, 2022). According to ISTAT, in 2019 almost 15% of full time equivalent jobs in the agriculture, forestry and fisheries sector was undeclared (ISTAT, 2022). Similar forms of exploitation have been documented for the fishery sector as well (Marschke and Vandergeest, 2016; Mackay, Hardesty and Wilcox, 2020). For example, to counteract this, existing legislation is in place for promoting working conditions (Directive 2017/159/EU) that implements the Work in Fishing Convention of the International Labour Organisation[36]. Other initiatives to further respond to these issues are ongoing[37].

Livestock production in the EU has a relevant physical[38] and financial scale and has far-reaching environmental, economic and social consequences. In 2017, the value of livestock production and livestock products in the EU-28 was equal to € 170 billion, representing 40% of the total agricultural activity (Peyraud and MacLeod, 2020). The EU is also a net exporter of animals and animal products[39]. The impacts of livestock farming are manifold and dependent, e.g., on the feeding methods and the feed type and origin, manure management, eventual grazing systems and so on. Livestock farming

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[34] The F2F strategy set out a 25% target of EU agricultural land under organic farming by 2030 (European Commission, 2020a) and put forward a roadmap for stimulating the conversion to organic farming that includes, for example, the increase of consumers' demand (Consolidated version of Regulation (EU) 2018/848, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02018R0848-20220101). Furthermore, a revision of the directive on pesticide use and on integrated pest management is planned for the second quarter of 2022 (European Commission, 2020a).

[35] *Caporalato* is a form of illegal hiring and exploitation of farm daily workers through an intermediary.

[36] https://osha.europa.eu/en/legislation/guidelines/the-fishing-agreement-title-unknown

[37] In February 2022, the Commission adopted a proposal for a Directive on corporate sustainability due diligence with the aim of fostering sustainable and responsible corporate behaviour in the company's own operations, their subsidiaries and their value chains (European Commission, 2022a) https://ec.europa.eu/info/business-economy-euro/doing-business-eu/corporate-sustainability-due-diligence_en#documents. Moreover, discussion in EU Commission has started to ban products made with forced labour on the EU market. https://single-market-economy.ec.europa.eu/document/785da6ff-abe3-43f7-a693-1185c96e930e_en

[38] The EU has a sizeable livestock population: in 2020, there were 146 million head of pigs, 76 million head of bovine animals (such as cattle or buffaloes), and an estimated 75 million head of sheep and goats on EU farms (Eurostat, 2021c).

[39] The EU also recorded a trade surplus for animals and animal products (EUR 15.2 billion) (Eurostat, 2021c).

poses issues related to animal welfare and, specifically, to animal abuse and to the negative consequences of intensive selection and production. The excessive use of antimicrobials may contribute to antimicrobial resistance, with potential consequences for animal, human, and ecosystem health (Schar *et al.*, 2020). Similar issues are valid for aquaculture, even though with the advent of vaccination the use of antimicrobial has been reduced (European Medicines Agency and European Surveillance of Veterinary Antimicrobial Consumption, 2021)[40]. The overall decline in the sale of antibiotics between 2011 and 2017 was 32% (Peyraud and MacLeod, 2020). The EU banned the use of antibiotics as growth promoters in 2006 and their prophylactic uses from 2022[41].

Primary production comprises also **fisheries and aquaculture** with EU producers representing around 2% of the global fisheries and aquaculture production. A rough estimate places EU consumption at around 5% of global production, which increases to about 6.5% if non-food uses are included. While seafood production has increased globally, thanks to the expansion of aquaculture, overall EU production has decreased in the last decade. Aquaculture, a growing source of animal and alternative protein, poses several sustainability related questions, and most of them are not fully quantified. Some of these potential threats are mainly related to the use of non-therapeutic antimicrobials (Schar *et al.*, 2020), farm escapees, water pollution. While Recirculating Aquaculture Systems (RAS) may have a significant environmental impact, however as closed systems, they can be better monitored and mitigated, rather than the impact/pollution being "dispersed" in the ocean". The EU has about 57,000 active vessels landing about 4 million tonnes of seafood worth €6.3 billion, while the aquaculture sector reached a production of about 1.2 million tonnes worth €4 billion in 2019 (STECF[42], 2020, 2021). The EU self-sufficiency in seafood products is around 30%: EU countries consume three times more than what they produce. Hence, the fish processing and distribution sectors are very dependent on global fish trade. Overfishing has been reduced, but further efforts are still required in the Mediterranean Sea and the Black Sea (European Commission, 2021e). The evolution of the fishing mortality over the fishing mortality at MSY for the Mediterranean and Black Seas for assessed fish stocks is twice the optimal, or twice the legal one according to the CFP, while the same trend for EU waters in the northeast Atlantic has been around 1 or even below, thus showing a big improvement. In the case of the Mediterranean Sea, most fish stocks are overfished, and in particular the big important commercial stocks, such as hake (STECF, 2022). Furthermore, fishing activities have a major role in macroplastic[43] release into the ocean with 640,000 tonnes of gear lost or abandoned annually, with fishing gear and single use plastic representing more than 50% of total presence of beach litter on the EU coast (Hanke *et al.*, 2019).[44]

Food and drink manufacturers

In 2018, the EU-27 food and drink manufacturing industry employed around 15% of the manufacturing total workforce and had a turnover of more than EUR 1000 billion (Eurostat, 2021c). It is characterised by many small-medium enterprises (99%), but there are a few large multinationals that have great influence on the whole sector. For example, according to the Agri-food Atlas (Heinrich Böll Foundation, 2017), 50 manufacturers account for half of global food sales in the industry. Another study estimated that of 61 popular grocery items in the USA, the top companies control an

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[40] The European Commission committed to reduce overall EU sales of antimicrobials for farmed animals and in aquaculture by 50% by 2030 (European Commission, 2020a).

[41] The Veterinary Medicinal Products Regulation (Regulation (EU) 2019/6) updated the rules on the authorisation and use of veterinary medicines in the European Union (EU) when it became applicable on 28 January 2022. https://www.ema.europa.eu/en/veterinary-regulatory/overview/veterinary-medicinal-products-regulation

[42] STECF (Scientific, Technical and Economic Committee for Fisheries) expert working groups: https://stecf.jrc.ec.europa.eu/meetings/2022

[43] Together with the Single Use Plastic Directive Directive 2019/904 to decrease plastic waste (European Commission, 2019b), the Zero Pollution Action Plan includes a target to improve water quality by reducing waste, plastic litter at sea (by 50%) and microplastics released into the environment (by 30%) (European Commission, 2021b).

[44] The Directive on Port Reception Facilities regulates the delivery of waste and prevents marine pollution from ships by assuring their adequate disposal on land (European Commission, 2019a).

average of 64% of the sales (Lakhani, Uteuova and Chang, 2021). Figures for the EU were not available, however similar numbers can be expected. The commitment towards sustainability of the biggest food and beverages manufacturing companies has increased over time, according to an Oxfam report[45] (Sahan, 2016). Even if progress has been reported, improvements are still needed in the areas of protecting land rights, tackling gender inequality, managing water, ensuring fairness for farmers and workers in the supply chain. On the other hand, more efforts have been registered for reducing the impacts on the climate and for improving transparency.

Best environmental management practices (BEMPs) are available to help improve the environmental performance of manufacturers with respect to current practices (Dri *et al.*, 2018). The food and beverage manufacturing sector[46] accounts for around 6% of all EMAS (Eco-Management and Audit Scheme)-registered organisations (233 out of 3928 total in October 2015). There is a register for best available technologies reference documents (BREFs[47]) which represents a useful tool to identify information for realising sustainable food operations. BREF documents and best available technologies (BAT) can be used by any stakeholder to obtain information about food production processes. However, they include only key environmental aspects, such as emission rates, associated with specific industrial activities[48].

