Deliverable 2.3

Resumé on performance of EU food systems towards European FNS and SDGs

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Document History and Information

VERSION	DATE	DESCRIPTION AND COMMENTS	AUTHOR
1.1	11 February	Clarify the relation with SUSFANS Indicate how results made available for uptake by stakeholders	Hao David Cui, Thom Achterbosch, et al.
1.2	15 February	Improved description of methods Consistency and less detail in graphical presentation Improved synthesis Reference to online database	Hao David Cui, Thom Achterbosch, et al.
Final	1 March	Improved reporting on the analysis. Improved description of methods Revised highlights	Hao David Cui, Thom Achterbosch, et al.

Content

Highlights

- The EU has committed to the sustainable development goals (SDGs). In this study, we explored the extent to which **the evolution of the EU food system to 2030 is likely to contribute to the SDGs for Europe**, yet in a global context, with a focus on a subset of indicators related to social, economic, and environmental issues, representing respectively **SDG2 Zero Hunger, SDG10 Reduced Inequalities, and SDG13 Climate Action**.
- The indicators and their quantification approach are developed on the basis of an **index for assessing the sustainability performance of the EU food systems**, developed in the **SUSFANS project**. Three **advanced modelling** tools are employed to study the synergies and trade-offs towards these SDGs using a quantitative foresight approach. For most of the indicators examined jointly by the three models, the model results show a certain level of inconsistency in the sense that one or two models may project an opposite change in the SDG indicators in one or more scenarios.
- The scenario results are considered to be **robust** when the consistency between the direction of the average of the changes projected by all the three models and the direction of the average of the changes projected by most models (i.e. two of them) is at an acceptable level. Consistencies are considered to have reached in projecting EU's per capita food consumption and agricultural emissions intensity in all the three socio-economic challenge scenarios, calorie density in food consumption in the medium and low challenge scenarios, and Nutrient Rich Dietary scores and agri-food emissions in the high challenge scenario.
- By contrast, inconsistencies in the scenario results between models reveal to some extent the underlying **uncertainty** in future developments of these indicators as they appear to be sensitive to different model settings and assumptions. Inconsistencies are still expected to exist in projecting Nutrient Rich Dietary scores and total agri-food emissions in the medium and low challenge scenarios and in projecting calorie density in food consumption in the high challenge scenario.
- On the basis of robust projections, we assess the challenges in the EU in achieving the SDGs by 2030. The Zero Hunger SDG2 indicators in Europe appear to develop in mixed directions towards 2030, i.e. with **trade-offs between sub-goals on the SDG2 Zero Hunger goal in the EU**. The models on average project a **moderate increase in per capita food consumption at the EU average**, an SDG indicator considered to paramount in assessing the goal of zero hunger. This moderate increase in food consumption appears to be coupled with a **reduced energy balance of the diet** in the medium and low socio-economic challenge scenarios as models on average project increased calorie density in food consumption at the EU average. In the high challenge scenario, models on average project **improved dietary adequacy in terms of the availability of 12 macro and micronutrients** in consumption at the EU average, reflected by increased scores on the Nutrient Rich Diversity index. Since the lower/higher socio-economic challenges are specifically linked to the assumed expansion/contraction of EU's population, this naturally suggests that a low population growth in the EU is more likely to see improved nutrition.
- The growing food consumption in the EU also does not appear to move in parallel with improvements in wage equality, as revealed by MAGNET projections, indicating **potential trade-offs in achieving both SDG2 of ending hunger and SDG10 of reducing inequality**. In particular, wage inequalities between agricultural and non-agricultural sectors at the EU average are expected to enlarge over the projection period, as is the case for the country average outside the EU.
- The synergies and trade-offs between **SDG2 Zero Hunger and SDG13 Climate Action are relatively difficult to judge** as models fail to offer consistency in projecting the change in EU's

agri-food GHG emissions in the medium and low challenge scenarios. This **inconsistency** may be driven by different model assumptions associated with the trade system since a relatively flexible trade system may reduce the pressure on the expansion of domestic agricultural production in order to meet the growing food demand. In the high challenge scenario, however, models consistently project a decrease in agri-food GHG emissions as population in the EU is assumed to contract in this scenario.

- EU member states perform widely different in their achievement on the SDG challenges, which can be seen as creating **front-runners and laggard countries in the EU**. Despite the aforementioned inconsistencies across model projections, all the models project that the SDG indicators assessed in this study would be more scattered across EU member states than across scenarios. In other words, the synergies and trade-offs across SDGs appear to be more sensitive to regional distribution than to scenario assumptions, suggesting that **further policy and research & innovation actions may need to be directed towards addressing disparities** across EU member states.
- Alignment with FIT4FOOD2030 RRI processes at national and EU level have been accomplished and can be extended with support from project partners. Taking into account the strengths and limitations of the quantitative foresight approach and its results, the combination of the SUSFANS framework, a database of quantified foresight drivers and scenarios results presented in a SUSFANS visualiser tool can inform urgencies and priority-setting for R&I iin the national policy labs as well as the EU Think Tank.

1 Introduction

The Sustainable Development Goals (SDGs), adopted by all United Nations member states in 2015, are an urgent call for action by all countries - developed and developing - as they recognize the importance of working together to combat the growing challenges facing the world. The multiple development goals with a focus on sustainability cover a wide range of social, economic, and environmental topics including, but not limited to, ending poverty, improving health and education, reducing inequality, spurring economic growth, tackling climate change, and preserving natural resources. As the heart of the 2030 agenda, these well-inclusive policy goals provide a shared blueprint for prosperity for all people on the planet, with a clear-targeted, traceable, and measurable approach.

There is an expanding literature that has assessed the importance of food systems transformation in achieving the global goals. Agricultural development is essential for the reduction of poverty and hunger (World Bank 2008). Natural resource use related to agriculture and food is inequitable at present, and the benefits from the food system are unequally distributed (The Economics of Ecosystems and Biodiversity (TEEB), 2018). In order to achieve the SDGs there is a need for combined action towards a food supply that is within the long-term carrying capacity of the planet’s ecology and towards consumer diets that contribute to reduce all forms of malnutrition (Haddad et al. 2016, Willet et al. 2019). In this paper, we explore the extent to which the evolution of the EU food system to 2030 is likely to contribute to achieving dedicated SDGs considering also interactions, synergies, and trade-offs with the rest of the world. Given the multiplicity of the SDGs, we examine a subset of goals and indicators, related to major social, economic, and environmental issues. In particular, we trace the developments of representative SDG indicators up to 2030 in order to identify possible synergies and trade-offs towards meeting these goals using a modelling toolbox comprised of economic agricultural sector models. FIT4FOOD2030 deliverable 2.1 (Wepner et al., 2018) has discussed several foresight drivers in detail and in isolation. As will be detailed below, our assessment goes beyond this approach towards a quantitative scenario assessment developed from the perspective of the EU in the world, delivered in the framework of the research project SUSFANS (See Box 1 for an introduction). The quantification approach brings considerable implications for the breadth of the approach.

Box 1. Introduction into SUSFANS

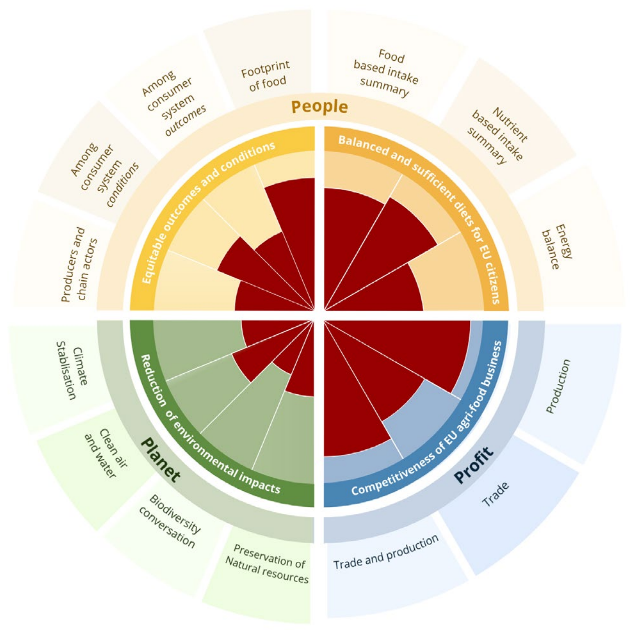
SUSFANS delivers high-quality research on metrics, models and foresight to support evidence-based policies and innovation strategies for a sustainable and food and nutrition secure EU.

How SUSFANS works

The research work in SUSFANS is divided in three pillars, aiming at: 1) Assessing sustainable Sustainable Food and Nutrition Security (FNS) in the EU using conceptual mapping and innovative metrics for the food system; 2) Modelling sustainable FNS, its outcomes and possible innovation pathways; 3) Foresight and policy guidance for European diets and food systems at large.Assessing sustainable food and nutrition in the EU.

Framework for assessing the sustainability performance of eu food systems

An integrated approach was developed in four steps to assessing sustainable food and nutrition security of the EU food system with the input and endorsement of the SUSFANS stakeholder core group: 1) a conceptual framework of the EU food system, 2) an integrated, hierarchical set of metrics for assessing options for change, 3) a modelling strategy for estimating the metrics and 4) a visualization tool across the metrics to enable an informed stakeholder debate on food system change (Zurek et al. 2018). See figure.



Toolbox for modelling sustainable FNS, its outcomes and possible innovation pathways;

Our modelling toolbox comprises three models that are highly complementary in sectoral disaggregation, geographical resolution, and policy coverage: the Modular Applied GeNeral Equilibrium Tool (MAGNET), Global Biosphere Management Model (GLOBIOM) and Common Agricultural Policy Regionalised Impact (CAPRI). MAGNET (Kuiper et al. 2018; Woltjer, et al. 2012) is a global economic simulation model that has been extended with the newly developed MAGNET SDGs Insights Module which includes a suite of official and supporting indicators, covering twelve of the seventeen SDGs. GLOBIOM is a global partial-equilibrium model of the agricultural and forestry sectors with detailed spatially explicit representation of land, production activities and systems, and related environmental and socio-economic impacts (Havlík et al. 2014; Frank et al. 2015). CAPRI is a partial-equilibrium model of the global agricultural sector with focus on the EU that provides a wide range of economic and environmental indicators. Together, these models form a toolbox for the assessment of the evolution of the EU food system using a suite of European indicators developed within the Sustainable Food and Security (SUSFANS) project, complemented with SDG indicators for the rest of the world.

More information: www.susfans.eu

In SUSFANS, a multidisciplinary team has developed a comprehensive framework for assessing the sustainability performance of the European and national food system in the EU (Zurek et al. 2018), and has provided quantitative foresight on this (Frank et al. 2018).

We examine how the EU food system fares under alternative scenarios, and which scenarios are most and least consistent with progress towards the SDGs. We also assess how the synergies and trade-offs towards SDGs are sensitive to different scenario settings. The resulting conclusions aim to galvanize policy actions to address potential issues emerging from our analysis as they are critical in ensuring the EU food system to be on track in achieving the ambitious SDGs. In particular, the ambition is to support the prioritization of European challenges for research and innovation at the European and national level, and possibly at subnational levels of decision-making. By presenting the results from this study with detail for individual member states and for an EU average, the study may incite stakeholder debate on their implications for R&I challenges. This process will be further enabled when full visualisations of the results are made available as an on-line interactive tool under the SUSFANS project.

The key SDGs investigated in this study include SDG2 Zero Hunger, SDG10 Reduced Inequalities, and SDG13 Climate Action. We use these SDGs as representative goals to explore issues across the social, economic and environmental dimensions, respectively. Our analysis will first be centred on SDG2 Zero Hunger, using a suite of indicators including per capita food consumption index, daily per capita calorie availability, and Nutrient Rich Dietary (NRD) scores, to assess whether the EU food system is on track towards achieving this SDG and whether there are any synergies and trade-offs among the indicators associated with this SDG. Since indicators for SDG2 relate to the social domain, we will then explore the synergies and trade-offs between SDG2 and SDG10 which mainly involves indicators related to wage distributions across sectors and skill levels, and then synergies and trade-offs between SDG2 and SDG13 which primarily uses indicators related to emissions per calorie produced.

While the SDG reporting framework in this study is in principle aligned with the official monitoring system of the EU for its performance on the SDGs (European Commission 2017), we use different indicators in this study for certain individual SDGs in order to help provide more informative analysis. Malnutrition, for example, is reported by (European Commission 2017) using obesity rate, while in our study, malnutrition is quantified using a range of variables including consumption of calories and other macro- and micronutrients. This enables us to assess not only the possible trends towards obesity developments, but also the distribution of micronutrients which are an essential part of a healthy diet and which have widely been neglected in past food security research (Nelson et al. 2018). This approach to the quantification of nutrition indicator uses indicators for diet quality and micronutrient availability in consumption, as developed in SUSFANS (Frank et al. 2018).

2 Using the SDGs as food systems performance indicators

2.1 The distinction and connection between SDG and SUSFANS frameworks

This study distinguishes itself from SUSFANS (e.g. Frank et al. 2018, Latka et al. 2018) in several aspects including an extended coverage to the global scale, distinctive indicators dedicated for SDG analysis, as well as realignment to the SDG reporting horizon. Despite these differences, the analytical framework developed for SDGs is consistent with the SUSFANS framework in many ways. They share a common database and similar scenario assumptions, and have the same participating models (CAPRI, GLOBIOM, and MAGNET) from collaborative research teams. Several indicators employed for SDG analysis are similar to the indicators used for SUSFANS as both frameworks aim to assess issues associated with social, economic, and environmental dimensions. In SUSFANS, a conceptual framework known as “sustainable food and nutrition security” is developed to assess these issues

(Zurek et al. 2018). The individual components of conceptual framework in spirit correspond to the SDGs elected in our assessment, as mentioned above. In this sense, our SDG framework may be viewed as a reassembly of the SUSFANS metrics, guided by an updated storyline towards SDGs. A mapping between SUSFANS metrics and SDGs, as shown below, paints a clear picture of the relationship between the two analytical frameworks.