Regulatory marketing standards are in place for fishery products. However, these standards are considered having a narrow scope in terms of products covered and by their focus on quality, thus hindering their capacity of providing information on sustainability of products (European Commission, 2022b). The current marketing standards, which exist since 25 years, lay down uniform quality characteristics for certain fishery products sold in the EU, whatever their origin.[49]

Packaging manufacturers, logistic actors, retailers

The **packaging industry** has experienced a significant growth in the past decades. Global production in 2020 rose to 367 million tonnes (a 36% increase compared to 2010). Europe produced roughly 55 million metric tons of plastic in 2020, with a decrease of 3.5% since 2010. This decrease however was mainly driven by the COVID-19 pandemic and the market has already seen a steep increase in 2021 (European Association Of Plastics Recycling & Recovery, 2021). The recycling rate of plastic packaging waste[50] (including packaging for food and drink) for the EU27 in 2019 was 44%, compared to an EU target of 22.5% (Eurostat, 2021b). This figure may seem high, but EU27 recycling rates for paperboard and for metal and glass are almost double. It is estimated that in 2018 food packaging accounted for 40% of total plastic packaging (8.2 of 20.5 million metric tonnes) (Geijer, 2019). The packaging industry faces several challenges: European consumers are expecting a decrease in the use of plastic, however figures show that it expected to increase (for example because of the increased number of households or the increased share of food sold in packaging, e.g. 60% of fruit in 2018 versus 56% in 2014) (Geijer, 2019). This complex issue may be tackled by reducing the

[45] Unfortunately, this monitoring by Oxfam has been interrupted in 2016, however it is still useful to gain some insights on the weakest areas of the food industry.

[46] NACE codes 10 & 11. https://ec.europa.eu/environment/emas/emas_for_you/news/news12_en.htm

[47] These are reference documents that cover specific technologies and provide descriptions of a range of industrial processes and for example, their respective operating conditions and emission rates. For the food systems, there are three BREFs on: Food, Drink and Milk Industries; Intensive Rearing of Poultry or Pigs; Slaughterhouses, Animal By-products and Edible Co-products Industries https://eippcb.jrc.ec.europa.eu/reference/

[48] There are also other tools that food and drink companies may use for managing GHG emissions, such as the Carbon Disclosure Project (FoodDrink Europe, 2012), while the Global Reporting Initiative allows companies to report and communicate their performance on several sustainability aspects; https://www.globalreporting.org/

[49] The European Commission is currently working to identify sustainability criteria and indicators for both fisheries and aquaculture products on the EU market, independently of their origin (domestic and imports).There are two STECF expert working groups. The EWG 22-12 on Marketing standards is a review of fishery criteria and underlying methodologies. The EWG 22-13 on Marketing standards is a review of proposed sustainability criteria/indicators for aquaculture, and has taken place in September 2022.

[50] The recycling rate includes only material recycling and no other forms of recycling, i.e. exclusively material that is recycled back into plastics.

weight of packaging, increasing the share of recyclability, using bio-based plastic or switching to reusable packaging and by combining these strategies.

Logistic operations, above all transport, have an impact on the overall sustainability of the food system. About 1.2 billion tonnes of agriculture, forestry and fishery products were transported on roads in the EU in 2019, along with 1.6 billion tonnes of food, beverages and tobacco products (Eurostat, 2021c), including EU products and imported goods. Statistics indicate that the payload distance[51] over which products were transported increased in 2008-2019 on average by 1.6% per year for agriculture, forestry and fishery products (Eurostat, 2021c). Globally, transportation contributes 4.8% (or 0.86 Gt CO_2-eq yr^{-1}) to food-system GHG emissions, approximately the same as retail (4.0%) (Crippa *et al.*, 2021). Most emissions arise from local to regional transport via road (81%) or rail (15%), rather than navigation (3.6%) or aviation (0.4%), also because of the great variation in the energy needed for different modes of transport[52].

Modern **retails** are growing in number and in areas in the past years, gaining larger shares of market. The top 10 European food retail companies in 2011 had a combined market share of 31% (European Commission, 2014). Increasing concentration can also be seen at the procurement level, through the development of buying groups. Buying groups are organizations created by several shops or retailers with the aim of improving their purchasing conditions as well as enhancing their market competitiveness. These and other trends contribute to increase the influence of retailers over both producers and consumers (Heinrich Böll Foundation, 2017; Bock, Bontoux and Rudkin, 2022). In contrast, there are so-called Territorial Supply Constraints which are barriers imposed by private operators (suppliers) in the supply chain, which can affect retailers or wholesalers (European Commission, 2020c). These practices hamper or limit the retailers' or wholesalers' ability to commerce their goods in other EU countries than the one they are based in, and/or prevent them from distributing (i.e. reselling) goods to other EU countries than the one in which they are based.

Best environmental management practices for the retail trade sector are available and may be followed to improve energy performance, the sustainability of retail supply chains, transport and logistics operations, waste, use of more environmentally friendly paper, and other (Schönberger, Galvez Martos and Styles, 2013). For example, buying a standard shopping basket in a hypermarket has an environmental impact 10 times higher than buying in a municipal market (Sanyé-Mengual *et al.*, 2012). Major environmental impacts[53] of the retail section of the supply chain are related to refrigeration and transport. Packaging is also relevant for assessing the sustainability of products. Choosing the least packaged products available in hypermarkets could reduce between 15.4 and 59.0% the associated environmental impact of a standard basket (Sanyé-Mengual *et al.*, 2012). The number of materials used for food packaging (plastic, aluminium foil, glass…) has decreased in recent years: for example, packaging for 33cl cans has been reduced by 55% and bottles in glass can be up to 60% lighter (FoodDrink Europe, 2012). This notwithstanding, in 2019 each person living in the EU generated 34.4 kg of plastic packaging waste[54]. Of this, 41% was recycled; even if the share recycled has increased by 10% since 2008, still the amount of plastic not recycled has increased due to the greater increase in the absolute value of plastic packaging waste generated (Eurostat, 2021b).

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[51] The payload distance (measured in tonne-kilometre) is a measure of freight transport which represents the transport of one tonne of goods (including packaging and tare weights of intermodal transport units) by a given transport mode (road, rail, air, sea, inland waterways, pipeline etc.) over a distance of one kilometre (https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Tonne-kilometre_(tkm)).

[52] Energy needed: marine shipping at 10–20 MJ t^{-1} km^{-1}, road transport at 70–80 MJ t^{-1} km^{-1} and aviation at 100–200 MJ t^{-1} km^{-1} (Crippa *et al.*, 2021).

[53] Most of these emissions are associated with energy use. From the electricity grid, 62% of energy use is consumed as heat and 38% as power.

[54] Between 2009 and 2019, the volume of plastic packaging waste generated per inhabitant increased by 24% (+6.7 kg). The recycling volume of plastic packaging waste increased sharply over the same period, by 50% (+4.7 kg). Despite this improvement, the amount of plastic packaging that wasn't recycled increased by 2.0 kg per inhabitant since 2009 due to the greater increase in the absolute value of plastic packaging waste generated (Eurostat, 2021c).

Consumers

Food consumption represents around 40% of the climate change impacts of EU consumption, with 3.5 tonnes of CO_2-eq per capita (European Commission - Joint Research Centre, 2022a; Sala and Sanyé-Mengual, 2023a). Consumers are the most numerous actor group in the food system. Food production is strongly driven by food availability, income, prices, marketing as well as by culture, but dietary preferences of consumers also have a role in shaping it (UNEP, 2016). Food consumption patterns also have an effect on peoples' health. Furthermore, consumers generate more than half of the total EU food waste with 70% of food waste arising at household, food service and retail (Stenmarck *et al.*, 2016). Consumers can also exert influence when acting collectively (Bock, Bontoux and Rudkin, 2022), for example, when aggregating in group purchase programs or when adhering to zero km initiatives. Estimates for Italy show that about 12% of respondents of a dedicated survey purchased foods through group purchase programs (Forno and Graziano, 2020). Alternative food networks evolved in the recent years from group purchase programs into communities that offer many services and food from short supply chain and local farmers (e.g., the food assemblies[55], which is now widespread in many EU member states).