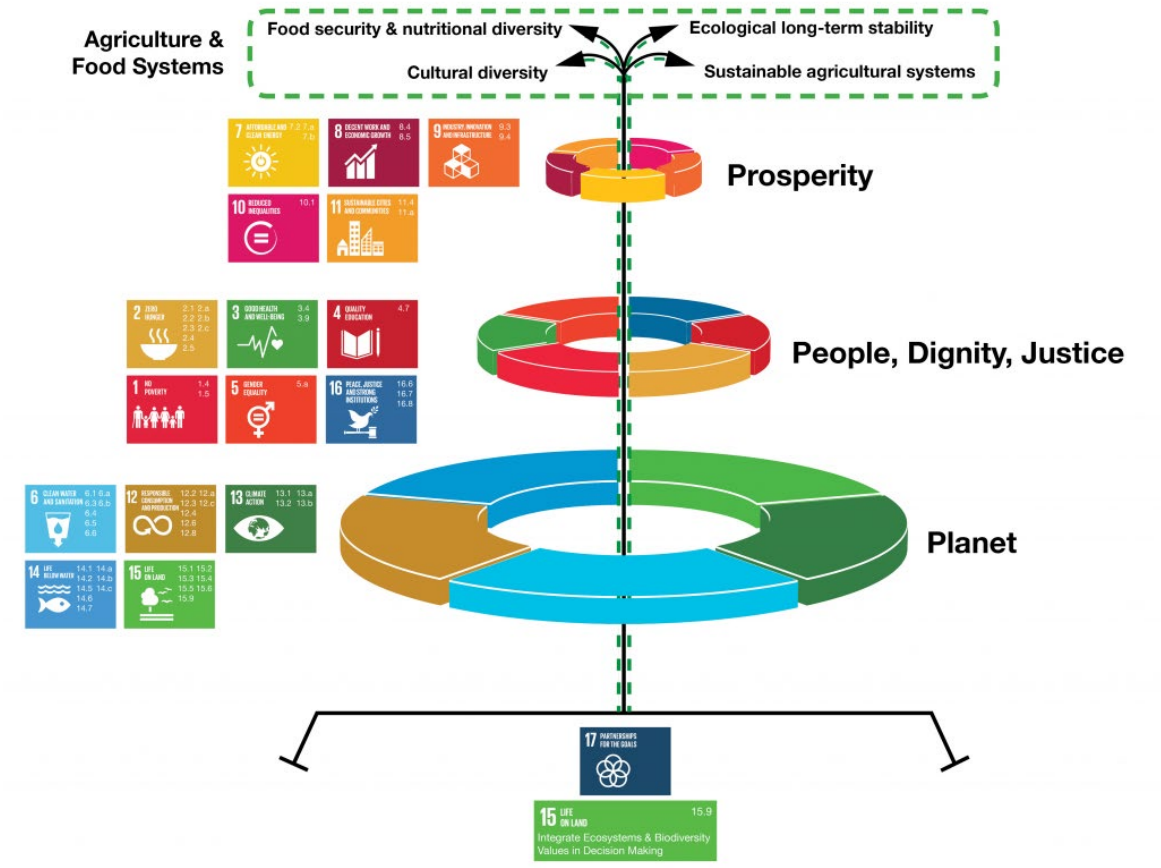
2.2 Mapping of the SUSFANS metrics to SDGs

Mapping the EU SUSFANS metrics to the global SDGs shows a more complex picture than is first expected. In this document we consider the implications of mapping the SUSFANS metrics to the SDGs (the first task in FIT4FOOD Task 2.3). The SUSFANS metrics exist on multiple levels which lead to one another (Individual variable>Derived variable>Aggregate indicator>Performance metric>Policy goal). This exercise shows that the level at which the two sets of indicators are mapped is important and leads to different outcomes with potentially different interpretations. Crucial to this mapping exercise, is the understanding that *if* the two sets of indicators are to be explicitly linked *then* a change in one set of metrics must be interpretable as the same as a change in the other set i.e. they must move in tandem.

A thematic mapping is a simple matching of the SUSFANS policy goals with the SDGs as shown in the diagram below. The starting point for this mapping is a diagram from The Economics of Ecosystems and Biodiversity (TEEB) project, which reimagines the SDG indicators in a food systems approach (Figure 1a). Applying this categorisation to the SUSFANS policy goals gives the diagram on the right (Figure 1b). The thematic mapping is intuitive but leaves several SDGs uncategorised.

The thematic mapping can be extended to one level lower in the SUSFANS metrics, at the level of the Performance Metrics as shown in Table 1 below. At this lower level, more SDGs come into play, and some of the SDGs appear twice in the framework. Note that although this seems desirable, the SUSFANS metrics may only cover part of the SDG indicators and thought needs to be given as to whether a change in these metrics can be interpreted as a change in the SDG itself.

A more detailed mapping of SUSFANS metrics to SDG targets, and full detail across all the levels in the SUSFANS indicator hierarchy levels is available in an accompanying Excel workbook. The conclusion of this exercise is that a detailed mapping from SUSFANS metrics to SDGs is not straightforward for all policy goals except Balanced and Sustainable Diets (SDG2). Only few SUSFANS metrics have directly comparable SDG indicators so care should be exercised when linking the two. This is particularly important for the SDG13 Climate Stabilisation indicators which relate to natural disasters, strategic planning and finance for action rather than e.g. emission levels. We build however on a common understanding that the UNFCC Paris Agreement provides the de facto target for SDG13 Climate Action. This agreement stipulates a global framework for reducing greenhouse gas emissions to a level aligned with at most 2 degrees and preferably 1.5 degrees of global warming compared to pre-industrial levels.



Source: http://doc.teebweb.org/wp-content/uploads/2016/10/SDGcake-e1476453400279.png

(a) SDG targets related to food systems *(b) Mapping SUSFANS metrics to SDGs*

Figure 1. Alternative perspectives to link the SDGs to the food system, from TEEB (panel a) and SUSFANS (panel b).

Table 1. The mapping of SUSFANS metrics to Sustainable Development Goals

SUSFANS Performance Metrics	SDGs
Balanced and Sufficient Diets	
Food based summary score	SDG2 Zero Hunger
Nutrient based summary score	SDG2 Zero Hunger
Energy balance	SDG2 Zero Hunger
Competitive and viable business	
Production & value added	SDG17 Partnerships for the Goals
Employment	SDG1 No Poverty
Productivity	SDG8 Decent Work and Economic Growth SDG9 Industry, Innovation and Infrastructure
True-cost pricing	SDG12 Responsible Consumption and Production
Reduced Environmental Impacts	
Climate stabilization	SDG13 Climate Action
Clean air, soil and water	SDG11 Sustainable Cities and Communities SDG6 Clean Water and Sanitation SDG15 Life on Land
Biodiversity conservation	SDG15 Life of Land
Preservation of natural resources	SDG6 Clean Water and Sanitation SDG14 Life Below Water SDG15 Life on Land
Equitable Conditions & Outcomes	
Equity among consumers: food system outcomes	SDG2 Zero Hunger SDG1 No Poverty
Equity among consumers: food system conditions	SDG3 Good Health and Well-Being SDG1 No Poverty SDG2 Zero Hunger
Equity among producers and chain actors	SDG4 Quality Education
Equity in foot printing of food	SDG12 Responsible Consumption and Production

Source: for SUSFANS metrics, Zurek et al. (2018)

3 Scenario and modelling approach

A short overview of the scenario and modelling approach is as follows:

- The approach is developed under the foresight work of the project SUSFANS. A concise and non-scientific description of the approach is presented in Havlík et al. (2018). We apply a novel SDG lens for this résume.
- The scenarios provide three plausible directions for change in the EU food system at EU28 and member state level, in the global context, towards 2030 and 2050.
- The challenges to meet the SDGs are quantified using three advanced modelling tools which are often used to evaluate EU agriculture and environment policies: CAPRI, GLOBIOM and MAGNET (Box 1).
- A database on quantified drivers, including economic growth, demographic change, technological change and trade policy change with detail for EU member states is available (link to the data: https://susfans.eu/research-data).
- An advanced user-friendly visualisation tool to assess the future food systems challenges at EU and member state level is in progress.

We analyse the performance of the EU in achieving the SDGs using a set of contextual scenarios for the EU as developed in SUSFANS (Havlík et al. 2018), and a database on the quantified challenges for the EU as developed in SUSFANS (Frank et al. 2018). We keep the projection period consistent with the SDG reporting horizon (up to 2030). We consider three possible paths of development for the EU food system based on adjustments to the Shared Socio-economic Pathways (SSPs), which summarize the possible future challenges facing the world with respect to climate change mitigation and adaption (O'Neill et al. 2017). The SSP scenarios are part of the analytical toolkit of the Assessment Reports of the International Panel on Climate Change, and provide a global standard for scenarios in the field of integrated assessment of earth and sustainability challenges. The SSP framework brings inherent limitations for the analysis of sustainable food systems, notably due to shortcomings in addressing inequalities in societies (van Dijk et al. 2016). The SUSFANS scenario framework has been informed by stakeholder dialogue which indicated the need for adjustments to the SSP driver quantification in the perspective of EU food systems research (Vervoort and Zurek. 2017). As summarized in Table 2, the scenario framework includes a middle-of-the-road pathway with intermediate challenges (REF0), a low-challenge pathway with a focus on sustainable technologies and consumption (REF+), and a high-challenge pathway with focus on resource use and fragmentation (REF-). The challenges in each of these contextual scenarios are characterized by assumed gross domestic products (GDP) and population trajectories. These socio-economic trends, along with assumed technological progress (changes in land productivity) and trade policy developments (changes in border tariffs), define the three scenarios included in our SDG analysis.

We examine how the EU food system fares in each of these scenarios and which scenarios are most and least consistent with progress towards the SDGs. We also assess how the synergies and trade-offs towards SDGs are sensitive to different scenario settings. Apart from the scenario dimension, we add to the analysis a multi-level geographical dimension. We examine not only the EU food system as a whole, but also whether the synergies and trade-offs towards SDGs differ by region. In particular, we assess how the developments of SDG indicators are distributed across EU member states and how these developments differ between the EU and the rest of the world.

Table 2 summarizes the assumed socio-economic challenges including GDP and population, as well as technological progress and trade policy changes (captured as border tariff changes) in all the three scenarios by aggregate region (EU and Non-EU).

Table 2 Socio-economic drivers and policy assumptions associated with different scenarios (2010-2030)

	Low challenges (REF+)		Moderate challenges (REF0)		High challenges (REF-)	
	EU	Non-EU	EU	Non-EU	EU	Non-EU
Population growth	4.0	16	3.0	20	-2.1	24
GDP growth	33	117	29	102	20	90
Land productivity growth	9.7	10.1	8.8	8.8	8.2	7.8
Border tariff change	-100	-50	-100	0	-100	50

Source: SUSFANS database. https://susfans.eu/research-data

Note: REF+, REF0, REF- are scenarios with assumptions derived from the shared socioeconomic pathways (SSPs), respectively SSP1, SSP2, SSP3. See Havlik et al. (2018).

4 SDG2 Zero hunger: is the EU on track?

The policy goal of SDG2: Zero Hunger aims to end hunger, achieve food security and improved nutrition. In this section, we employ a number of indicators to assess to what extent the EU food system is on track in achieving this goal. Achievement towards this goal will then be used as a reference in the following sections, in order to help identify possible synergies and trade-offs towards this goal and other SDGs.

A paramount indicator for assessing this goal is per capita food consumption. The three models employed in this study on average project increases in per capita food consumption from 2010 to 2030 in all the three scenarios, with the baseline scenario (REF0) expected to increase by 3.9%, and the low and high challenge scenarios expected to increase by 4.6% and 2.1%, respectively. The variations in food consumptions across scenarios are consistent with the assumed socio-economic challenges in the respective scenarios. As presented in Table 1, the SSP3-based global high challenges scenario correlates with a population decline and comparably low GDP growth at the EU level.

While the variations across scenarios are consistent with the assumptions made towards socio-economic challenges described earlier, these variations are dominated by the variations across models as large gaps (e.g. ranging from -0.5% to 6.8% in REF0) between the results coming from different models have been observed. Figure 1 reports projected per capita food consumption in the EU in different scenarios by the three participating models (more detailed projection results at the EU member country level are provided in Appendix A.3). In each of the three scenarios, two of the three models project positive growth in food consumptions while one model projects slightly negative growth. These differences across model results indicate a certain level of uncertainty associated with projected per capita food consumption growth.

Apart from the underlying uncertainty associated with projections of per capita food consumption, the projected increases in this indicator value based on model averages should also be interpreted in conjunction with observations on food intake in the general population. Mertens et al. (2018) report on an innovative standardised analysis of food intake patterns in 4 member states, i.e. Czech Republic, Denmark, France and Italy. Despite significant country-to-country and within-country differences, and undernourishment among specific vulnerable groups in the population, the average pattern reveals a situation of excess consumption in the EU. This is implied in the observation that energy intake exceeds physical requirements for a large proportion of the EU population. While this indicates that the EU as a whole is meeting the undernourishment sub-goals of SDG2, a more complete assessment of diet quality is needed to assess if the EU is on track in meeting the consolidated goals of ending hunger and all forms of malnutrition including obesity. Anyway, a projected increase in food consumption in the EU will point to a further growth in excess consumption, and rise of diet-related non-communicable diseases.

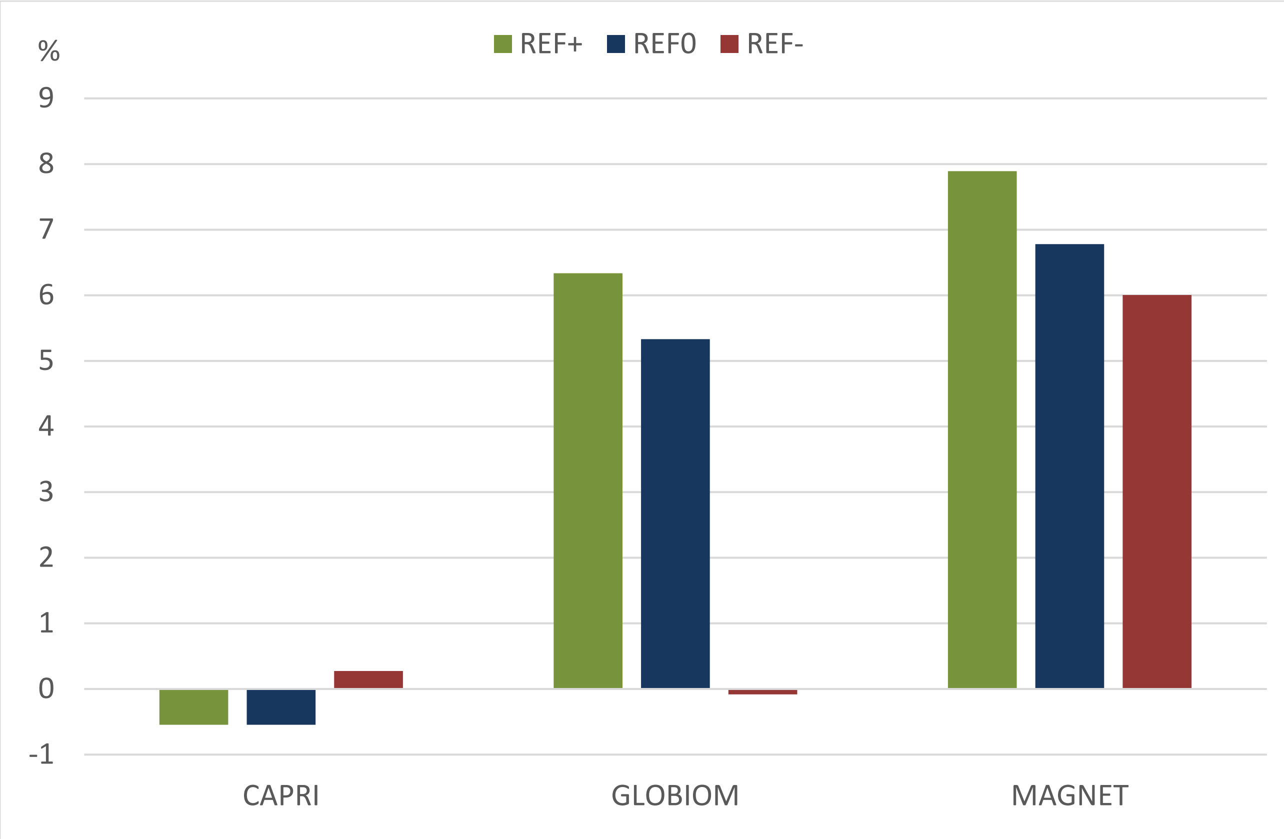


Figure 1 Projected EU per capita food consumption growth rate2010-2030

The overall uptrend in per capita food consumption and the growth variation across scenarios observed at the EU average are also maintained at the member country level. However, as shown in Figure 1 which plots the growth rates of per capita food consumption in REF0, these growth rates differ significantly across EU member countries. While most EU countries are expected to experience a rise in per capita food consumption with several countries including Sweden, Netherlands, and Belgium expected to lead the uptrend, some eastern EU countries including Lithuania, Latvia, Bulgaria, Poland, and Estonia are expected to experience a decline in per capita food consumption. It is noteworthy that the growth rate variations across regions dominate the variations across scenarios, indicating that the issue associated with future food consumption growth in the EU will be more of regional disparity than the assumed socio-economic challenges facing the EU.