In Europe, an estimated 20-30% of food is not consumed at home, but in restaurants, canteens and other services (Bock, Bontoux and Rudkin, 2022). Out-of-home consumption needs to be addressed for the different set of issues it poses and the related potential to promote sustainable practices: from the composition of proposed menus, to portion sizes, to food waste.

Consumers need to be able to make informed choices, thus the necessity of clear labels that also include information about the sustainability of products. For example, many certification schemes, sustainability labels and claims exist for food products (Stein and de Lima, 2021). Some of them address the whole supply chain and ensure responsible sourcing of ingredients from developing countries (e.g. programs on cocoa[56], coffee[57] or palm oil[58]), other focus on specific phases of the supply chain (for instance, agriculture or breeding practices) or specific aspects (e.g., animal welfare).

Though there are many different dietary patterns, the observed trends show that globally, we are moving towards higher per capita caloric demand, higher consumption of meat and of empty calories[59] (Tilman and Clark, 2014). Furthermore, there is rising concern regarding inappropriate advertising of the so-called ultra-processed food, especially for kids, that leads to unhealthy food choices and eventually unhealthy habits (Bock, Bontoux and Rudkin, 2022). A diet that is unbalanced towards too much meat, animal products and empty calories has also effects on many diet-related diseases (Willett *et al.*, 2019), has a higher consumption footprint (Sala and Sanyé-Mengual, 2023b), and higher environmental impacts (e.g., higher ammonia emissions from animal production (Sutton *et al.*, 2011).

In Europe, around 50% of total protein intake has animal origin (Peyraud and MacLeod, 2020). Consumer attitudes towards eating meat have changed in the past decades. For example, during 2004-2020, there was a rapid increase in the production of poultry meat, with EU production rising overall by 44.6%. On the other hand, the production of bovine meat has decreased, in 2020 it was about 10% lower than in 2004 (Eurostat, 2021a).

Finance actors and international trade actors

A growing role for non-state actors in the governance of food systems has been observed (UNEP, 2016; SAPEA, 2020). Finance actors should value not only economic returns of investments, but also

[55] https://laruchequiditoui.fr/en

[56] E.g. Cocoa Life (https://www.cocoalife.org/); Cocoa horizon (https://www.cocoahorizons.org/)

[57] E.g. Smithsonian Bird Friendly (https://nationalzoo.si.edu/migratory-birds/bird-friendly), Nescafé Grown Respectfully (https://www.nescafe.com/cup-of-respect/grown-respectfully)

[58] E.g. Roundtable on Sustainable palm oil (https://rspo.org/certification)

[59] Empty calories include calories coming from refined fats, refined sugars, alcohols and oils.

environmental and social ones (e.g., initiatives such as EU Sustainable Finance or the EU taxonomy for sustainable activities).[60]

The financialization of the food systems including, but not limited to, the trading of agricultural commodities in financial markets, has several implications for the food systems sustainability. For instance, it is deemed to exacerbate the existing imbalances of power and wealth in the food system and to increase economic and ecological vulnerabilities (Clapp and Isakson, 2018). Moreover, the stability and security of global agricultural trade flows are affected by the current Russian invasion of Ukraine. This implies increasing prices of agricultural commodities and growing concerns regarding the risk of supply disruptions of fertilizers (Colussi, Schnitkey and Zulauf, 2022; Paulson *et al.*, 2022). This in turn is likely to exacerbate food insecurity, especially in developing countries with high shares of grains imported from these countries (Behnassi and El Haiba, 2022).

To conclude, different actors have a different capacity of influencing the food system. At the same time, prices typically do not reflect negative environmental, social or health effects of food production and consumption so that externalities are endured by the society as a whole (Hendriks *et al.*, 2021). Thus, current practices by the different actors of the food chain do not reflect a systematic adoption of sustainability principles, generating significant impacts on the food system.

[60] The sustainable finance EU taxonomy and the following EU taxonomy Climate Delegated Act support sustainable investment practices. In relation to the environmental dimension of sustainability, the financial impact assessment of the EU taxonomy concludes that additional financial investments to reach EU GHG reduction targets can be reached (Alessi *et al.*, 2019).

Annex 2. Literature review supporting the mapping between environmental impacts, activities of the food system and related policy initiatives, by impact category

This annex details the literature review supporting the mapping presented in Section 3.1, by environmental impact category:

Climate change

The current food system (production, transport, processing, packaging, storage, retail, consumption, waste management) is responsible for 30% of greenhouse gas (GHG) emissions in Europe (Crippa *et al.*, 2021).

Farm stages dominate the GHG emissions, representing 61% of the whole food sector's GHG emissions (Poore and Nemecek, 2018). Land use and land use changes (LULUC) associated with agricultural production represent the main GHG emissions source. In 2018 these were estimated to account for 4 Gt CO_2-eq year (FAO, 2020), or about 32% of the total food-system emissions (Crippa *et al.*, 2021). Deforestation and land degradation are the main drivers of LULUC climate change through emission of GHGs and reduced rates of carbon uptake (Olsson *et al.*, 2019; FAO, 2020).

The food system has become more and more energy intensive. GHG emissions derived from the production and use of energy and fuels required along the whole supply chain represent the second cause of GHG emission in industrialised as well as in developing countries (Crippa *et al.*, 2021). A significant share of energy is required at farm level, especially for fertilisers manufacturing, use of machinery and irrigation. Food packaging, retail and supermarkets are also energy intensive processes within the food supply chain (Notarnicola *et al.*, 2017; European Environment Agency, 2019b), as well as food processing industry and households, which represent 30% and 20% of total food systems' energy emissions, respectively (UNEP, 2022). Food transportation has been estimated to account between 5% and 11% of the total emissions from energy in the global food systems (Poore and Nemecek, 2018; Tubiello *et al.*, 2022). However, when the relevant international and domestic transport distances and commodity masses used by the global food sector are accounted for, transportation account for almost the 20% of the total food-system carbon footprint (Li *et al.*, 2022).

Another important climate change driver is represented by non-CO_2 GHG emissions sources. Although since 1990 non-CO_2 GHG emissions from agriculture have declined, agriculture remains the largest contributor to total EU non-CO_2 GHG emissions (European Environment Agency, 2019b). Agricultural non-CO_2 emissions are constituted mainly by methane (CH_4) and nitrous oxide (N_2O). Enteric fermentation of ruminant livestock is the major source of methane emissions, which make up the largest share (38 %) of all GHG emissions in the sector. Nitrous oxide generating from the use of fertilisers (both synthetic and organic) represented 25 per cent of total agricultural emissions in 2019 (FAO, 2020) .

Although methane emissions from enteric fermentations and nitrogen emissions from fertilizers have decreased in Europe in the last decades, global emissions continued to grow after 2010 (FAO, 2020; UNEP, 2022).

The food sector contributes to climate change, but it is also vulnerable to climate change. Changes in CO_2 concentration, temperature and precipitation patterns as well as weather and climate extremes are already influencing crop yields and livestock productivity in Europe (European Environment Agency, 2019b). Climate change may favour the productivity of certain crops, being longer growing seasons and more suitable crop conditions in certain world areas. However, the number of extreme climate events is expected to increase, accelerating land degradation, altering water availability and quality (Bezner Kerr *et al.*, 2022), introducing land use changes and biodiversity loss (European Environment Agency, 2019b), with consequent negative impacts on food quality and production stability (Ebi and Loladze, 2019; Rama *et al.*, 2022). Climate change affects ocean and marine systems as well. Ocean warming has decreased sustainable yields of some wild fish populations and has already affected farmed aquatic species (Rama *et al.*, 2022).

Nevertheless, the agricultural sector may contribute mitigating climate change, through the removal of CO_2 from the atmosphere by implementing adaptation strategies that increase carbon sequestration and storage, such as cover crops, crops diversification and rotation, minimum or no tillage, increased irrigation efficiency, organic and precision farming, improved grassland and pastures (European Environment Agency, 2019b).

Ozone depletion

As widely recognised in the literature, the main compounds causing significant ozone depletion are represented by refrigerants, including chlorofluorocarbons (CFCs), carbon tetrachloride, methyl chloroform, halons, hydrochlorofluorocarbons (HCFCs), hydrobromofluorocarbons (HBFCs) (European Environment Agency, 2016), which are strictly regulated by international[61] and European[62] measures. Another important compound is methyl bromide. Although banned in european countries as agricultural pesticides, it is still used throughout the developing world, especially as a fumigant to control pests in soils, structures and commodities (European Environment Agency, 2016).

Other anthropogenic factors affecting the ozone layer are constituted by certain GHG emissions, such as methane and nitrous oxide (Ravishankara, Daniel and Portmann, 2009). Nitrous oxide (N_2O) is nowadays considered as the dominant ozone-depleting substance (Ravishankara, Daniel and Portmann, 2009; Portmann, Daniel and Ravishankara, 2012). In agriculture, this gas results from nitrogen surplus on farm, especially deriving from application of nitrogen-fertilisers (Tuomisto *et al.*, 2012; Meier *et al.*, 2015). Therefore, interventions in decreasing the use of fertilisers and ameliorating fertilisation practices by increasing their efficiency may favour a reduction of N_2O emissions, and thus a reduction of ozone depletion at primary production stage of the food supply chain.

Land use

The food system is recognised to be one of the major drivers of land use and land use changes worldwide (Poore and Nemecek, 2018; Willett *et al.*, 2019). Almost half of all habitable land is used for agriculture (Ritchie and Roser, 2022) which is among the dominant sectors driving land degradation due to land use changes and unsustainable land management practices (Olsson *et al.*, 2019). Indeed, farmland expansion, driven by the necessity of higher production, have caused land use changes, converting different ecosystems areas to agricultural land. Over the period 2011-2015, almost 30% of the deforestation (i.e. long-term permanent conversion of forest to non-forest land uses) occurring at global scale was attributed to commodity production (including palm oil, soybean and cattle grazing), and shifting agriculture was estimated to cause 24% of global forest disturbance (Curtis *et al.*, 2018). Livestock production is an important driver of deforestation due to the rapid expansion of pastures but also to the increasing demand for high-quality protein feeds, such as soybean. It has been estimated that, in South America, livestock is responsible for more than 85% of deforestation (71% for grazing and 14% for animal feed)(Bonnet *et al.*, 2020).

Land degradation cannot be reduced to a problem to be dealt with at local level; it is in fact expected that it will affect 90% of soils globally by 2050. At European level, costs related to land degradation already exceed 50 billion Euro per year (Kraamwinkel *et al.*, 2021). Unsustainable farming practices may provoke land degradation, including soil erosion, compaction, salinisation and soil organic carbon and nutrient losses (Olsson *et al.*, 2019; Hayo M. G. van der Werf, Knudsen and Cederberg, 2020), deteriorating in such way the overall soil quality and fertility. Contrarily, sustainable practices may

[61] The first international agreement aimed at protecting the ozone layer was the Vienna Convention (1985). The Montreal Protocol of 1987 (and subsequent Amendments and Adjustments) aims to eliminate the production and use of ozone-depleting substances worldwide (EEA, 2022).

[62] EU measures and policies to protect the ozone layer include the Regulation (EC) No 1005/2009 on substances that deplete the ozone layer lays down rules on the production, use, trade, recovery, recycling, reclamation and destruction of ODS and sets out requirements and measures for products and equipment containing these substances. On 5 April 2022, the European Commission put forward a legislative proposal to replace it (European parliament 2022, https//www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2022)738195)

reverse land degradation (Olsson *et al.*, 2019). Indeed, preferring organic fertilisers, green manure, intercropping, no or reduced tillage, agroforestry, livestock integration and other sustainable practices often applied under organic and agroecological agriculture, it has been demonstrated to favour soil fertility and quality (Gomiero, Pimentel and Paoletti, 2011; Wezel *et al.*, 2014). These practices moreover may also increase the carbon stock of soils, acting as soil carbon storage, influencing positively GHG emissions at farm level (Wezel *et al.*, 2014; European Environment Agency, 2019b; Olsson *et al.*, 2019). Nonetheless, under large-scale implementation of organic or agroecological food production, the land requirement for agriculture would increase, due to the lower yields obtainable from organic systems in comparison with conventional systems (Röös *et al.*, 2022). However, it has been demonstrated that if combined with a reduction in food waste and shifts to plant-based diets (allowing a reduction in farmed animals and feed crop production), organic agriculture could contribute to feeding more than 9 billion people in 2050 (Benton *et al.*, 2021).

Water use

Food systems are nowadays incredibly resource intensive, also concerning water use (Poore and Nemecek, 2018). It has been estimated that almost 70% of global freshwater is withdrawn for irrigation and livestock production (Foley *et al.*, 2011; WWAP UNESCO World Water Assessment Programme, 2019). Irrigation is performed only on 20% of the global arable land, producing 40% of the global food production. More efficient irrigation practices and wastewater treatments are key to increasing the resilience of food systems (Mohtar and Fares, 2022). The remaining production relies on water-fed, which faces growing water risk due to climate change and water use competitions. Indeed, in many regions, agriculture is increasingly subject to extreme weather events (such as droughts, floods, storms, and sea-level rise), which translates into significant yields decline (Gruère, Shigemitsu and Crawford, 2020). Furthermore, these risks are exacerbated by the growing competition for water from energy, industry or domestic use in urban areas (Gruère, Shigemitsu and Crawford, 2020).

Almost all animal-based products have a higher water footprint than plant-based products (Watts *et al.*, 2016), since livestock systems use water for feedstock cultivation, but also for drinking and animal servicing, stable washing and cooling, as well as for the maintenance and operation of slaughterhouses and processing plants (Steinfeld *et al.*, 2006).

Food processing is estimated to consume 20% of all extracted fresh water (FAO, 2012).

Eutrophication

Eutrophication is defined as the excessive plant and algal growth in waterbodies due to the increased availability of one or more limiting growth factors needed for photosynthesis (Schindler, 2006), such as sunlight, carbon dioxide, and nutrient fertilizers. Food systems, besides being a major responsible for water consumption, also concur in polluting aquatic ecosystems through both point-source discharges and non-point loadings of limiting nutrients, especially nitrogen and phosphorus compounds and organic matter (Mateo-Sagasta, Zadeh and Turral, 2017; Ringler *et al.*, 2022).

Primary production is the main responsible of eutrophication along the entire food supply chain (Notarnicola *et al.*, 2017).

In crops cultivation, eutrophication generally occurs when fertilizers are applied at a greater rate than they are fixed by soil particles or exported from soil profiles (Mateo-Sagasta, Zadeh and Turral, 2017). A recent systematic review of life cycle assessment (LCA) studies comparing organic and conventional cropping systems by Boschiero et al. (forthcoming) reveals that organic crop systems present lower eutrophication impacts, irrespectively by lower yields.

Livestock husbandry also plays a key role in generating eutrophication. Although organic fertilisers (i.e. manure) have positive impacts on soil fertility and soil biodiversity, a high concentration of livestock in a given zone risks to eliminate these positive impacts by generating an excess of nutrients and thus leading to water pollution (Bonnet *et al.*, 2020). In extensive livestock production systems,

usually a diffuse water pollution takes place, due to natural manure or slurry fertilisation of pastures and grazing areas. In intensive systems the associated production of wastes tends to go beyond the buffering capacity of surrounding ecosystems, thereby polluting surface waters and groundwater (Mateo-Sagasta, Zadeh and Turral, 2017).