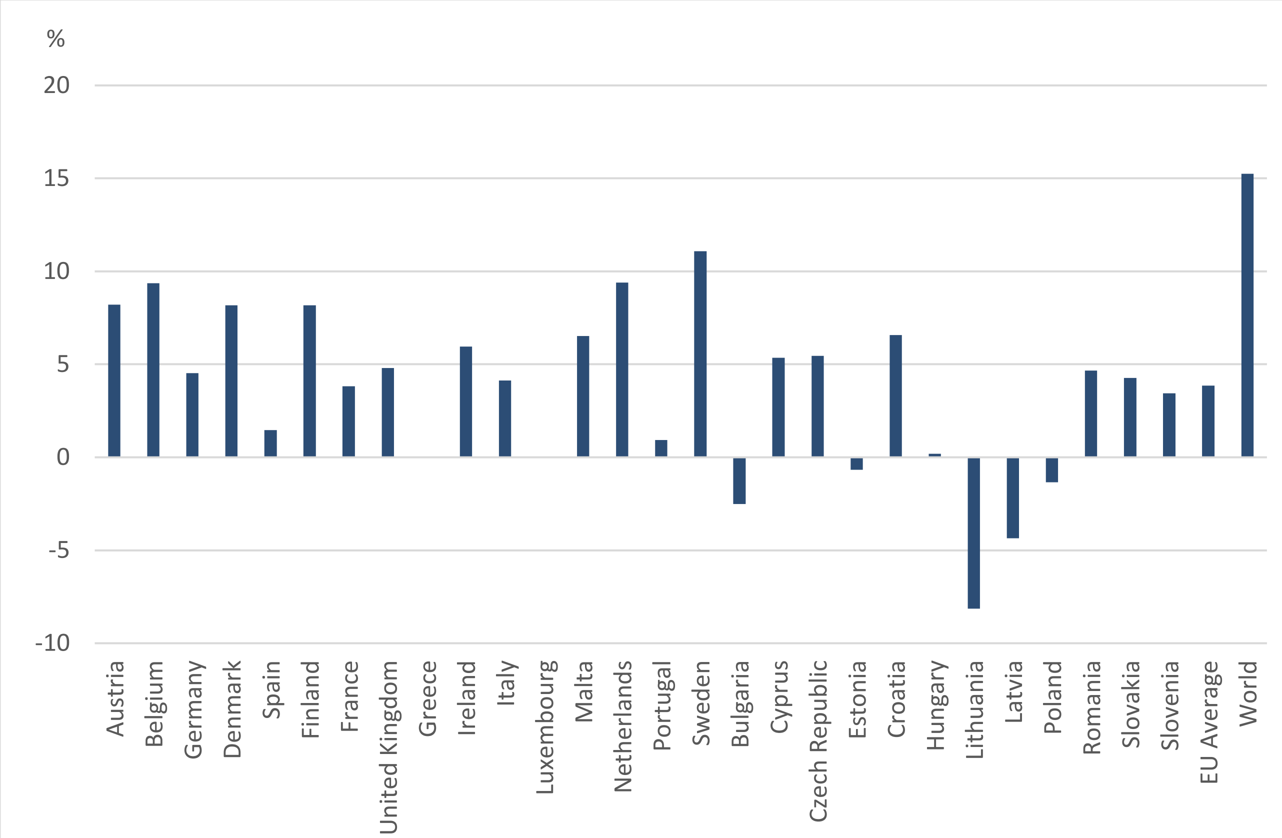


Figure 2 Per capita food consumption growth rate across EU member states 2010-2030

It is also insightful to review the projected consumption in the EU versus rest of the world. The degree of challenges facing the EU moves against the trend of food demand, that is, a higher challenge scenario in the EU typically meets with a lower demand for food. As a result, the lower challenge scenario is expected to lead to a relatively faster growth in EU per capita food consumption while the higher challenge scenario is expected to have a slower growth rate. In-line with the stronger impact of the degree of challenges for the EU as compared to non-EU countries, also the per capital food consumption increase is lower in the EU than in non-EU. However, this must be seen with regard to the current situation – both for per capita food consumption and GDP – which is already at a high level in the EU, as compared to the global (non-EU) average, and the scenarios all assume that the world will move toward reduced disparities.

Compared to the EU average, the world on average are expected to experience faster growth in per capita food consumptions (Figure 1). This is not surprising since the rest of world lump together all the developing countries which are expected to experience higher income growth over the coming decades that is set to boost food consumptions. Similar to the EU, Non-EU countries on average are also expected to experience faster per capita food consumption growth in a lower challenge scenario. However, the faster food consumption growth in the rest of world is mainly driven by faster economic growth (represented by a higher GDP growth rate) since a lower challenge scenario in the Non-EU average is assumed to have a lower population growth. This is in contrast with the EU average which is assumed to experience a faster population growth in the lower challenge scenario.

5 Zero hunger and improved nutrition

Despite the growing per capita food consumptions in the EU, this broad metric needs to be broken down into sub-food levels through including nutrient-specific indicators in order to assess developments in malnutrition associated with unbalanced diets. According to FAO, a balanced diet must be composed of a variety of different foods from different food groups so that it contains all the many macronutrients and micronutrients the person needs (FAO, 2004). Malnutrition due to unbalanced diet is by far the single largest contributor to disease in the world (FAO, 2018). Thus, the SDG2 of ending hunger, as well as SDG3 of promoting healthy lives, call for assessments of a broad spectrum of nutrition indicators covering calorie and other macro- and micronutrients. In this sense, assessing the relationship between food consumption trends and nutritional developments forms an integral part of the assessment of the potential synergies and trade-offs towards these SDGs.

Similar to the projections for per capita food consumption growth, the results from the three models do not provide a consistent indication for the relative growth of calorie intake to the growth of food consumptions. Figure 3 shows that, in the three simulated scenarios, two of the three models project a relative increase in calorie intake – an indication of calorie density increase in food consumptions, while one model projects a relative decrease in calorie intake. Inconsistency also exists across scenarios as the same two models (CAPRI and GLOBIOM) project a slower increase in calorie density as socio-economic challenges become higher, which is however opposite to the trend projected by MAGNET.

Given the uncertainties reflected in the model gaps, we take the average of calorie density changes projected by the three models as an indication for the possible change in the future. The average projections show that the EU on average is expected to have a minor increase in calorie density in REF+ and REF0 and a minor decrease in calorie density in REF-. This again suggests uncertainty associated with scenario projections as changes in calorie density in food consumption are likely to be influenced by the assumptions on socio-economic challenges. In this situation, a conclusion may be drawn with caution that calorie density in food consumption at the EU average is likely to remain largely unchanged over the coming decade.

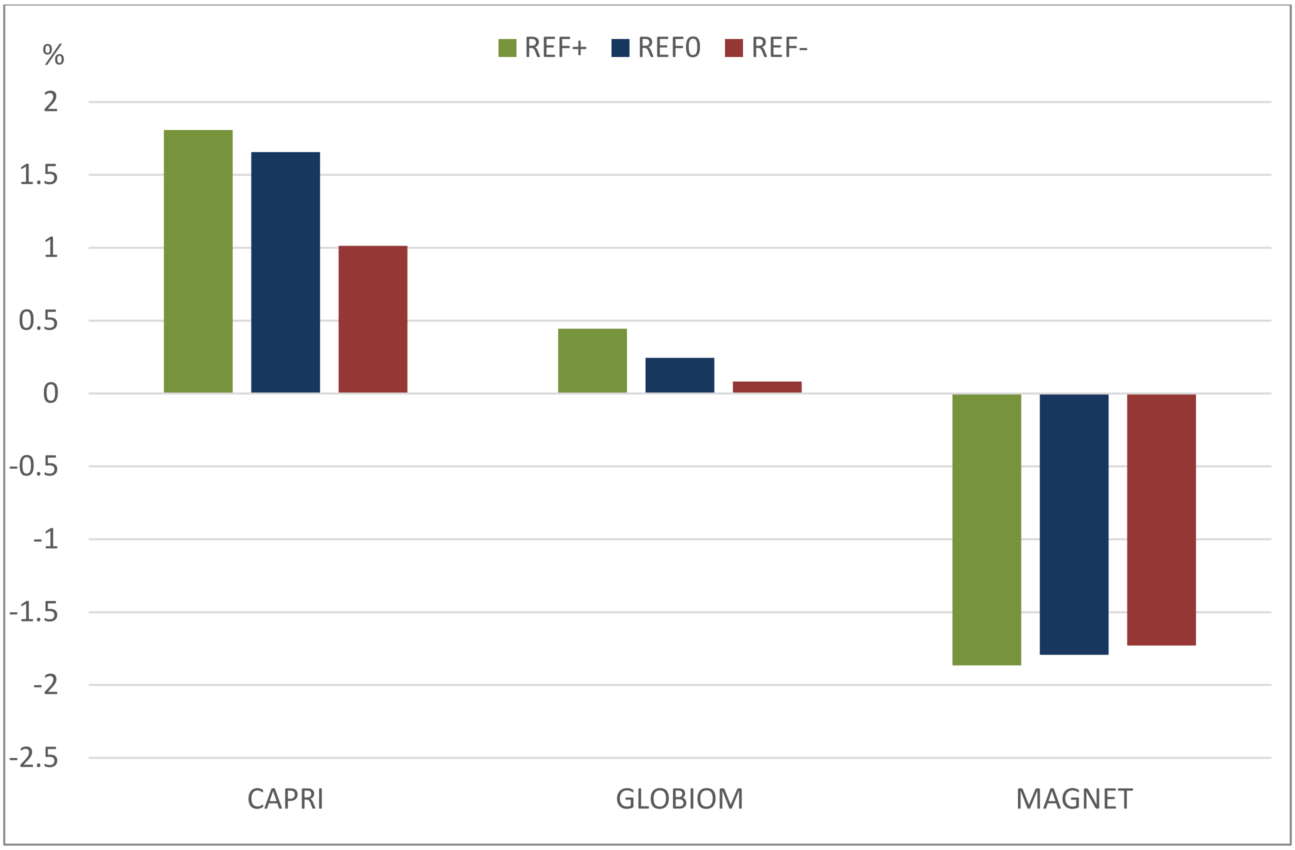


Figure 3 2010-2030 growth rate deviations: calorie intake relative to food consumption in the EU

The largely unchanged calorie growth trajectory observed at the EU average, however, covers up the landscape when viewed from the regional perspective that involves a comparison across EU member states and a comparison between the EU and the rest of the world. Focused again on REF0, Figure 4 shows a clear structural gap between the eastern and western EU countries in terms of changes in calorie density. Most of the western EU countries are expected to have a decrease in calorie density which is in stark contrast to the rising density observed at the eastern EU countries. Notably, this high-calorie pick-up pattern – eastern EU relative to western EU, also appears at the world level where Non-EU countries, particularly developing countries, are expected to catch up with a high-calorie food consumption trajectory.

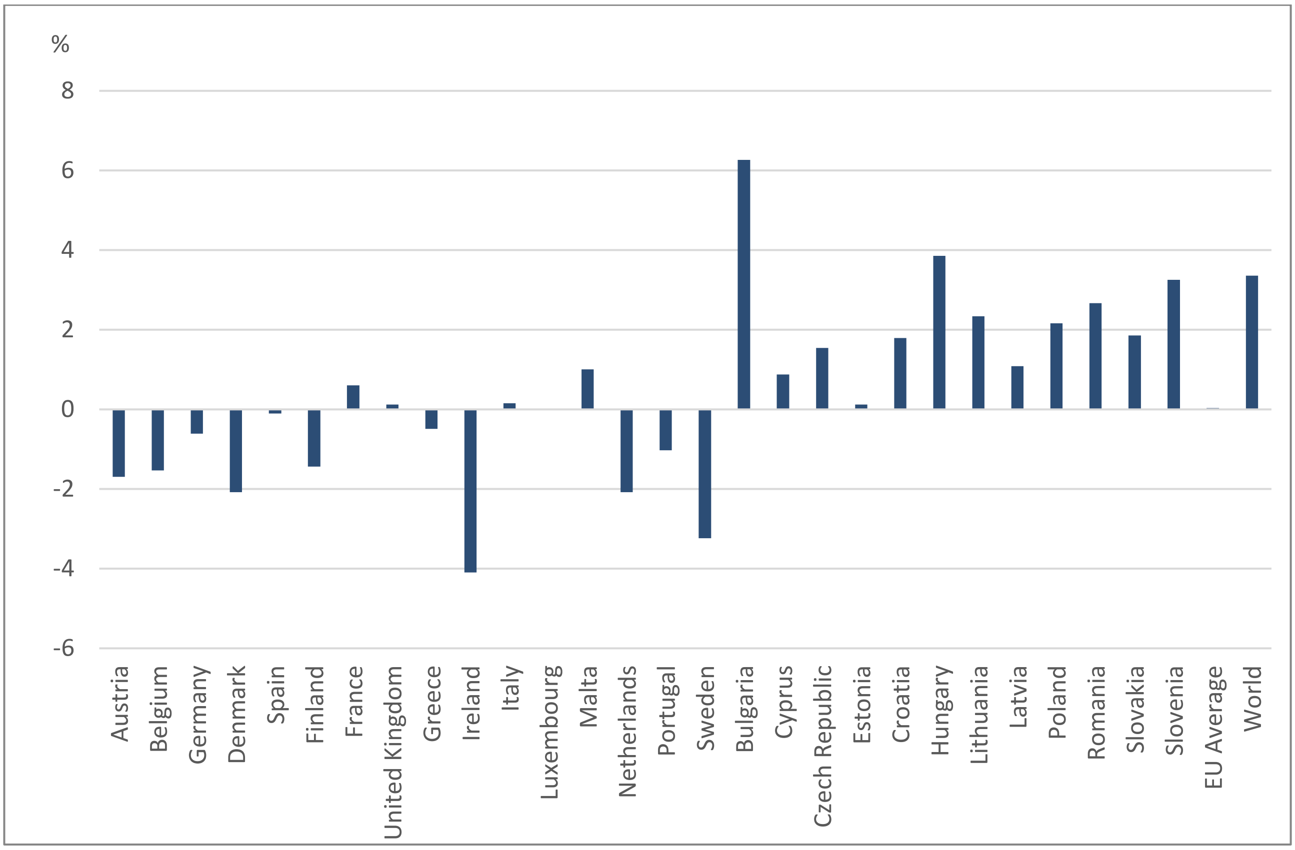


Figure 4 2010-2030 growth rate deviations: calorie intake relative to food consumption across EU member states

The structural gap inside the EU in terms of calorie density in food consumption is a concerning sign as high-calorie food consumptions are typically regarded as a driver of malnutrition and associated with a wide range of diseases. Recommendations are often given to reduce energy intake in consumption by substituting energy-dense foods (meat, processed grains, and products containing oil and fat) with other food products such as wholegrain products, fruits and vegetables. Thus, an analysis developed here is to examine the impact of a low/high energy intake in food consumption on dietary quality. For this analysis, we apply a Nutrient Rich Dietary (NRD) indicator which scores the consumption levels of twelve qualifying nutrients (minimum intake recommended) and one disqualifying (maximum intake recommended) nutrients (Table 2) that essentially trace the underlying changes in consumption patterns of the associated food commodities. The nutrients consumption base data were derived from the GENuS data base of global average nutrient availabilities (Smith et al. 2016), and normalized to a 2000 calorie per day diet. The normalized nutrients consumptions were assessed against Dietary Recommended Value (DRV) – for qualifying nutrients, and against Maximum Recommended Value (MRV) – for disqualifying nutrients. Basically, the idea is that increased consumptions of qualifying nutrients would lead to a higher score until it reaches the cut-off (DRV) while increased consumptions of disqualifying nutrients will be given a punishment score. The overall

NRD12.1 score, an average of the scores for individual nutrients, ranges from 0 to 100, assigned to each model region.