Fish excreta and uneaten feeds from fed aquaculture diminish water quality and concur to eutrophication, even though this is much lower than the agriculture-related contribution (Mateo-Sagasta, Zadeh and Turral, 2017).

Ecotoxicity

Worldwide, pesticide use increased from 1.5 to 2.6 kg active ingredient per ha of cropland from 1990 to 2015 (Hayo M. G. van der Werf, Knudsen and Cederberg, 2020). If agrochemicals undoubtedly permitted an intensification of production and increased yields, to the other side they are recognized as a major cause of environmental burdens and impacts, such as ecotoxicity (UNEP, 2016).

It is demonstrated that generally organic production presents a lower ecotoxicity impact compared to conventional crop systems (Boschiero et al, forthcoming), although relying on copper-based agrochemicals.

Beside crop production, also animal farming and aquaculture are responsible for ecotoxicity impacts, with emissions of nutrients, hormones, antibiotics and heavy metals to the environment (Du and Liu, 2012; UNEP, 2016; Watts *et al.*, 2016).

In 2020, with food representing around 45% of the environmental impacts of EU consumption, the EU food system alone transgresses several planetary boundaries, including freshwater ecotoxicity (5 times) (European Commission - Joint Research Centre, 2022b; Sala and Sanyé-Mengual, 2023a).

Resources minerals and metals

Food systems heavily rely on metals and minerals. Primary production uses minerals and metals as source of fertilisers and pesticides (UNEP, 2016). Conventional systems use significant amount of phosphorous (P) and potassium (K) which represent fundamental fertilisers for crop production Organic cultivation, which is one of the most restrictive standards in terms of pesticides and fertilisers use, although forbidding synthetic fertilisers and pesticides, allows sulphur and copper and sulphur-based compounds, which are extensively used, especially as pesticides (Tamm et al. 2022).

Packaging is another step of the food supply chain that consumes metals (Notarnicola *et al.*, 2017), such as aluminium, iron, tin and bauxite. For instance, about 17% of aluminium in Europe is used in packaging (UNEP, 2016). The metals used in building the infrastructures and machineries used during food processing, transport, storage and waste treatment should also be considered, however they are of minor extent (UNEP, 2016).

Particulate matter

In 2020, the EU food system alone transgresses several planetary boundaries, including particulate matter (6 times) (European Commission - Joint Research Centre, 2022b; Sala and Sanyé-Mengual, 2023a). Food systems contribute to particulate matter (PM) formation in several ways. Road transportation and energy consumption required along the whole food supply chain represent the principal source of coarse (PM_{10}) and fine ($PM_{2.5}$) particulate matter (European Environment Agency, 2021a).

Other emissions of PM_{10} arise from farm-level operations, such as soil tillage and crop harvesting, and from burning crop residues and, to a lesser extent, grasslands (EEA). Primary $PM_{2.5}$ caused by the agricultural sector largely derives from dust from tillage, livestock dust, field burning, and fuel combustion in agricultural equipment use (Domingo *et al.*, 2021).

Biodiversity loss

The most important drivers of biodiversity loss are: habitat changes, climate change, pollution, invasive alien species and overexploitation (Millennium Ecosystem Assessment, 2005; Steinfeld *et al.*, 2006; Crenna, Sinkko and Sala, 2019).

The global food system plays a key role in decreasing biodiversity (Benton *et al.*, 2021), as it contributes directly or indirectly to all these drivers, at the local and global scale.

Land use changes caused by the conversion of natural land to agricultural land result in habitat changes and destruction (Benton *et al.*, 2021). Crop and animal farming has been behind much of these changes (Steinfeld *et al.*, 2006), due to deforestation caused by the rapid expansion of pastures but also to the increasing demand for high-quality protein feeds, such as soybean or the cultivation of certain plant commodities (e.g. oil palm).

Agriculture contributes to climate change and causes the release of nutrients and pollutants, as described above. Pesticides are indeed recognized as a major driver of biodiversity loss in both terrestrial and aquatic ecosystems (Hayo M. G. van der Werf, Knudsen and Cederberg, 2020). The sector also directly affects biodiversity through invasive alien species and overexploitation, for example through overgrazing of pasture plants (Steinfeld *et al.*, 2006) or overfishing of natural stocks.

However, certain sustainable farming practices, often applied in agroecological and organic systems, such as diversification of crops species and animal breeds, use of old cultivars, ecological structures (e.g. hedgerows, herbaceous strips, woodlot preservation) may promote biodiversity conservation (Gomiero et al., 2011; Jeanneret et al., 2021; van der Werf et al., 2020; Wittwer et al., 2021). Nevertheless, some authors argue that, due to the lower yield of such systems, a large-scale conversion to sustainable agriculture would require converting more natural habitats for agricultural production, negatively affecting biodiversity conservation (i.e., Clark & Tilman, 2017; Zewide & Sherefu, 2021). Major improvements on biodiversity may be reached only when a conjunction of actions is implemented, including sustainable farming techniques, drastic dietary changes, food loss and food waste reduction, expansion and increase of protected areas in key biodiversity areas, minimising agricultural expansion into species rich areas and increasing international trade from high yielding nations with low biodiversity to low yielding nations with high biodiversity (Willett *et al.*, 2019; Röös *et al.*, 2022).

Waste generation

Waste generation is increasing in the EU with an increase in total waste generation of 5.0% between 2010 and 2018 (114 million tonnes) (European Environment Agency, 2022b). Agriculture, forestry and fishing accounted in 2016 for around 20% of the total share of waste (European Environment Agency, 2018). Although not the major cause of waste production, the food system produces large volumes of wastes, generated from the production, preparation, packaging and consumption of food.

The packaging sector seems to contribute significantly to waste generation. Over the 2009–2020 period, the generation of all types of packaging waste material increased of about 20% (Eurostat, 2013). Paper and cardboard were the main packaging waste material in the EU (32.7 million tonnes in 2020) followed by plastic and glass (15.5 million tonnes for plastic and 15.1 million tonnes for glass waste materials in 2020) (Eurostat, 2013).

Food and beverage packaging accounts for almost two-thirds of total packaging waste by volume and approximately 50% of total packaging sales by weight (Marsh and Bugusu, 2007), and it is estimated to represent two- thirds of total European packaging in terms of market share value (European Commission and Directorate-General for Environment, 2019). Materials that have traditionally been used in food packaging include glass, metals (e.g., aluminium, tinplate, and tin-free steel), paper and paperboards, and plastics (Marsh and Bugusu, 2007).

The packaging sector is the biggest user of plastics (around 40%) and plastic packaging is responsible for around 60% of post-consumer plastic waste in the EU, most of which is only used once and then discarded (European Plastics Strategy, 2018). While plastics production is growing, the recycling of plastics is still low. Less than a fifth of plastic packaging waste is recycled globally and a lot ends up

in the environment, is incinerated or landfilled (Heinrich Böll Foundation, 2019). In the EU 28+2, only 41,9% of the 16,7 tonnes of plastic packaging waste was recycled (Eurostat, 2013).

It has been estimated that in 2018, in the European Union 28+2 countries, the agricultural sector used approximately 1 million tonnes of plastics for packaging purposes (FAO, 2021a). This figure may be underestimated, since data were not available for usage in storage, processing, and distribution.

Food waste generation

Estimates for the EU indicate that around 88 million tonnes of food are being wasted yearly across the food supply chain, roughly corresponding to 9% of the total food produced in the EU (De Laurentiis et al., 2021; European Commission & Eurostat, 2022[63]). Food waste occurs along the whole food supply chain, from food production to consumption. However, the consumption stage is identified as the major contributor to the total amount of food waste generated along the food supply chain (Stenmarck *et al.*, 2016; De Laurentiis *et al.*, 2021). Households, retail and food services are estimated to produce altogether 931 million tonnes of food waste per year at a global level (UNEP, 2021), being households the larger food waste producers (79 kg/year), followed by food services (26 kg/year) and retail activities (13 kg/year).

Household food waste can occur throughout the household management stages, including purchasing, storing, preparing, and consuming (Vittuari *et al.*, 2023).

Food processing and manufacturing are responsible for a lower share of food waste, especially concerning fruits, vegetables, cereals, meat and dairy products (De Laurentiis *et al.*, 2021).

Causes of food losses and waste differ based on supply chain stage and geographical setting. Among the drivers, Canali et al. (2014) highlighted 271 drivers of food waste generation per food supply chain segment and context category; while the study of Vittuari et al. (2022) provides a literature review of food waste prevention drivers and levers at consumer level according to the motivation-opportunity-ability (MOA) framework .

Waste in primary production can depend on technological inadequacies in harvesting and post-harvest management, caused by lack of appropriate infrastructure and equipment. Inefficiencies can affect operations throughout the supply chain: suboptimal management during food processing and cold chain logistics can aggravate waste production. Other managerial shortcomings, such as imprecise matching between supply and demand/forecasting, together with poor control over inventory and corporate policies on product aesthetics are indicated as leading causes of wholesale and retail waste. Faulty communication and lack of cooperation between supply chain actors can exacerbate operation failures (Canali *et al.*, 2014; FAO, 2019).

Biotic resource (overexploitation)

Since biotic resources are limited, it has been widely recognized that a transition to a sustainable exploitation of such resources is necessary (Lampert, 2019), exploiting them at a rate that permits their natural reproduction or regeneration capability.

Overfishing is still widespread across the pan-European region. Globally, the share of overfished fish stocks (meaning that fishes are catch at a rate faster than the natural fish reproduction rate to sustain population levels) has more than doubled since the 1980s (Ritchie and Roser, 2022) leading to unsustainable biotic resource depletion. In 2017, one third (34%) of the of global fish stocks was overfished (Ritchie and Roser, 2022). According to the EU blue economy 2022 (European Commission, 2022e), the situation of wild populations depends on the geographical area. In the North-east Atlantic Ocean and Baltic Sea, 28% of assessed fish and shellfish stocks are within safe biological limits, meaning that the number of stocks within safe biological limits has experienced a 3.5-fold increase,

[63] Data from press release on 25-10-2022.

from 8 in 2003 to 28 in 2020. In contrast, 87% of the assessed stocks were overfished in the Mediterranean and Black Seas.

Livestock and aquaculture play an important role in the overall pressure on demand for fish (Steinfeld *et al.*, 2006; Ritchie and Roser, 2022), being the 16% of world fishery production used for fishmeal and fish oil for feeds in 2017 (Naylor *et al.*, 2021). Approximately 17% of the fishmeal produced in the world is manufactured from trimmings from food fish processing, having an indirect impact on fish stocks. However, the remaining 83% come from direct marine capture fisheries (Steinfeld *et al.*, 2006).

Annex 3. Food waste and waste generation

Further information on data sources employed for the grey and scientific literature review is here provided by topic.

Within the European Union, food waste is defined as all foods, including both edible and inedible parts, leaving the food supply chain to become waste (i.e. a substance that the holder discards or is required to discard). This definition is laid out in Directive (EU) 2018/851, which also requires Member States to reduce food waste at each stage of the food supply chain, monitor food waste levels and report on progress made European Commission, 2018). Losses taking place before harvesting/slaughtering do not refer to food and are therefore excluded from the EU definition of food waste, coherently with the General Food Law. However, no official definition of food losses is provided in EU legislation. Conversely, FAO adopts alternative definitions, differentiating between food losses – occurring at production, post-harvest and processing stages, and food waste – taking place at retail and consumption stages (FAO, 2011). The lack of agreed definitions at international level hampers common international quantification efforts, as elaborated in the following paragraphs.

Food losses include both crop and livestock production losses. However, definitions, calculation methods and estimates available in the scientific literature differ. De Laurentiis et al. (2021) estimate food losses accounted in 2016 for several food groups at EU level, including everything that is left on the field and losses linked to animal mortality, as equivalent to in total almost 17 million tonnes (wet matter), of which around 25% are related to vegetables production, 23% to fruit, 21% to potatoes, and 15% to cereals.

The magnitude of the food waste issue has been also highlighted by recent global estimates, which suggest that the food waste problem might be even direr than previously thought. Retail, food services and households are estimated to produce 931 million tonnes of food waste per year at a global level (UNEP, 2021). The average food waste level for consumers in high income countries corresponds to 79 kg/year for household food waste, 26 kg/year for food services waste and 13 kg/year for retail activities (UNEP, 2021). Estimates for the EU indicate that around 88 million tonnes of food are being wasted yearly across the food supply chain, roughly corresponding to 20% of the total food produced in the EU (Stenmarck *et al.*, 2016; De Laurentiis *et al.*, 2021) with associated economic costs believed to reach 143 billion euros annually (Stenmarck *et al.*, 2016; De Laurentiis *et al.*, 2021). Food processing and manufacturing is a particularly complex stage of the food supply chain, due the variability of commodity characteristics and processes and to the lack of data on inefficiencies, both in scientific and technical literature. De Laurentiis et al. (2021) estimated that 13 million tonnes of food were wasted at this stage in 2016 in the EU, suggesting that this value might be an underestimation of reality. Yet, both Stenmarck et al. (2016) and (Caldeira, De Laurentiis and Sala, 2019) concur in attributing to the consumption stage the largest share of waste, even if the size of the problem might vary according to the country considered.

As the issue is becoming more prominent in international discourses, so are the efforts to counter food waste generation. These efforts should start with consistent quantification and measurement, instrumental in identifying hotspots and opportunities for reduction throughout the food supply chain and across product categories and geographies. From 2022, Member States are required to measure and report food waste levels which allow the establishment of national food waste baselines and for monitoring on the effectiveness of current and future reduction efforts towards reaching policy-mandated targets. The Farm to Fork Strategy outlines the Commission's commitment to SDG 12.3 to halving food waste at retail and consumer level by 2030, and reduce food losses along the food production and supply chains, while also announcing the establishment of legally binding targets to reduce food waste across the EU by end 2023 (European Commission, 2020b).

Addressing food waste is particularly challenging at consumer level, as waste generation can be a product of complex behavioural constructs, social norms and attitudes leading to faulty decision making (Stancu, Haugaard and Lähteenmäki, 2016; Schanes, Dobernig and Gözet, 2018; Chauhan *et al.*, 2021).

There are also overarching determinants of food waste along the supply chain, such as socio-demographic characteristics and institutional factors, some examples of which can be: the rise of one-person households not being reflected in food packaging sizes, as well as the dynamics of the broader food environment through marketing practices, offers and advertisements (Flanagan, Robertson and Hanson, 2019). Institutional factors can inadvertently affect the production of waste across the food supply chain through agricultural policies and related subsidies, regulation and marketing standards (Canali *et al.*, 2014; Garske *et al.*, 2020). A characteristic example influencing consumer food waste concerns the understanding of the dual system for expiration labelling and the difference between "use by" and "best before" dates, to avoid throwing away food. Ensuring food safety standards through low maximum thresholds for residues and contaminants can be linked to food waste and food security issues at local level by "legally" limiting the availability of food (Mylona *et al.*, 2018). Competing objectives between food safety requirements and sustainability concerns influences packaging choice and use, and ultimately food waste (Verghese *et al.*, 2015). Trade-offs and policy cohesion need to be considered in creating an enabling environment for food waste prevention (Garske *et al.*, 2020).