Table 1 Nutrients and dietary/maximum recommended value

Nutrients	DRV or MRV	Cut-off Value
Protein	DRV	25 g/day
Fiber	DRV	42 g/day
Calcium	DRV	805 mg/day
Mono-unsaturated fatty acids	DRV	39 g/day
Zinc	DRV	6.9 mg/day
Iron	DRV	6.5 mg/day
Potassium	DRV	3500 mg/day
Magnesium	DRV	325 mg/day
Vitamin A	DRV	530 microgram RE/day
Vitamin C	DRV	95 mg/day
Vitamin B1	DRV	0.95 mg/day
Vitamin B2	DRV	1 mg/day
Folate	DRV	250 microgram/day
Saturated Fat	MRV	22 g/day

Source: Mertens et al. (2018). based on Annex III in SUSFANS deliverable 2.2. The cut-off value is the average recommended value for men and women.

The simulation results combining the three models still show a mixed message on where the EU on average is heading in terms of changes in NRD scores. Out of the three models, two models project a marginal decline in the NRD score in REF0 and REF+ scenarios and two models project an increase in this score in the REF-scenario (Figure 5). Taking the average projections of the three models, we may notice a slight increase (less than half a point in all the three scenarios) at the EU average.

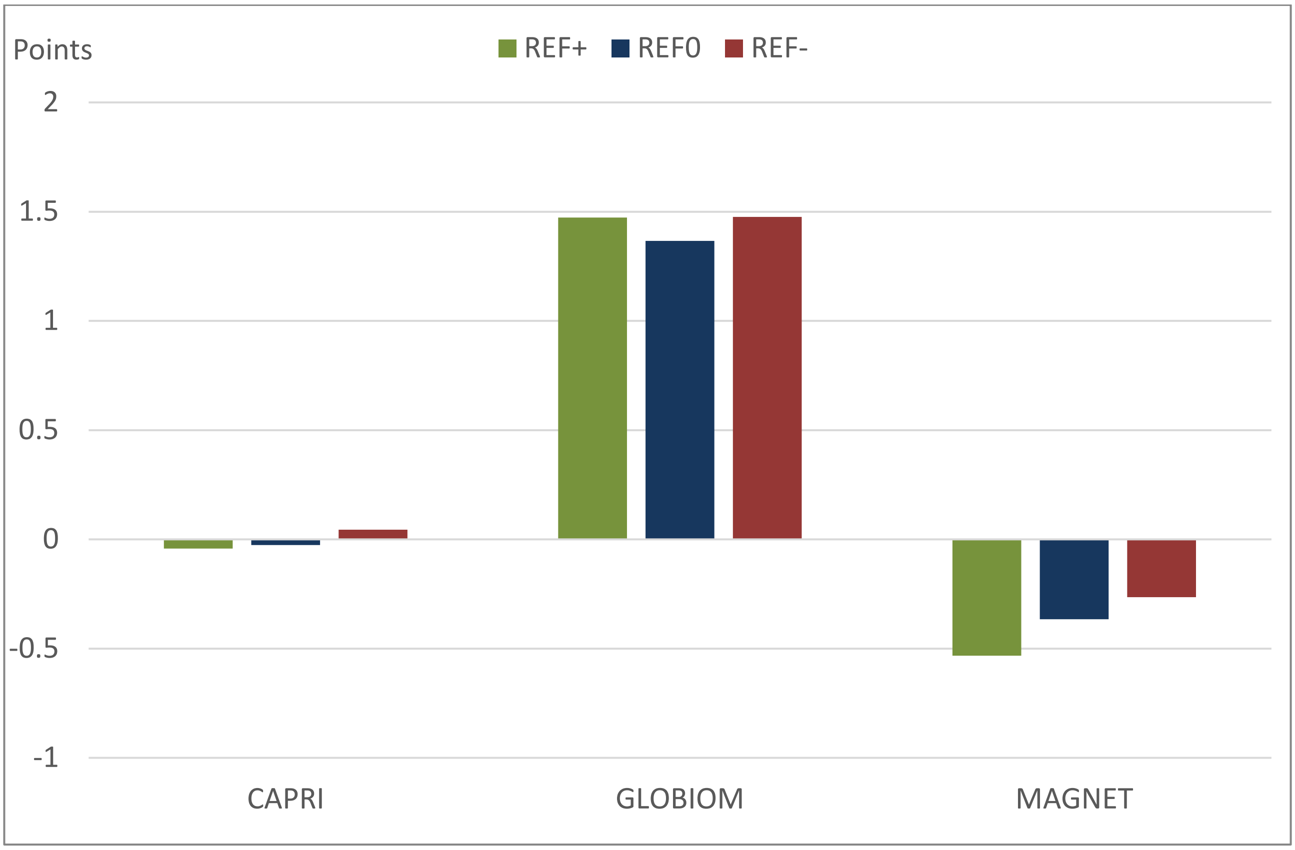


Figure 5 Projected changes in Nutrient Rich Dietary (NRD) scores in the EU 2010-2030

Zooming into the individual EU countries, the messages on improved nutrition are still mixed. While many countries show an increase in NRD scores, quite a few countries also show a decline in these scores. Unlike the projected changes in calorie density in food consumption which shows a clear gap between eastern and western EU countries, the projected changes in NRD scores do not seem to be significantly affected by this structural gap. This seems to suggest that changes in calorie density in food consumption, if not very significant, do not necessarily lead to an appreciable improvement or worsening of overall dietary quality, when evaluated using the given NRD scoring system.

Countries outside the EU appear to have a different story as NRD scores for these countries on average show a pronounced decline over the projection period, indicating developing countries as a whole are catching up with a high-calorie food consumption growth trajectory.

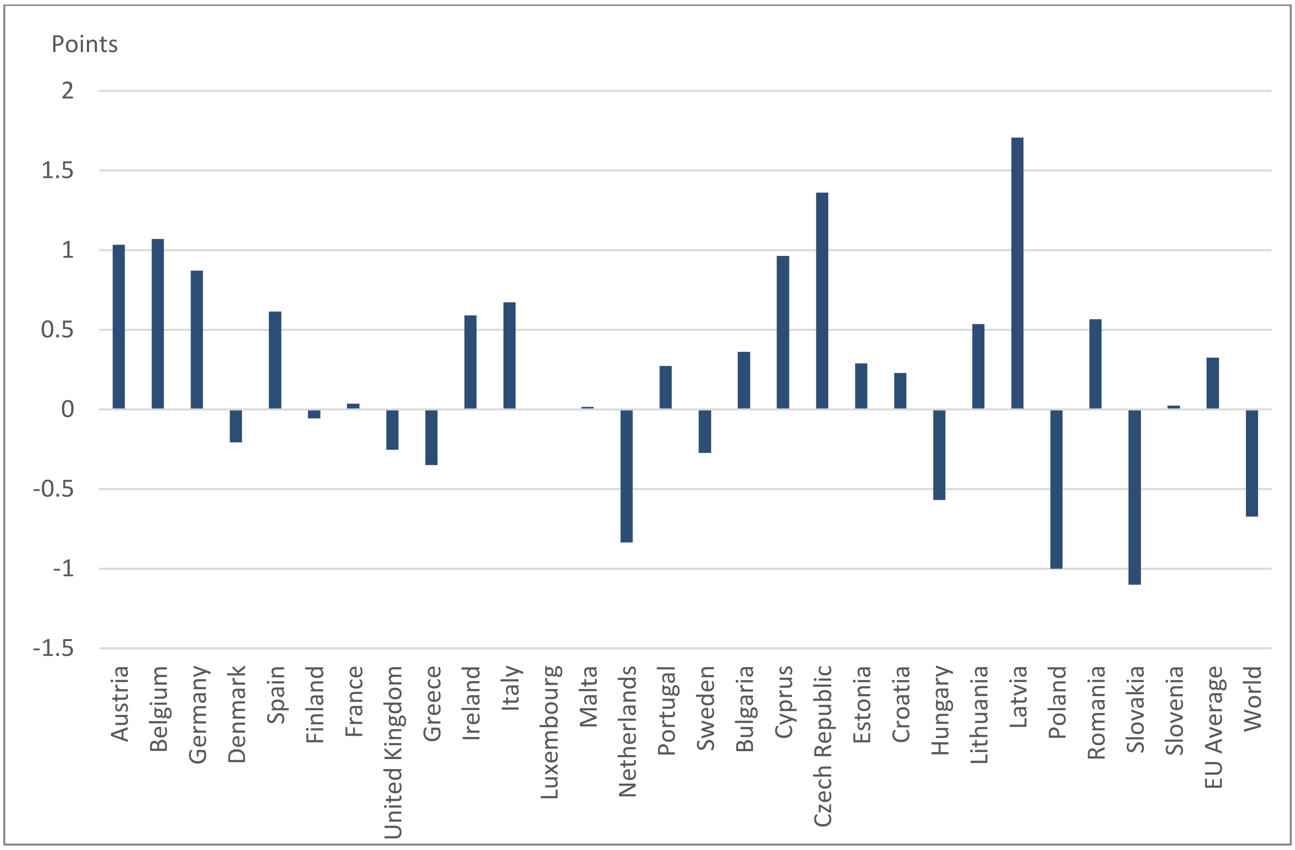


Figure 6 Changes in Nutrient Rich Dietary (NRD) scores across EU member states 2010-2030

6 Zero hunger and reduced inequalities

The expansion in agri-food sectors driven by increasing demand is expected to have impacts not only on food and nutrition security but also on income distribution across the economy. This makes the assessment of synergies and trade-offs between SDG2 Zero Hunger and SDG10 Reduced Inequalities a meaningful task. In this section, we conduct such an assessment using several indicators specifically related to wage distribution across sectors and skill levels, and due to the limitation of modelling tools, the results presented in this section are based only on the MAGNET model.

As an official SDG10 indicator monitored by the UN, labour (wage) share of GDP for the EU average is expected to experience a marginal decline over the projection period across scenarios. Compared to the base year where EU average labour share accounts for 35% of GDP, this share would drop by 0.2-0.4% by 2030 with a lower challenge scenario expected to see a larger drop (Figure 7). The declines at the EU average are also mirrored in most member countries, with the most significant declines (over 1%) being observed at some of the eastern EU countries including Latvia, Slovakia, and Czech Republic. On the other hand, some of the northern EU countries such as Sweden and Denmark are expected to experience a slight increase in the labour share of GDP. At the world level, countries on average are expected to have greater declines in the labour share of GDP (about 1.3%) than the EU average regardless of what the scenarios are, though a lower challenge scenario outside the EU also sees a greater decline.

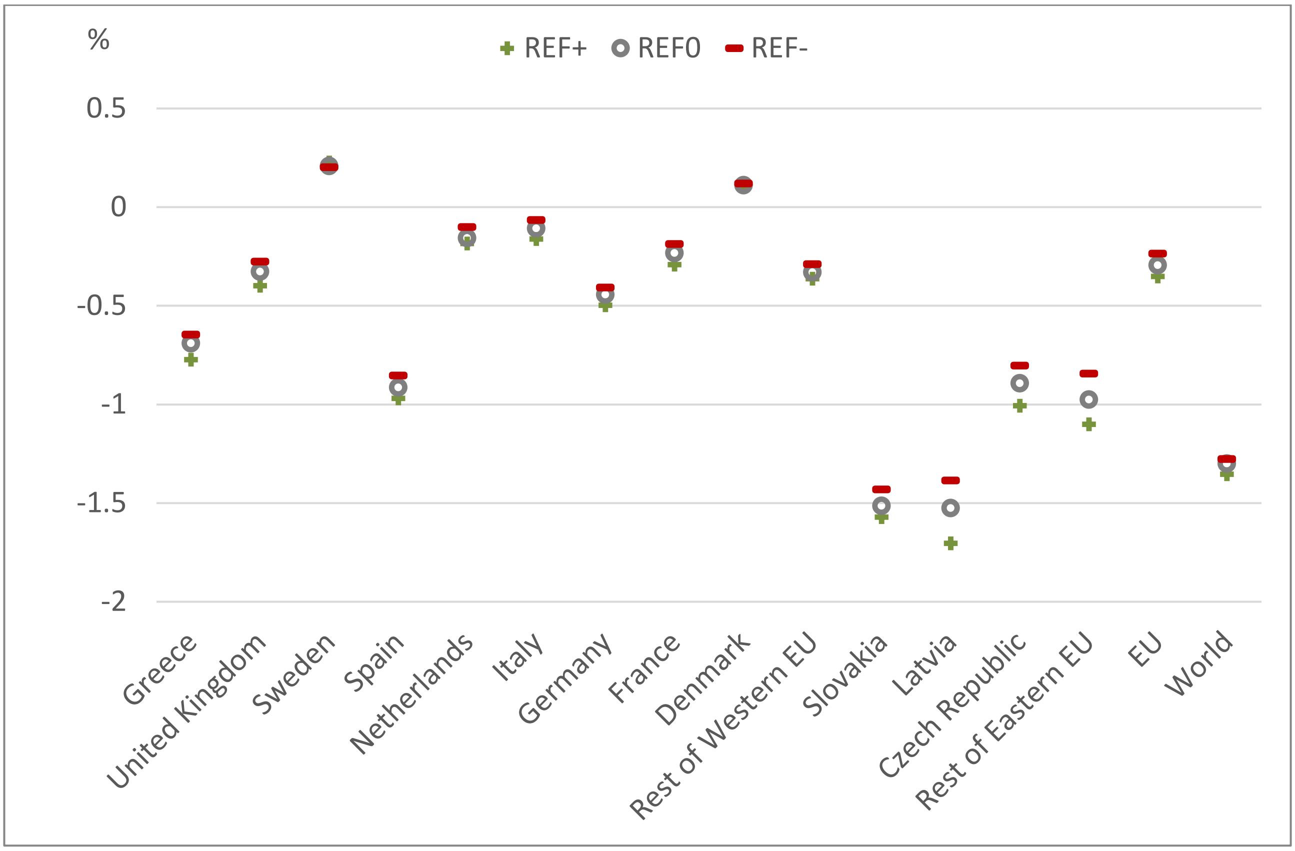


Figure 7 Projected changes in labour (wage) share of GDP 2011-2030[1]

While the changes in wage share at the EU average and member country level may not seem to be that impressive, some relative changes in wage growth are found to be more pronounced when zooming into skill levels and sectors. At the EU average, the relative wage growth of skilled labour to the wage growth of unskilled labour ranges from 0% to nearly 2% depending on sectors and this range expands to (-3.2%, 2.5%) for the Non-EU average (Figure 8). Compared to the relative wage growth across skill levels, relative wage changes across sectors are even more pronounced, with the EU average agricultural wage growth lagging non-agricultural wage growth by 7-15% depending on sectors and scenarios and the Non-EU average agricultural wage growth lagging non-agricultural wage growth by 18-23% depending again on sectors and scenarios. Relative to the wage growth in non-agricultural sectors, a slower wage growth in agriculture would be expected in all scenarios and regions, with the lower challenge scenarios in general seeing an even slower relative wage growth in agriculture, both inside and outside the EU.

[1] Note: in MAGENT, Rest of Western EU includes: Austria, Belgium, Finland, Ireland, Luxembourg, Malta, and Portugal; Rest of Eastern EU includes: Cyprus, Estonia, Hungary, Lithuania, Poland, Slovenia, Bulgaria, Croatia, and Romania.

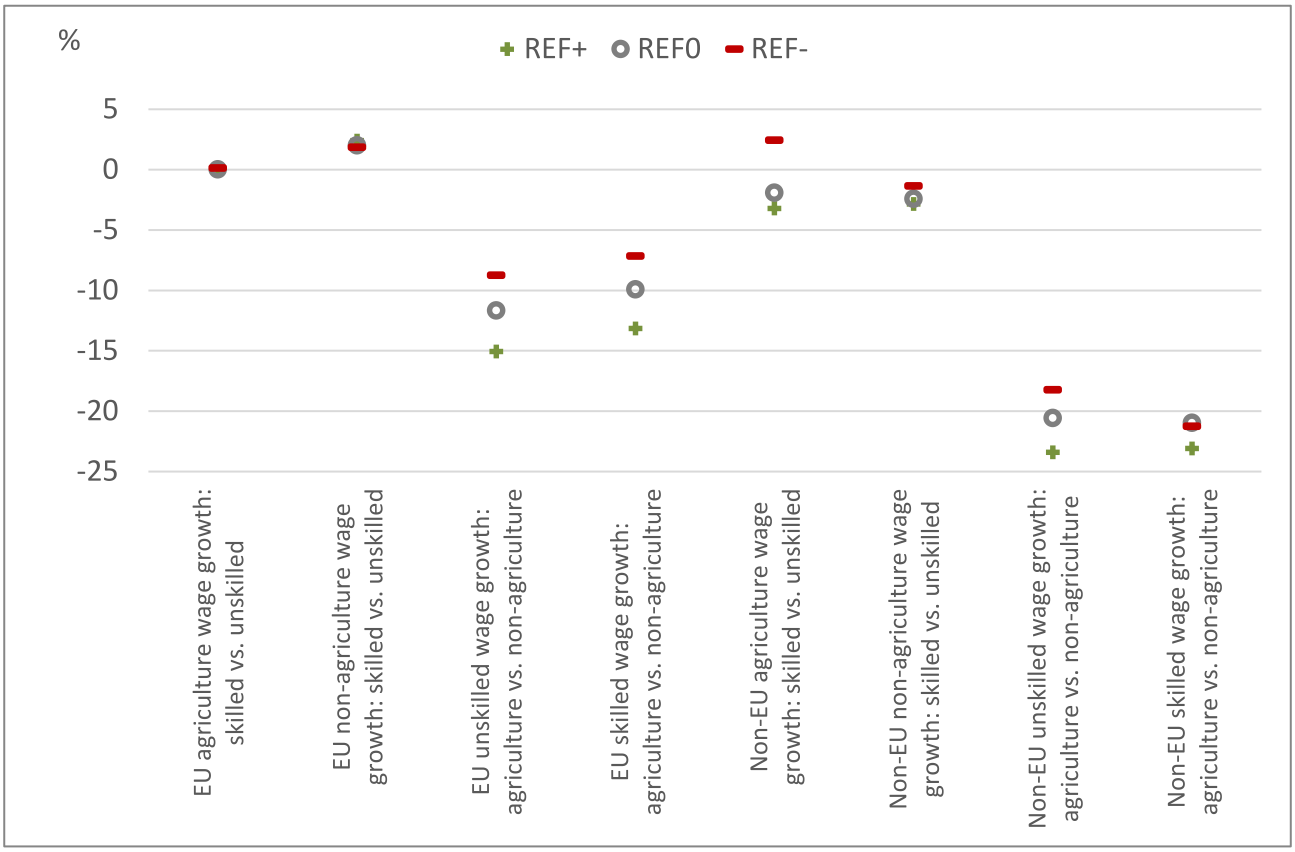


Figure 8 Relative wage growth across skill levels and sectors 2011-2030

7 Zero hunger and climate action

Economic growth achieving both food security and environmental sustainability is desirable, as indicated respectively by the aforementioned SDG2 Zero Hunger, and SDG13 Climate Action - a policy goal calling for urgent mitigation and adaptation action to combat climate change. In this section, we use a set of environmental indicators focused on emissions in agri-food sectors (tons CO2 equivalent) and these emissions in terms of per calorie produced to assess the synergies and trade-offs between the two SDGs.

The three models appear to disagree on the directions of the change in GHG emission in EU agri-food sectors in two of the three scenarios, despite the expected increase in food consumptions in these scenarios. CAPRI and MAGNET suggest that EU agri-food GHG emissions would increase in REF+ and REF0 scenarios (with a range from 1% to 3.2%) while GLOBIOM projects a 5.8%-9.2% decline in these two scenarios and this leads to the decline in the average projections of the three models in these two scenarios (Figure 9). However, in the REF- scenario, the three models consistently project a decline in agri-food GHG emissions, though CAPRI and MAGNET project only minor declines. The three models on average project a 1.8% decline in EU GHG emissions in this scenario.

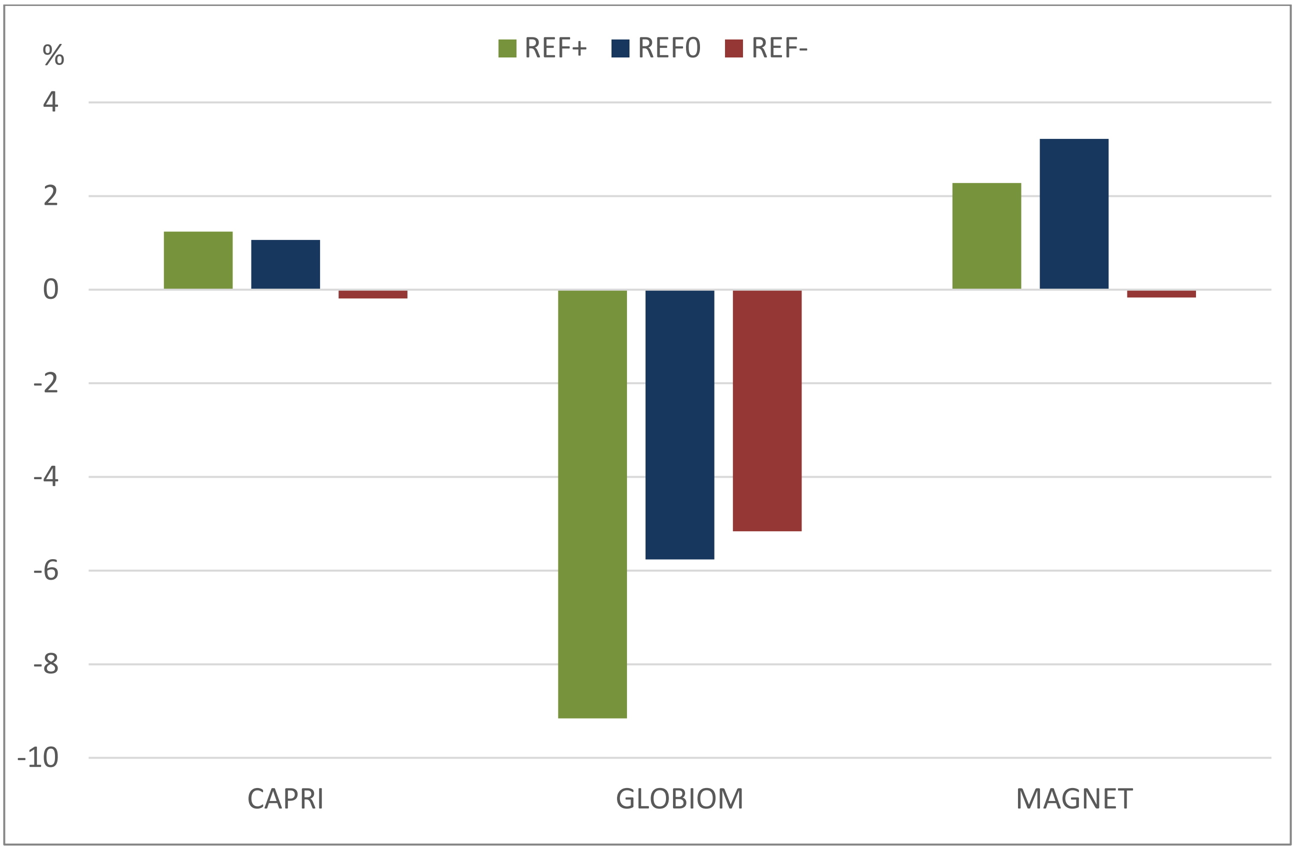


Figure 9 Changes in GHG emissions in agri-food sectors in the EU 2010-2030

Emissions at the EU member country level diverge significantly from the EU average. Based on the REF0 scenario, Figure 10 shows that, while many EU countries are expected to experience a rise in agri-food GHG emissions with Sweden expected to lead the rise in GHG emission, many other member states are also expected to have a decline in the emissions with Latvia expected to lead the decline in the emissions. The mixed ups and downs in GHG emissions across EU member states explain why the EU average GHG emissions barely change in this scenario.

In high contrast to the EU, countries outside the EU on average are expected to have a significantly higher emissions increase from agri-food sectors, driven obviously by fast economic growth in most developing countries. This leads to a 13% projected increase in world average agri-food GHG emissions.

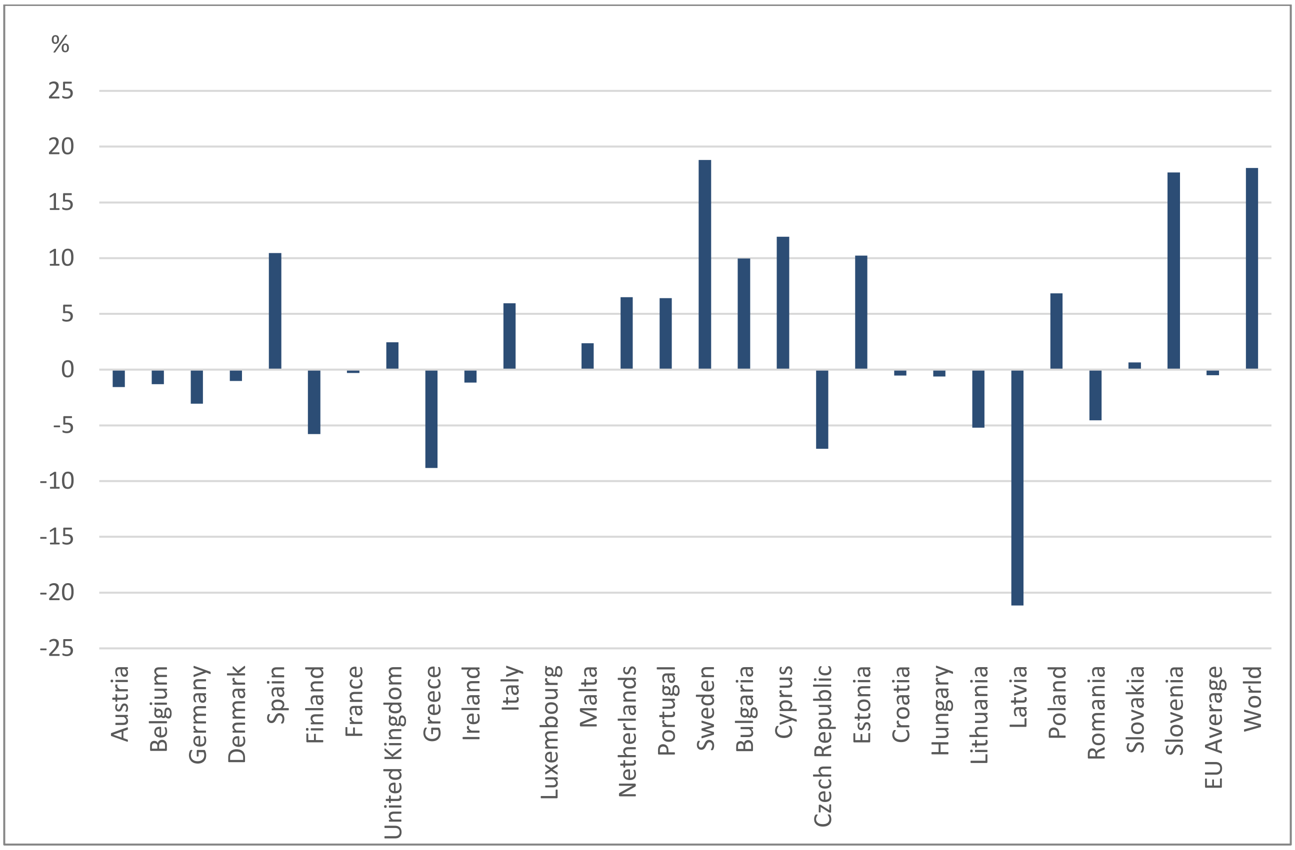


Figure 10 Changes in GHG emissions in agri-food sectors across EU member states 2010-2030

While inconsistency exists across models on the projected change in EU agri-food total GHG emissions in two of the three scenarios, the three models consistently project a decline in emissions intensity – expressed as emissions per calorie produced, in EU agriculture in all the three scenarios (Figure 11).. By 2030, EU average agricultural emissions per calorie produced are projected to decrease by 6.2%-9.4% (scenario range) based on the average projections of the three models. Clearly, these consistently projected declines in EU agricultural emissions intensity are consistent with the scenario assumptions for land productivity growth over the projection period. As described in Table 1, land productivity in the EU is assumed to increase by 8.2-9.7% by 2030.