A recent study questions some of the well-known positive aspects of plastic packaging. The study was conducted in the UK, aiming at reducing packaging for the industry, where key recommendations were provided such as removing data labels from fresh products and reducing plastic packaging for fresh-produce items, while the presence of that packaging showed no or little meaningful effect on extending the life of these products. In contrast, the research conducted by WRAP concluded that when food products were sold loose and the best-before dates removed, it could save more than 10,300 tonnes of plastic and about 100,000 tonnes of food from being wasted each year. Therefore, further research should be conducted to find the right balance between the amount of packaging and food waste prevention.

Packaging reduction

The main initiatives targeting packaging reduction or better sorting that were explored are the following:

- Assessment report of the voluntary pledges under Annex III of the European Strategy for Plastics in a Circular Economy 2019: https://ec.europa.eu/docsroom/documents/34267
- Plastics Europe's Voluntary Commitment to increasing circularity and resource efficiency: https://plasticseurope.org/knowledge-hub/plastics-2030-plasticseuropes-voluntary-commitment/
- Queensland Government
    - Plastic Pollution Reduction Plan & Single-use plastic items ban: https://www.qld.gov.au/environment/management/waste/recovery/reduction/plastic-pollution/tackling-plastic-waste
    - Container refund Scheme: https://www.qld.gov.au/environment/management/waste/recovery/reduction/container-refund/container-refund-about
    - Australian Packaging Covenant: https://www.qld.gov.au/environment/management/waste/recovery/reduction/covenant
- Zero Waste Europe:
    - The #GETBACK campaign asks for reuse systems to be scaled up and harmonised across Europe through well-designed systems; and for the right infrastructure and policy to be put in place to support this: https://zerowasteeurope.eu/our-work/eu-policy/product-redesign/packaging/getback/

- The Plastic Waste Trade Manifesto which is a call to EU institutions to legislate, through the Waste Shipment Regulation, an end to plastic waste exports from the Union and intra-EU management of European plastic waste that is in line with a genuine circular economy: https://zerowasteeurope.eu/library/the-plastic-waste-trade-manifesto/
- Clarification on the manufacture of plastic packaging goods in the fourth delegated act of the EU Taxonomy: https://zerowasteeurope.eu/wp-content/uploads/2022/09/Joint_letter_DA04_DG_FISMA.pdf
- Recommendations of waste prevention targets. The report includes a mapping of waste prevention targets and policies at national and local level:https://zerowasteeurope.eu/wp-content/uploads/2022/07/Joint-paper-Recommendations-on-Waste-prevention-targets-July-2022.pdf
- Pledge - Setting a truly circular recycling system to define the civil society position towards chemical recycling and recovery technologies: https://survey.zohopublic.eu/zs/muBjpU

Voluntary guidelines and key agreements analysed

The main voluntary approaches taken up at EU level are:

- Commission Notice — Guidelines for the feed use of food no longer intended for human consumption - C/2018/2035
- Commission Notice – EU guidelines on food donation – C/2017/361/1
- Guidance on reporting of data on food waste and food waste prevention according to Commission Implementing Decision (EU) 2019/2000

In 2016, the Food Loss and Waste Protocol was issued, which provides guidance for food waste measurements for each step in the supply chain (Hanson et al., 2016). This is an international initiative.

Table A1. Voluntary agreements and partnerships to reduce food waste in the supply chain

Country	Title	Aim	Promoted by	Actors engaged	Effectiveness	Quantity of FW prevented	National Web
Netherlands	United against food waste	Commitment to reaching SDG 12.3	Ministry of Agriculture and Food, WUR, Bank	NA	Yes	Information from specific sectors (such as retailers and food service/restaurants)	https://samentegenvoedselverspilling.nl/
UK	Food waste reduction roadmap	Implement the Target, Measure, Act approach	WRAP	number of actors involved: 314	Yes	27% reduction per capita since baseline/ 1.7 mT/year reduction; 13-15% reduction in waste per tonne of food handled; 60k tonnes of food redistrubuted	https://wrap.org.uk/resources/report/food-waste-reduction-roadmap-progress-report-2021#download-file

Country	Title	Aim	Promoted by	Actors engaged	Effectiveness	Quantity of FW prevented	National Web
Hungary	Food is Value Forum (Élelmiszer Érték Fórum)	Commitment to reducing FLW from signataries; In line with international efforts, the Ministry of Agriculture, with the assistance of the Hungarian Food Bank Association, launched the Forum to reduce food waste and losses along the food supply chain. The Forum is a consultative body of organizations being able and willing to make substantial efforts to reduce food loss and food waste; Awareness-raising on the topic; strengthening knowledge management and information flow between stakeholders; identification of problems and solutions related to the topic; finding, presenting and adapting domestic and international good practices and existing projects.	Ministry of Agriculture	NA	No	NA	https://www.azelelmiszerertek.hu/hirek
Greece	Alliance for the reduction of Food Waste	Engage in coordinated action towards prevention and reduction, supports monitoring activities - key line of actions: education and prevention in school catering, prevention in catering and promotion of leftover consumption, guidelines for retailer, markets and catering	Boroume	NA	Yes	NA (progress report in Greek)	https://foodsavingalliancegreece.gr/

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Italy	PINPAS	Engage main FSC stakeholders to identify policy measures to reduce food waste; The agreement aims to support municipalities in identifying and implementing initiatives for the prevention and reduction of food waste in school and commercial collective catering. In particular, it provides for the experimentation, within a panel of schools, of a set of measures for the reduction of uneaten food with particular attention to measures aimed at reducing the "plate leftover" (leftover in the dishes) and experimentation in catering commercialization of the doggy-bag / family-bag in order to promote the take-away of uneaten food	Ministry of Environment , University of Bologna, ANCI	NA	No	NA	http://sprecoalimentare.anci.it/ristorazione-scolastica/documenti/pinpas-piano-nazionale-di-prevenzione-degli-sprechi-alimentari-le-azioni-prioritarie-per-la-lotta-allo-spreco/
Sweden	SAMS, Swedish Collaboration for the reduction of food waste	Network of public authorities and stakeholders	Swedish environmental Institute	Over 30 stakeholders from the food industry involved	Yes	NA data avaliable on YOY reduction from food services (in grams/plate)	https://www.ivl.se/download/18.147c3211181202f18d11217b/1656420904055/SAMS%20%C3%A5rsrapport%202021.pdf
	The Swedish Food Federation's Code of Conduct for sustainability in the food industry	Commitments for food industry companies concerning fossil fuel, food waste, circular packaging, social sustainability and use of water. Private commitment					https://www.livsmedelsforetagen.se/in-english/

Country	Title	Aim	Promoted by	Actors engaged	Effectiveness	Quantity of FW prevented	National Web
Denmark	Danmark mod madspild	Commitment from food business operators to monitor and reduce their food waste by 50% by 2030	Think tank One\third	NA	No	NA	https://danmarkmodmadspild.dk/
	Madspildsjaegerne 2.0	The Food Waste Hunters 2.0. is a project where food business are offered professional assistance to reduce food waste at retail and wholesale. The assistance consists of consultants who, with advice and guidance, are to help food businesses reduce their food waste.					*Information on this initiative could not be complemented from other sources besides the listed in the footnote of this table*
Finland		Ministry of Agriculture and Forestry				target of 13% reduction from baseline (2016) in preparation distribution and consumption	*Information on this initiative could not be complemented from other sources besides the listed in the footnote of this table*
Austria		VA with food business that encourages the redistribution of food for social purposes (and mandatory measurements, development of personal trainings and reporting of food waste data)	Federal Ministry for Climate, Action, Environment, Energy, Mobility, Innovation and Technology	Signed by the large retail companies in Austria			https://www.bmk.gv.at/themen/klima_umwelt/abfall/abfallvermeidung/lebensmittel/initiative/aktionsprog.html
Germany	Zu gutt fur die tonne	BMEL, associations in the agricultural sectors, the food and nutrition industry and the hotel and catering sector;	Federal Ministry of	NA	No	NA	https://www.zugutfuerdietonne.de/fileadmin/zgfdt/sektorspez