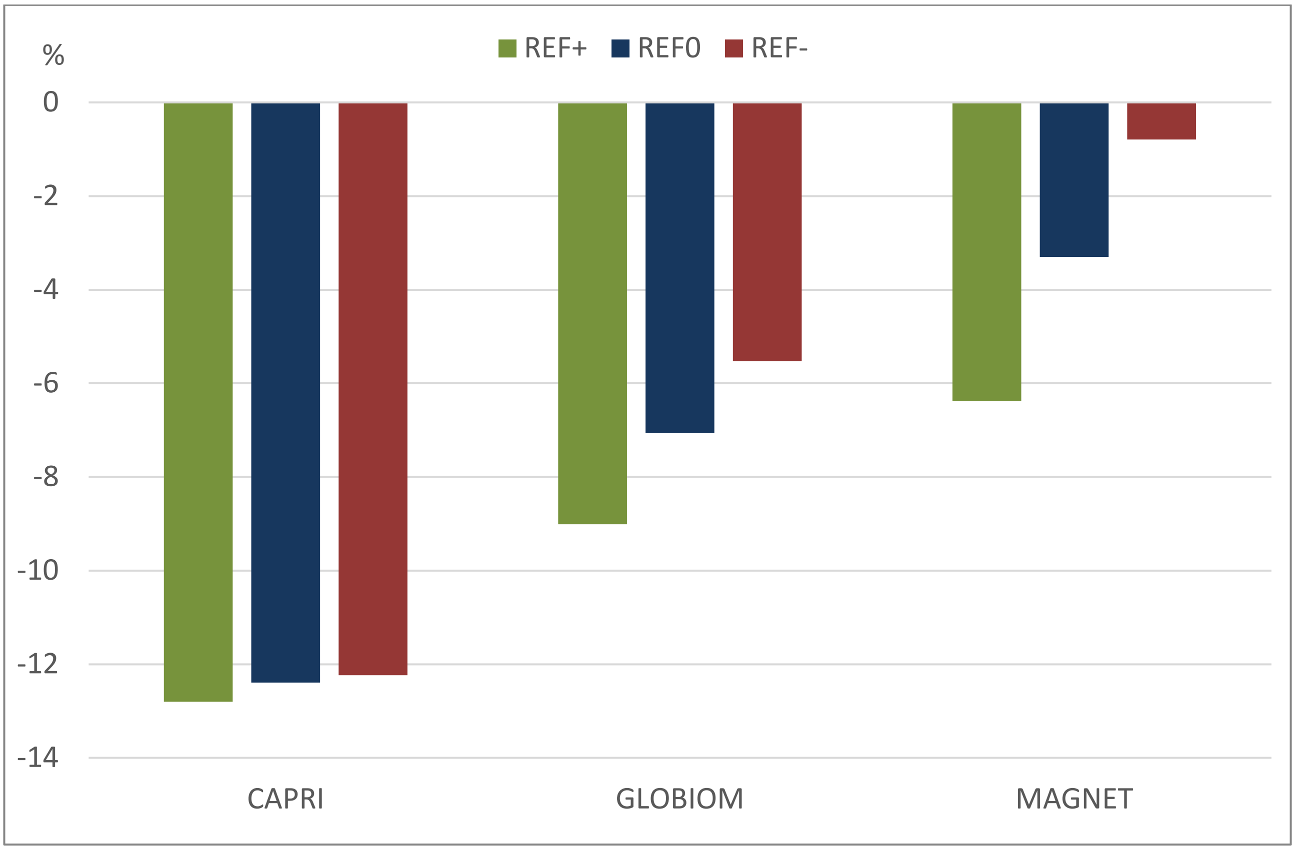


Figure 11 changes in agricultural emissions per calorie produced 2010-2030

Emissions intensity at the EU member state level, again, displays a large divergence from the EU average. While most EU member states show a decline in emissions intensity, which is consistent with the EU average, with Latvia showing the largest decline among member states (over 20%), several member states show a rise in emissions intensity with Slovenia showing the largest rise (nearly 10%)among member states. Similar to the EU, the world on average is also expected to experience a decline in agricultural emissions intensity, driven by the improved agricultural productivity as assumed in Table.

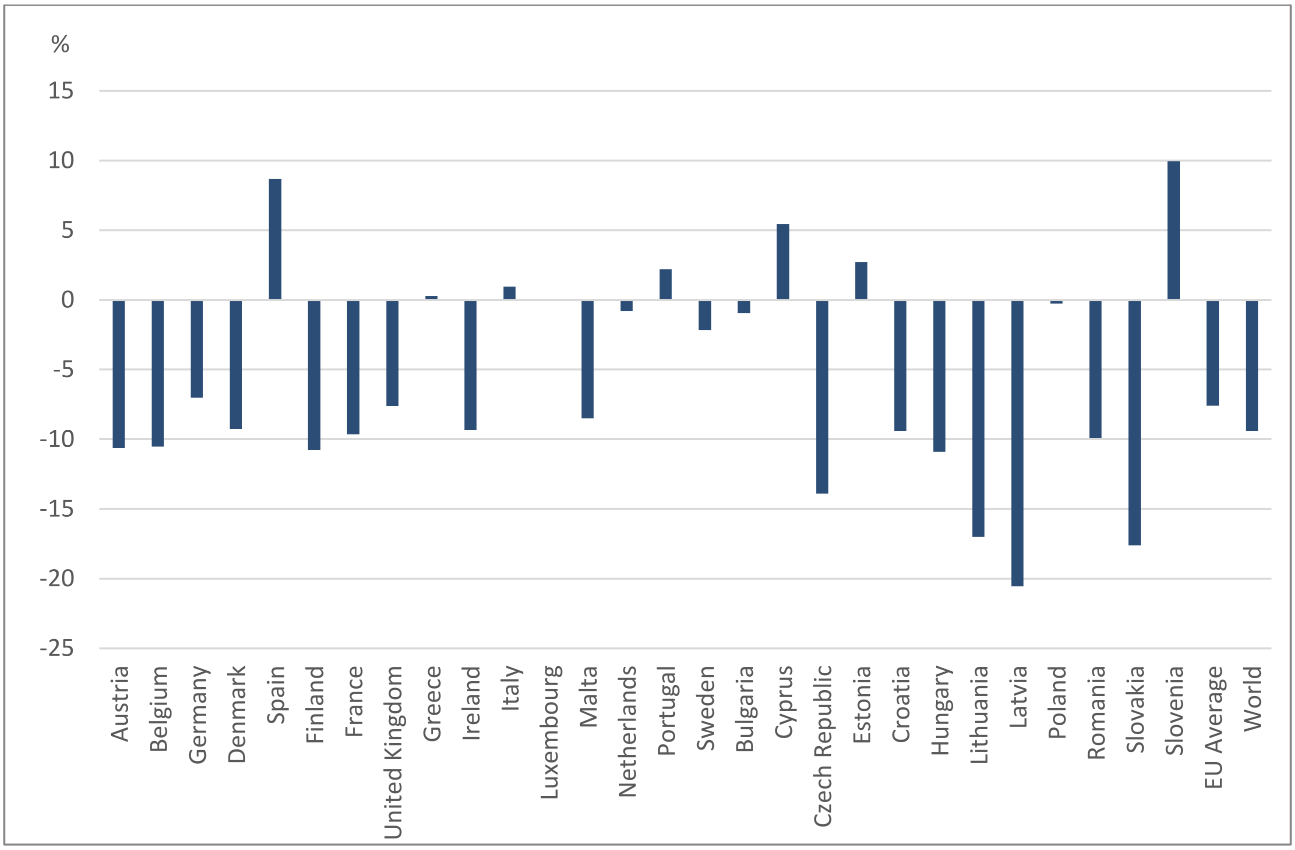


Figure 12 changes in agricultural emissions per calorie produced 2010-2030

8 Conclusion

In this study, we explored the extent to which the evolution of the EU food system to 2030 is likely to contribute to the Sustainable Development Goals in a global context, with a focus around a subset of indicators related to social, economic, and environmental issues, representing respectively SDG2 Zero Hunger, SDG10 Reduced Inequalities, and SDG13 Climate Action.

Three models are employed to study the synergies and trade-offs towards these SDGs. For most of the indicators examined jointly by the three models, the model results show a certain level of inconsistency in the sense that one or two models may project an opposite change in the SDG indicators in one or more scenarios. These inconsistencies reveal to some extent the underlying uncertainty in future developments of these indicators as they appear to be sensitive to different model settings and assumptions.

If taking the consistency between the direction of the average of the changes projected by all the three models and the direction of the average of the changes projected by most models (i.e. two of them) as an acceptable level, then consistencies are considered to have reached in projecting EU's per capita food consumption and agricultural emissions intensity in all the three socio-economic challenge scenarios, calorie density in food consumption in the medium and low challenge scenarios, and Nutrient Rich Dietary scores and agri-food emissions in the high challenge scenario. By contrast, inconsistencies are still expected to exist in projecting Nutrient Rich Dietary scores and total agri-food emissions in the medium and low challenge scenarios and in projecting calorie density in food consumption in the high challenge scenario.

Given this level of consistency, the models on average project a moderate increase in per capita food consumption at the EU average, a SDG indicator considered to paramount in assessing the goal of zero hunger. However, this moderate increase in food consumption does not appear to be coupled with improved nutrition in the medium and low socio-economic challenge scenarios as models on average project increased calorie density in food consumption at the EU average. In the high challenge scenario, models on average project improved nutrition at the EU average reflected by increased NRD scores. Since the lower/higher socio-economic challenges are specifically linked to the assumed expansion/contraction of EU's population, this naturally suggests that a low population growth in the EU is more likely to see improved nutrition.

The growing food consumption in the EU also does not appear to move in sync with improvements in wage equality, as revealed by MAGNET projections, indicating potential trade-offs in achieving both SDG2 of ending hunger and SDG10 of reducing inequality. In particular, wage inequalities between agricultural and non-agricultural sectors at the EU average are expected to enlarge over the projection period, as is the case for the country average outside the EU.

The synergies and trade-offs between SDG2 Zero Hunger and SDG13 Climate Action are relatively difficult to judge as models fail to offer consistency in projecting the change in EU's agri-food GHG emissions in the medium and low challenge scenarios. This inconsistency may be driven by different model assumptions associated with the trade system since a relatively flexible trade system may reduce the pressure on the expansion of domestic agricultural production in order to meet the growing food demand. In the high challenge scenario, however, models consistently project a decrease in agri-food GHG emissions as population in the EU is assumed to contract in this scenario.

Despite the aforementioned inconsistencies across model projections, all the models project that the SDG indicators assessed in this study would be more scattered across EU member states than across scenarios. In other words, the synergies and trade-offs across SDGs appear to be more sensitive to regional distribution than to scenario assumptions, suggesting that further policy actions may need to be directed towards addressing disparities across EU member states.

This paper further contributes to the completion of the stakeholder dialogue in the following respects.

- The setup of the quantitative foresight allows alignment with Policy Labs national and the Think Tank at EU level.
- A set of quantified scenario drivers and projection results, at the scale of EU member states and EU28, is made available to the project as a resource for the workshop organisers.
    - A non-scientific description of the foresight approach, developed in SUSFANS project, is presented in Havlík et al. (2018). We apply a novel SDG lens for this résume. The challenges to meet the SDGs are quantified using three advanced modelling tools which are often used to evaluate EU agriculture and environment policies: CAPRI, GLOBIOM and MAGNET.
    - A database on quantified drivers, with detail for EU member states is available (link to the data: https://susfans.eu/research-data).
    - An advanced user-friendly visualisation tool to assess the future food systems challenges at EU and member state level is in progress.
- In collaboration with WP5, the combination of SUSFANS framework and a database of quantified foresight drivers is made available to the organisers of national policy labs as well as the Think Tank. See Annex 1 for key slides of the training for the Lab organisers.
- The results can be integrated with the reporting on the qualitative drivers (Deliverable 2.1) into an encompassing foresight package for R&I prioritisation workshops.

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Appendix

A.1 SUSFANS foresight methods and contextual scenarios

Introduction

The overall objective of the work package 10 in SUSFANS is to provide foresight on the future development of sustainable food and nutrition security (SFNS) in the EU. This concept encompasses sustainable food systems and sustainable and balanced diets (Zurek et al., 2016).

The future of SFNS in the EU will depend, on the development of contextual variables such as economic growth and climatic change, and on the responses of the agro-food system through innovation and policies.

The foresight will rely on the SUSFANS modeling toolbox consisting of shortterm and longterm economic models to provide quantitative projections of indicators defining the sustainability of the EU food system. The quantitative information will be complemented by qualitative narratives derived from the scenarios reviewed by SUSFANS stakeholders.

This deliverable represents a first step in the quantitative part of the foresight (see Figure 1). Its main objective is to quantify the contextual variables to be used as input by models in the SUSFANS Toolbox.

The foresight has been deliberately designed to focus on solutions in terms of (a) innovation pathways, elaborated in the case study supply chains of livestock-fish and fruits-vegetables in WP5; and (b) agro-food-nutrition policies elaborated as a next step in WP10. From this perspective, the contextual scenarios are rather a mean to the foresight than its final outcome.

Quantitative foresight on food security has been expanding rapidly. It was decided to build on existing narratives and quantified scenario drivers rather than to develop a completely new set of contextual scenarios.

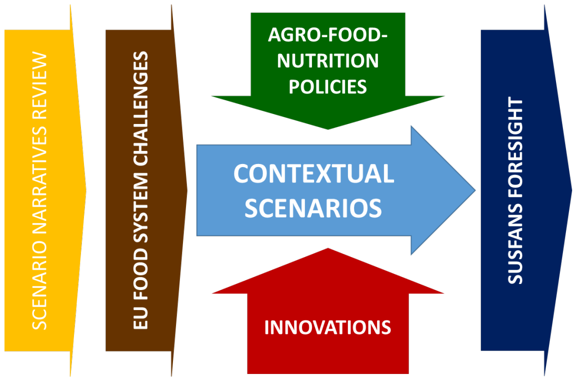


Figure 13. SUSFANS Foresight process

A literature review of existing scenarios, and participatory analysis with the SUSFANS stakeholder core group (Zurek, Vervoort and Hebinck, 2017) resulted in two decisions: first, to collate the narratives developed in the EU projects FOODSECURE (van Dijk *et al.*, 2016) and TRANSMANGO (Vervoort *et al.*, 2016) into a single new set; second, to combine them with quantified scenario drivers from the Shared Socioeconomic Pathways (SSPs), which represents a consistent set of contextual or `indirect‘ drivers of the global food system (see Figure 2, top left).

The SSPs (Riahi *et al.*, 2017) were developed by the scientific community initially to support climate change assessment within IPCC, but these scenarios progressively became the reference also in other assessments related to sustainability and global change, such as IPBES global assessment.

Three contextual scenarios were selected for quantification. From the policy making perspective, it seemed important to develop a business as usual baseline, REF0, representing the reference scenario with respect to which the innovation pathways and policies can be tested. In order to test the robustness of the developed solutions with respect to less favourable socio-economic developments, a scenario representing high challenges for EU sustainable FNS was implemented, REF-. Finally, to take into account also the potential alternative of highly positive development in socio-economic parameters and their capacity to contribute to solve the EU sustainable FNS issues, a contextual scenario representing low challenges for the EU FNS, REF+, was also applied.

For the purpose of this deliverable three groups of contextual variables were considered:

1. Variables matched with the SUSFANS scenarios narrative: Population, Gross Domestic Product (GDP), Technological change, and International trade policies
2. Variables constant across the scenarios: Common Agricultural Policy and Common Fisheries Policy. These policies, and their potential improvements, are subject of detailed standalone analysis at a next stage of SUSFANS.
3. Variables with multiple potential values for each SUSFANS scenario: Climate change impacts and climate change mitigation policies.

Driver quantification

In what follows we briefly document the quantification of the individual contextual variables.

Population. KC and Lutz (2017) provided quantification of future population developments consistent with SSPs by sex, age and education level for each country globally up to 2100. This data is available from the IIASA SSP Database (https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=welcome) and was directly used for quantification of population developments of the three SUSFANS contextual scenarios. In order to increase relevance of the quantification for EU FNS assessment, population projections from the EU Reference scenario 2016 developed for assessment of trends in energy and GHG emissions up to 2050 (EC, 2016a) were used for REF0 in the EU countries. For REF-/REF+ the EU REF0 values were shifted by the relative difference between SSP2 and SSP3/SSP1.

Economic growth. Similarly as for population development, economic growth projections have already been carefully quantified for the SSPs by Dellink *et al.* (2017) and are available from the IIASA SSP Database. For the EU, we followed the same procedure based on EC (2016a).

Inequality. At the time of preparation of this deliverable, no dataset representing income inequality consistent with the SSPs was available for EU. In order not to miss this important aspect completely, we have included in the SUSFANS drivers database the coefficient of variation of dietary energy consumption distribution across population at country level. This parameter, together with the average dietary energy consumption, allows at least to calculate the indirect effects of EU food system change on the prevalence of undernourishment in developing countries following the methodology of FAO (2008). Hasegawa *et al.* (2015) estimated projections of the coefficient of variation consistent with the different SSPs, and this quantification has also been used for the SUSFANS contextual scenarios.

Technological change. Crop yields and feed conversion efficiencies have been identified as the key variables characterizing technological change in the contextual scenarios. Crop yield projections for six main European and global crops – barley, maize, rapeseed, rice, soybean, wheat – have been quantified. Global crop yield projections for SSPs were estimated based on statistical relationship between country level yields and GDP per capita in the EU project ANIMALCHANGE (Havlík *et al.*, 2012). EU crop yield projections for REF0, were informed by the baseline yield projections from CAPRI and adapted for the REF-/REF+ scenarios by the relative difference between the SSP projected yields for SSP3/SSP1 compared to SSP2. Feed conversion efficiency projections for REF0 for pigs and poultry, and for dairy, beef and small ruminant meat were also quantified as part of the ANIMALCHANGE project (Soussana *et al.*, 2012) based on past trends and biophysical feasibility.

International trade policies. Trade policy instruments applied in the EU and in the rest of the world were summarized in the form of applied ad valorem equivalents based on information in the CAPRI database. For REF0, the ad valorem equivalents were considered constant. In the high challenges scenario REF-, existing tariffs were increased by 50%, and 10% tariffs were introduced for commodities, that had no ad valorem equivalent tariff in REF0. In REF+, existing tariffs were reduced by 50%.

Agricultural policies. EU Common Agricultural Policy (CAP) consists of a very diverse set of measures, which are represented in the models belonging to the SUSFANS toolbox in different ways, depending on the model structure and focus. In order to allow for a minimum level of harmonization in the contextual scenarios setup, the value of different CAP support measures were summarized for the SUSFANS Drivers Database into a single premium value expressed per hectare of utilized agricultural area based on CAPRI model data. Scenarios for CAP reform and other policies scenarios will be introduced in a forthcoming SUSFANS foresight report on policies.

Fisheries policies. Considering the structure and needs of the modelling toolbox, these policies were quantified as contextual variables in the form of capture fisheries and aquaculture capacity development at the level of ten species aggregates. EU Common Fisheries Policy (CFP) affects capture fisheries capacity in several ways, including through the introduction of a legal obligation for member states to achieve Maximum Sustainable Yield (MSY) for all stocks fished by 2020, and the gradual introduction of a landing obligation for species/stocks with a quota, to be fully implemented by 2019. At the same time, growth in EU aquaculture production is promoted (EC 2013) and member states are encouraged to set up multiannual plans to develop aquaculture. The quantification of future fisheries capacity was based on the GLOBIOM database in combination with Guillen *et al.* (2016), and for aquaculture, the Multiannual National Aquaculture Plans (EC, 2016b) were directly used.

Climate change impacts. Four alternative GHG emissions scenarios were considered to quantify climate change impacts related to the gradual climate change: these Representative Concentration Pathways, or RCPs (van Vuuren et al. (2011)), map a wide range of potential global warming, from less than +1.5 °C to more than +4 °C compared to pre-industrial levels. In order to map the uncertainty coming from global climate models, all five models selected within the ISI-MIP project (Warszawski *et al.*, 2013) were retained. Finally, the climate change impacts on crop yields simulated with the crop growth model EPIC, with a sensitivity analysis with respect to the CO_2 fertilization effect, were used (Leclère *et al.*, 2014). For quantification of climate change impacts on yield variability and the resulting market volatility, outputs of the HAPPI project were used. HAPPI was designed with the aim to assess the benefits of moving from the traditional climate change stabilization target of 2 °C above pre-industrial levels, to the 1.5 °C target stipulated by the 2015 Paris Agreement, with focus on assessment of extreme weather events such as droughts (Mitchell et al., 2017). Here we use results from the EPIC model available for three experiments, i.e. historical, 1.5 °C temperature increase, and 2 °C temperature increase; four climate models; 20 ensembles of each of the climate models; and CO_2 sensitivity (Schleussner *et al.*, submitted). For the quantification of contextual scenarios, the three experiments were summarized in terms of median, lower and upper quartiles, and the minimum and maximum values.

Climate change mitigation policies. Ambitious climate stabilization targets will likely require anthropogenic emissions turning negative. The land use sectors, on the one hand, contribute 25% of anthropogenic greenhouse gas emissions, and on the other hand, provide the only widely considered sources of negative emissions – carbon sequestration in biomass and soils, and bioenergy production with carbon capture and storage (BECCS). From this perspective, the relevant contextual variables are carbon price, forest area developments, and biomass supply for energy generation. The quantitative values consistent with different levels of the climate change stabilization, RCPs, were taken from the SSP2 scenario family as estimated by the MESSAGE-GLOBIOM integrated assessment modeling framework (Fricko *et al.*, 2017). However, for the sensitive case of first generation biofuels, we used for all the RCPs the baseline values from Lotze-Campen *et al.* (2014).

SUSFANS Drivers Database. For practical use in the SUSFANS toolbox, the projected values of the above discussed variables going up to 2050, have been included in the SUSFANS Drivers Database. The database is available online (http://susfans.eu/wp-10-foresight) in two formats: Microsoft Office Excel for fast access and quick overview by SUSFANS partners, stakeholders, and by the public, and CSV files for direct use by modelers.

15. The SUSFANS conceptual framework

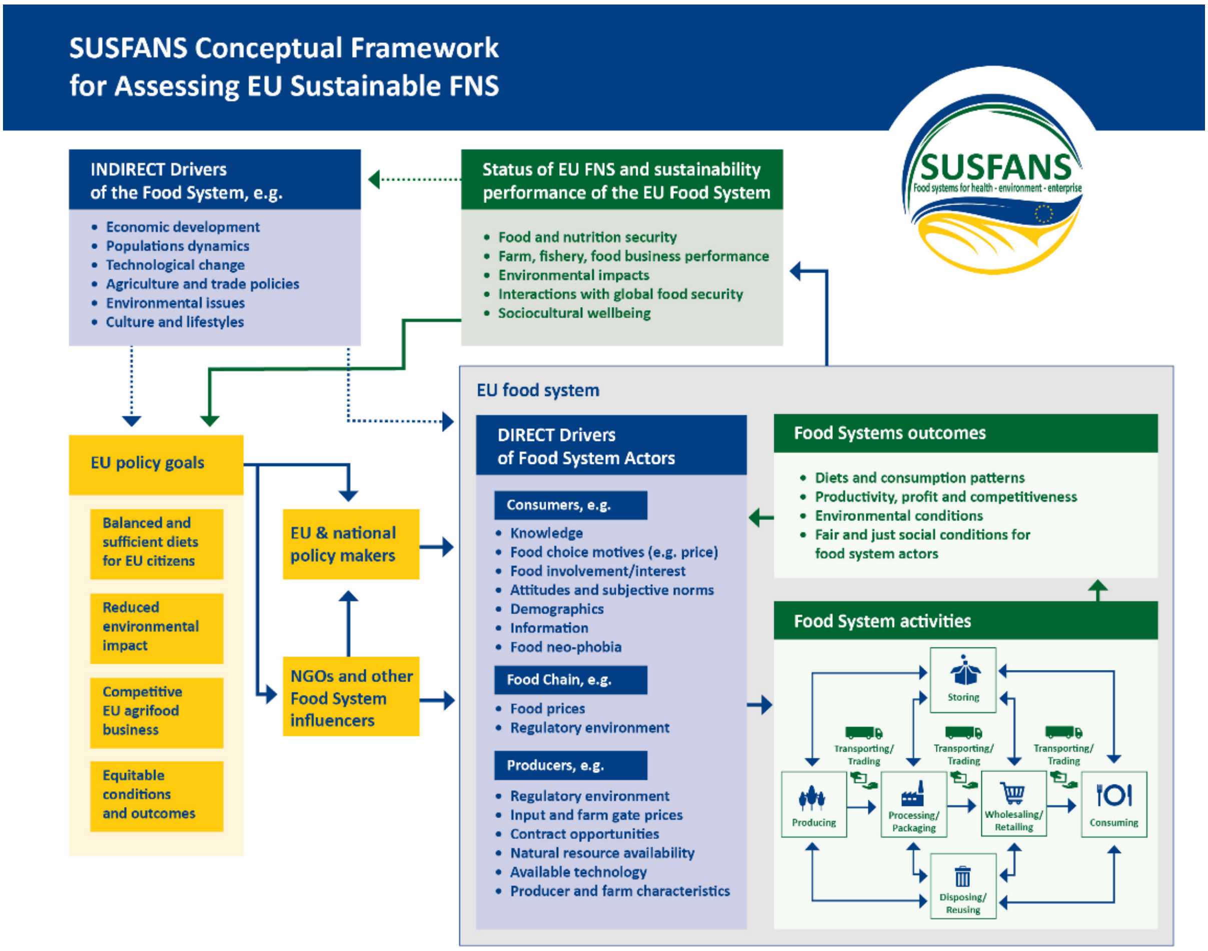


Table 2. SUSFANS scenarios drivers quantification table. Definition of the contextual scenarios in terms of the corresponding narrative scenarios and sources of quantified driver values as proposed in deliverable D6.2 (Zurek et al. 2017), with a complete list of the contextual variables

	Baseline REF0	**High challenges to EU FNS REF-**	**Low challenges to EU FNS REF+**
Scenario narrative	Stakeholder Scenario 1	Stakeholder Scenario 4 & 6	Stakeholder Scenario 7
Socio-economic variables			
Population	EU reference / SSP2	SSP3	SSP1
Economic growth	EU reference / SSP2	SSP3	SSP1
Dietary energy consumption distribution	SSP2	SSP3	SSP1
Crop yield growth	CAPRI baseline / SSP2	SSP3	SSP1
Feed conversion efficiency growth	SSP2	SSP3	SSP1
Policy variables			
Trade policy: Ad valorem equivalents	Current	Current +50%	Current –50%
CAP: Producer support		Current policies	
CFP: Aquaculture capacity		Current policies	
CFP: Fishery capacity		Current policies	
Climate variables			
Carbon price		RCP2p6, RCP4p5, RCP6p0, noMITIG	
Forest area		RCP2p6, RCP4p5, RCP6p0, noMITIG	
Biomass for energy supply		RCP2p6, RCP4p5, RCP6p0, noMITIG	
First generation biofuels		RCP2p6, RCP4p5, RCP6p0, noMITIG	
Crop yield change		RCP2p6, RCP4p5, RCP6p0, RCP8p5	
Crop yield change		Historical, Plus1p5, Plus2p0	

A.2 Key slides of the training for the Lab organisers on quantitative foresight

Contextual scenarios

Focus on 3 contextual scenarios

- SUSFANS stakeholder scenarios provide the narrative for indirect drivers

Contextual scenario	Stakeholder scenario
Business as usual (REF0)	Scenario 1
High challenges to EU FNS (REF–)	Scenario 4 Scenario 6
Low challenges to EU FNS (REF+)	Scenario 7

Source: Zurek et al. (2017), SUSFANS deliverable report D6.2

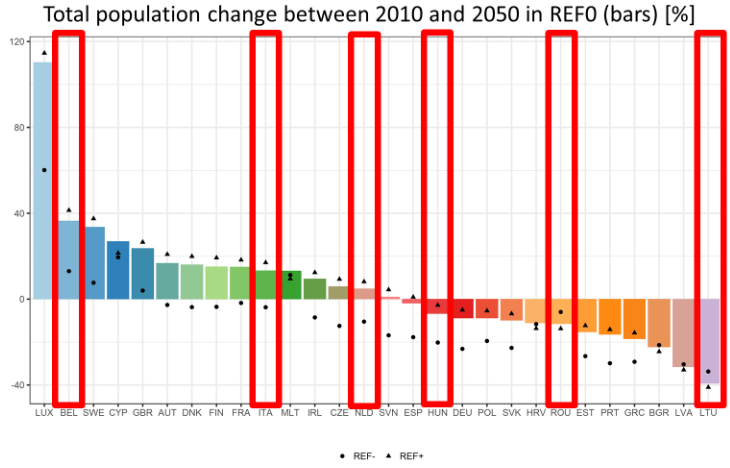
Challenges to sustainable FNS in Europe

Contextual scenarios *building on the stakeholder consultation in WP6* focusing on the main challenges and drivers for the sustainable FNS in Europe

- Demographic and income trends
- Technological change
- International trade policies
- Climate change: Impacts & Mitigation
- Policy context: Current agricultural and fisheries policies

Population growth: EU

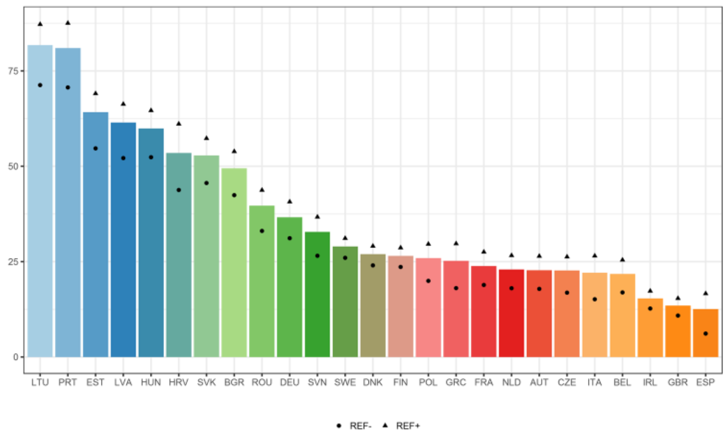
Total population change between 2010 and 2050 in REF0 (bars) [%]



Source: Own calculations based on EC (2016a), KC and Lutz (2017, IIASA SSP Database)

Crop yields: EU

Wheat yield change between 2010 and 2050 in REF0 (bars) [%]



Source: Own calculations based on CAPRI model baseline and Havlík et al. (2012)