Country	Title	Aim	Promoted by	Actors engaged	Effectiveness	Quantity of FW prevented	National Web
		Declare the willingness of the organizations involved to: encourage their members to put into practice the specific measures, to support in monitoring and reporting	Food and Agriculture				ifische_Dialogforen/Ausser-Haus-Verpflegung/General_Agreement_Reduction_of_Food_Waste.pdf
Ireland	Food waste charter	Follow a framework of pledges > measure > reduce > report	Major stakeholders	Available: 5 major retailers signed, representing 70% of Irish grocery retail market	No	NA	https://foodwasteforum.ie/the-charter/
Portugal	Unidos contra Desperdecio	Creation of specific points of contact for donation; facilitating donation and making food waste prevention a rule	Retail sector	NA	No	NA	https://www.unidoscontraodesperdicio.pt/
Norway	Matvett	Collaboration with research organizations and authorities, on behalf of private businesses; main goal is aligned with SDG 12.3. Aim of organziation (which is owned by trade associations) is to make it easier for actors to reach targets; definition of a common methodology for measurement and reporting	Food industry	34 major food companies	Yes	8% among producers, 5% reduction in consumers between 2009-2015	https://www.matvett.no/
	Bransjeavtale om reduksjon av matsvinn (Industry agreement on food	Negotiated agreement between five ministries and 12 food industry organisations.The agreement is a broad commitment on reduction of food waste through the entire value chain from primary production to consumer.The parties to the	Industry and government	NA			https://www.regjeringen.no/no/aktuelt/matsvinn-konferanse-med-tre-statsrader/id2891229/

Country	Title	Aim	Promoted by	Actors engaged	Effectiveness	Quantity of FW prevented	National Web
	waste reduction)	agreement will cooperate to promote better utilisation of resources and raw materials through prevention and reduction of food waste throughout the food chain. The agreement will thereby contribute towards reducing the environmental consequences associated with food production and consumption in Norway. The agreement will provide increased knowledge of the extent and causes of food waste, contribute to the exchange of experience between the actors and lead to cooperation across the food chain. The agreement will contribute towards better knowledge and attitudes among consumers and within the food industry in order to preserve food and prevent/reduce food waste. The agreement implies, inter alia, that the parties should facilitate consumer behavior that contributes to reduced food waste in households.					
France	National pact against food waste	Signatories commit to 19 objectives for public authorities and 16 for stakeholders	5 ministries	58 stakeholders	Yes	NA	https://agriculture.gouv.fr/pacte-national-de-lutte-contre-le-gaspillage-alimentaire-les-partenaires-sengagent
Flanders	Vlaamse ketenplatform	Commitment to reduction targets and collaboration to reduce waste (15% by 2020)	Regional government and food	8 associations at regional level	Yes	NA	https://www.voedselverlies.be/

Country	Title	Aim	Promoted by	Actors engaged	Effectiveness	Quantity of FW prevented	National Web
			supply chain stakeholders (Trade associations)				
Romania	"Retail Agreement on waste"	agreement to implement measures of food waste avoidance; voluntary agreement and action program	Main retailers	NA	No	NA	https://despre.kaufland.ro/responsabilitate/implicarea-face-diferenta/evitarea-risipei-alimentare.html
Australia		It brings together organisations in a pre-competitive collaboration to make the food system more sustainable, resilient, and circular. It focusses on prevention, reuse (donation), and food chain transformation and innovation	Food banks Retailers	NA	Partially	Some of Australia's biggest food businesses have already signed up to help tackle our $36.6 billion food waste challenge.	https://www.stopfoodwaste.com.au/australian-food-pact/
GLOBAL INITIATIVES							
Champions 12.3	10x20x30	Commitment to SDG 12.3 and engagement of supply chain partners to embrace the target measure act approach and the 50% reduction target	WRI	200 global companies	No	NA	https://champions123.org/
Consumer Goods Forum	Consumer Goods Forum's Food Waste Coalition	Commitment to SDG 12.3 and engagement of supply chain partners to embrace the target measure act approach and the 50% reduction target	Consumer Goods Forum	23 of the largest global companies	No	NA	https://www.theconsumergoodsforum.com/environmental-sustainability/food-waste/

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FAO	Voluntary Code of Conduct for Food Loss and Waste Reduction	The Voluntary Code of Conduct for Food Loss and Waste Reduction (CoC), endorsed by FAO Members, sets out a generic framework of actions and guiding principles to reduce FLW, while supporting the transformation of agri-food systems to be more efficient, more inclusive, more resilient and more sustainable	FAO	Multistakeholder engagement	NA	NA	https://www.fao.org/3/cb9433en/cb9433en.pdf

Source: EU Food Loss and Waste Prevention Hub, WRI, Consumer Goods Forum, and FAO.

Additional policy actions analysed that go beyond the analysis targeting waste or food waste directly or indirectly:

- Plastic Bags Directive (Directive 2015/720 of the European Parliament and of the Council 2015 amending Directive 94/62/EC as regards reducing the consumption of lightweight plastic carrier bags). It is an amendment to the Packaging and Packaging Waste Directive (94/62/EC) and was adopted to deal with the unsustainable consumption and use of lightweight plastic carrier bags.
- Landfill Directive (Directive 2018/850 of the European Parliament and of the Council amending Directive 1999/31/EC on the landfill of waste). It aims to prevent or reduce the adverse effects of the landfill of waste on the environment. It defines the different categories of waste and applies to all landfills. It also classifies the types of landfills and obliges Member States to minimize biodegradable waste to landfills.
- Commission Regulation (EU) 2021/382 of 3 March 2021 amending the Annexes to Regulation (EC) No 852/2004 of the European Parliament and of the Council on the hygiene of foodstuffs as regards food allergen management, redistribution of food and food safety culture (Text with EEA relevance).
- The ESTAT guidance further specifies what is to be quantified as "food waste" for the purpose of EU monitoring and reporting, indicating that food waste includes both edible and inedible parts of food.
- Delegated act 1597/2019 supplementing the Waste Framework directive on common methodology and minimum quality requirements for the uniform measurement of food waste levels.
- Directive 2014/95/EU of the European Parliament and of the Council of 22 October 2014 amending Directive 2013/34/EU as regards disclosure of non-financial and diversity information by certain large undertakings and groups Text with EEA relevance
- EU waste legislation requires that biowaste is collected separately or recycled at source by 2023. Currently a proposal for legally binding targets for food waste reduction are under development by the EU.
- Lithuania will separate household food waste as of 2024[64][1].
- Denmark set the target to achieve 60% organic foods in all public kitchens by 2020. This example is interesting as targeted food waste in an indirect way, by increasing organic food. The organic price premium is partly covered by reducing food waste, allowing more organic meals without an increase in operating budgets[65].
- Pay as you throw (also called trash metering, unit pricing, variable rate pricing, or user-pay) is a usage-pricing model for disposing of municipal solid waste. Users are charged a rate based on how much waste they present for collection to the municipality or local authority. Beyond the example of South Korea, there are other EU municipal authorities running this. For example in Italy or The Netherlands.
- Some cities in the United States have implemented organic waste bans to penalise bad sorting practices, such as in San Francisco[66].
- Queensland Organics Strategy and Action Plan. Provides a clear roadmap for how Queensland plans to avoid generating organic waste, reduce the impacts of organic waste on the environment and communities, transition to a circular economy and build economic and market opportunity for the organics recycling industry[67].

[64] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.164386/asr

[65] https://ec.europa.eu/food/safety/food_waste/eu-food-loss-waste-prevention-hub/eu-member-state-page/show/DK

[66] https://www.epa.gov/transforming-waste-tool/zero-waste-case-study-san-francisco

[67] https://www.qld.gov.au/environment/management/waste/recovery/reduction/organics-strategy

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