A.3 Indicators presented in full dimensions - by scenario, model, and region

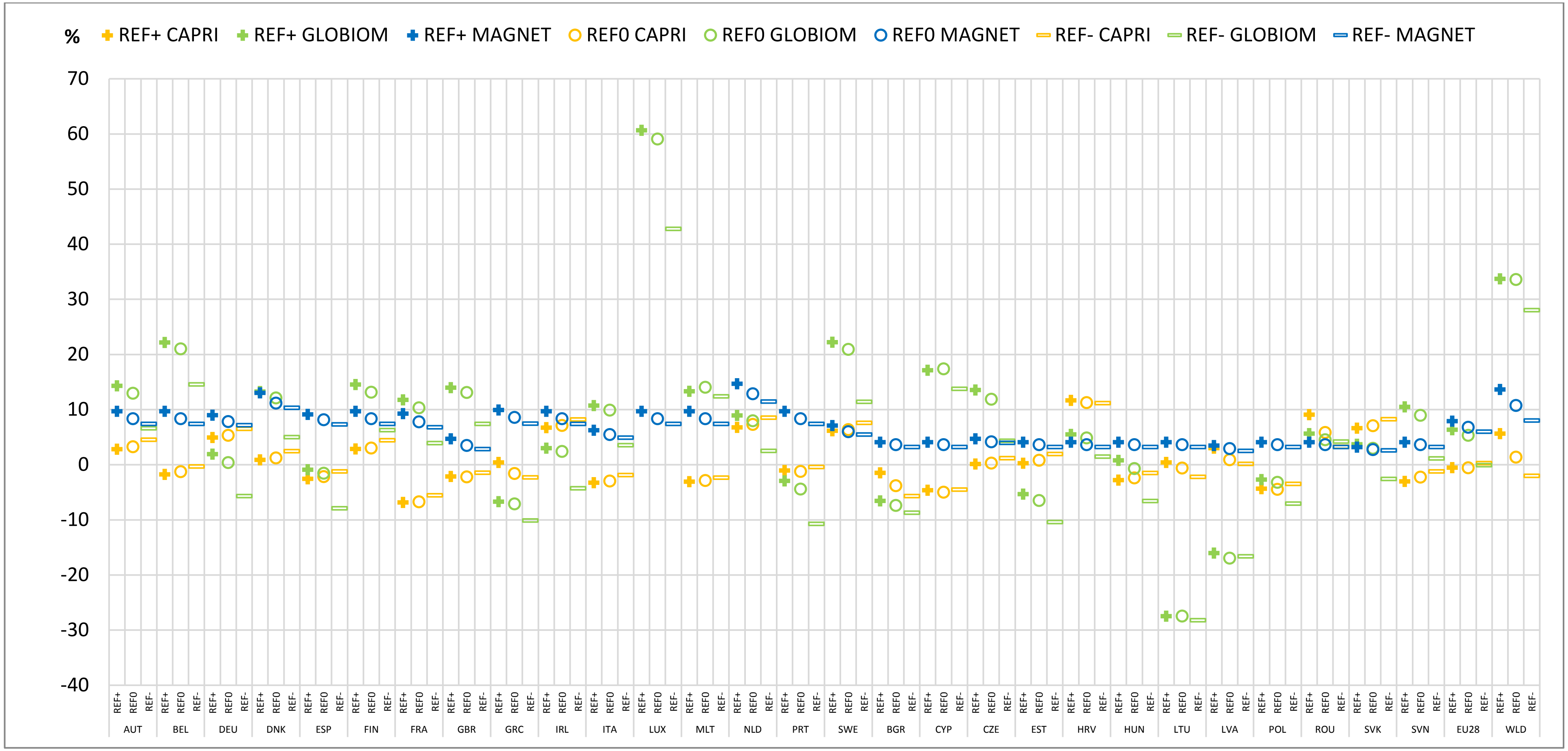


Figure A.3. 1 Projected food consumption growth rates across EU member states 2010-2030

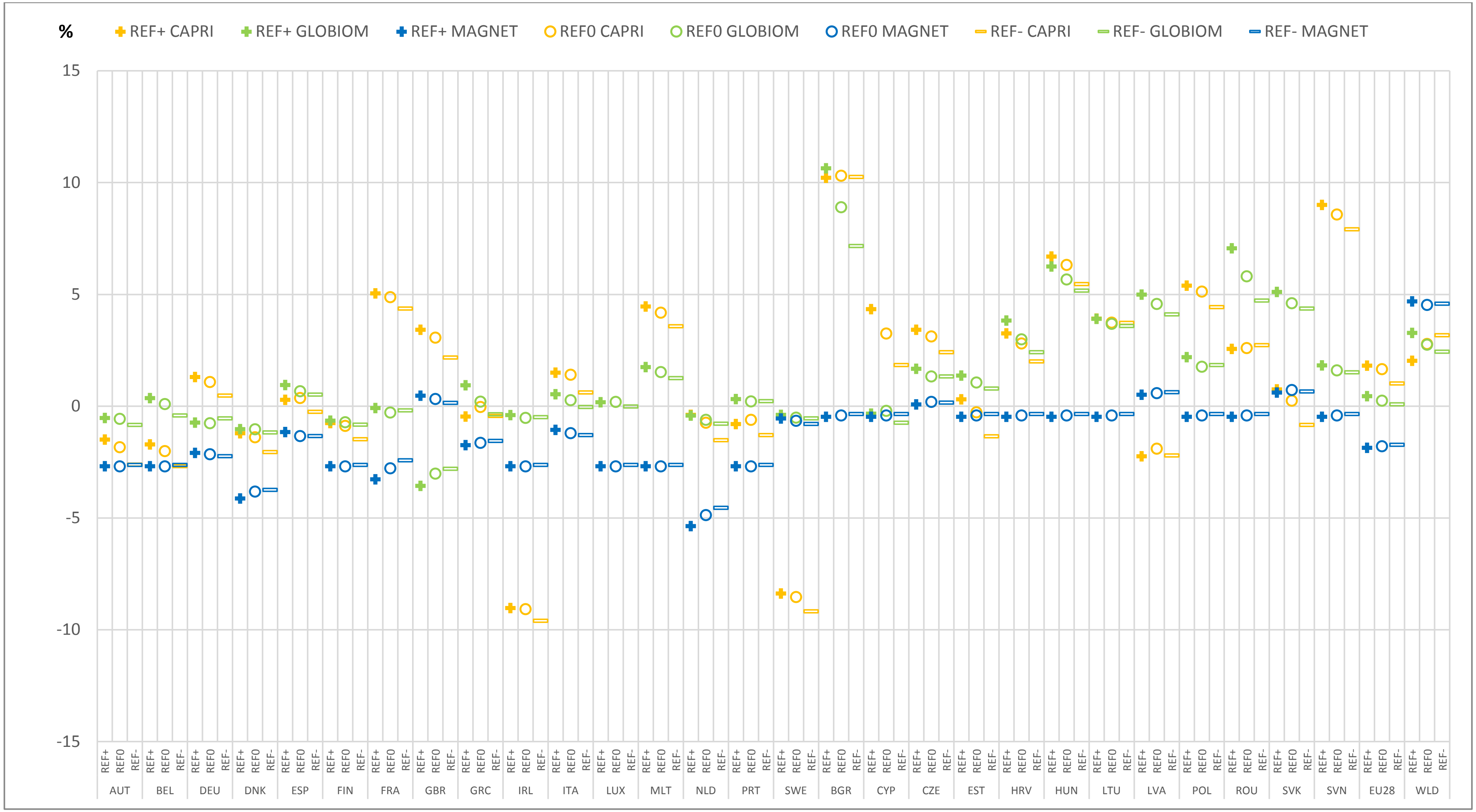


Figure A.3. 2 2010-2030 growth rate deviations: calorie intake relative to food consumption

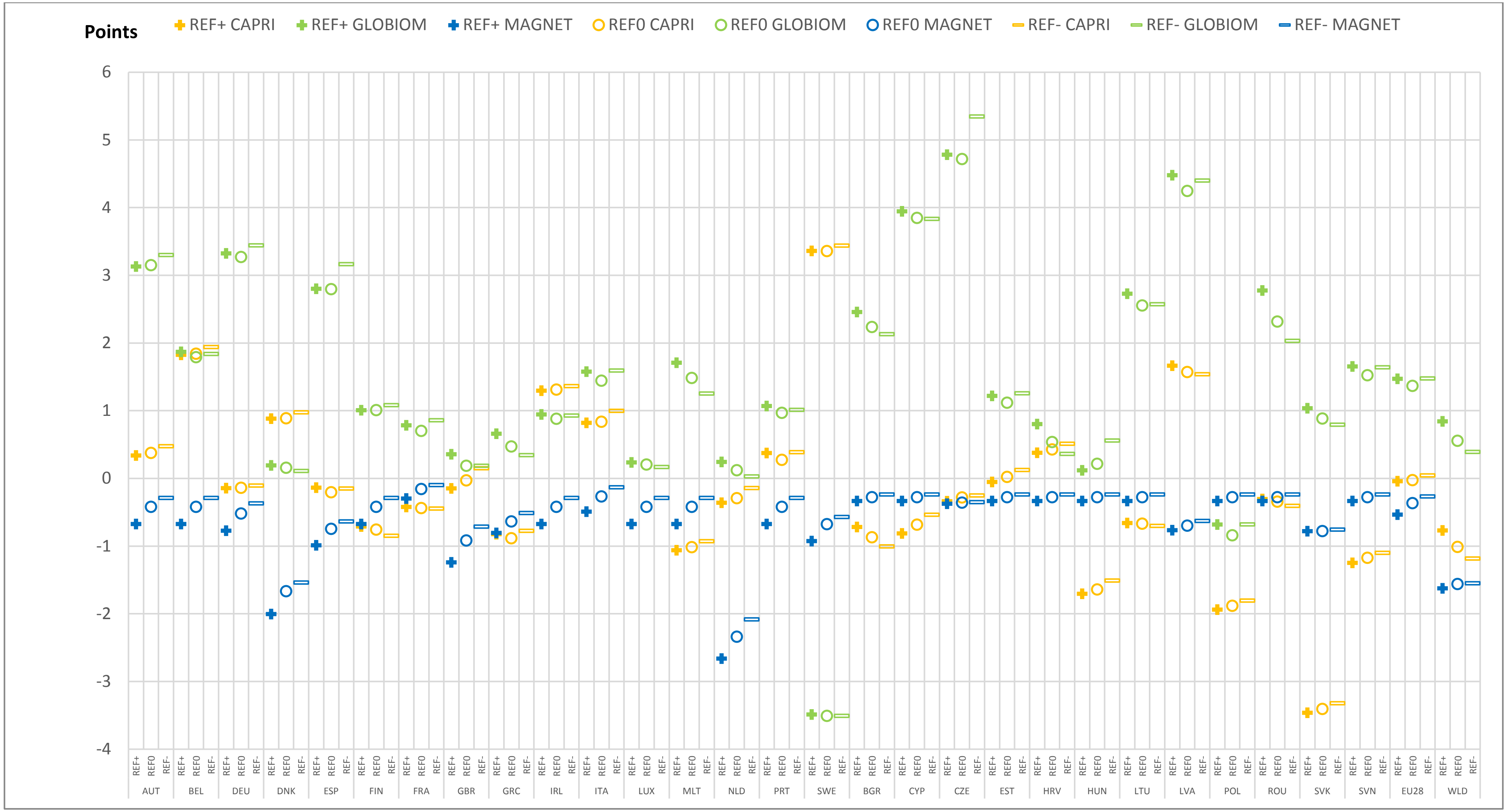


Figure A.3. 3 Changes in Nutrient Rich Dietary (NRD) score points across EU member states

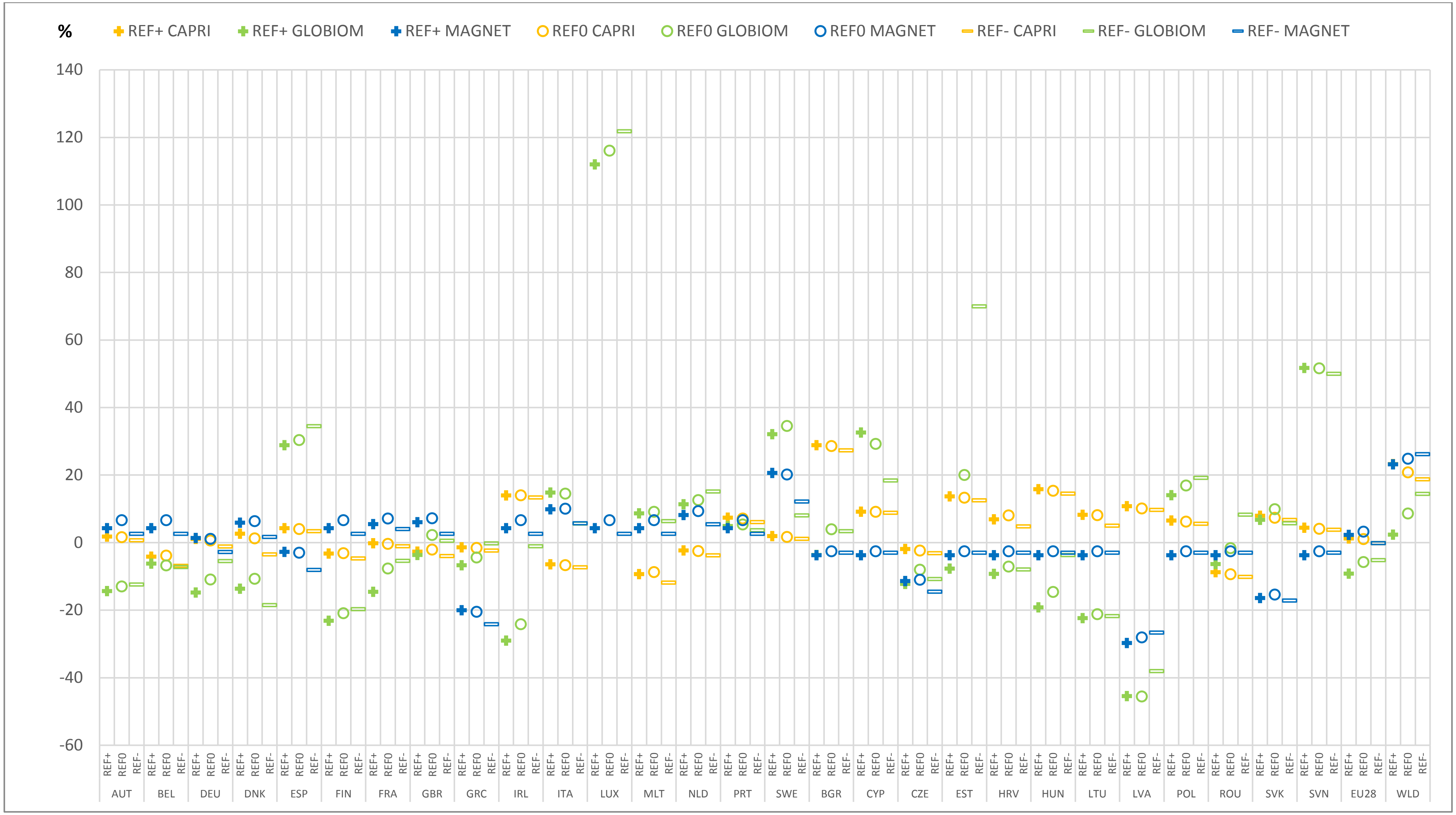


Figure A.3. 4 Changes in GHG emissions in agri-food sectors 2010-2030

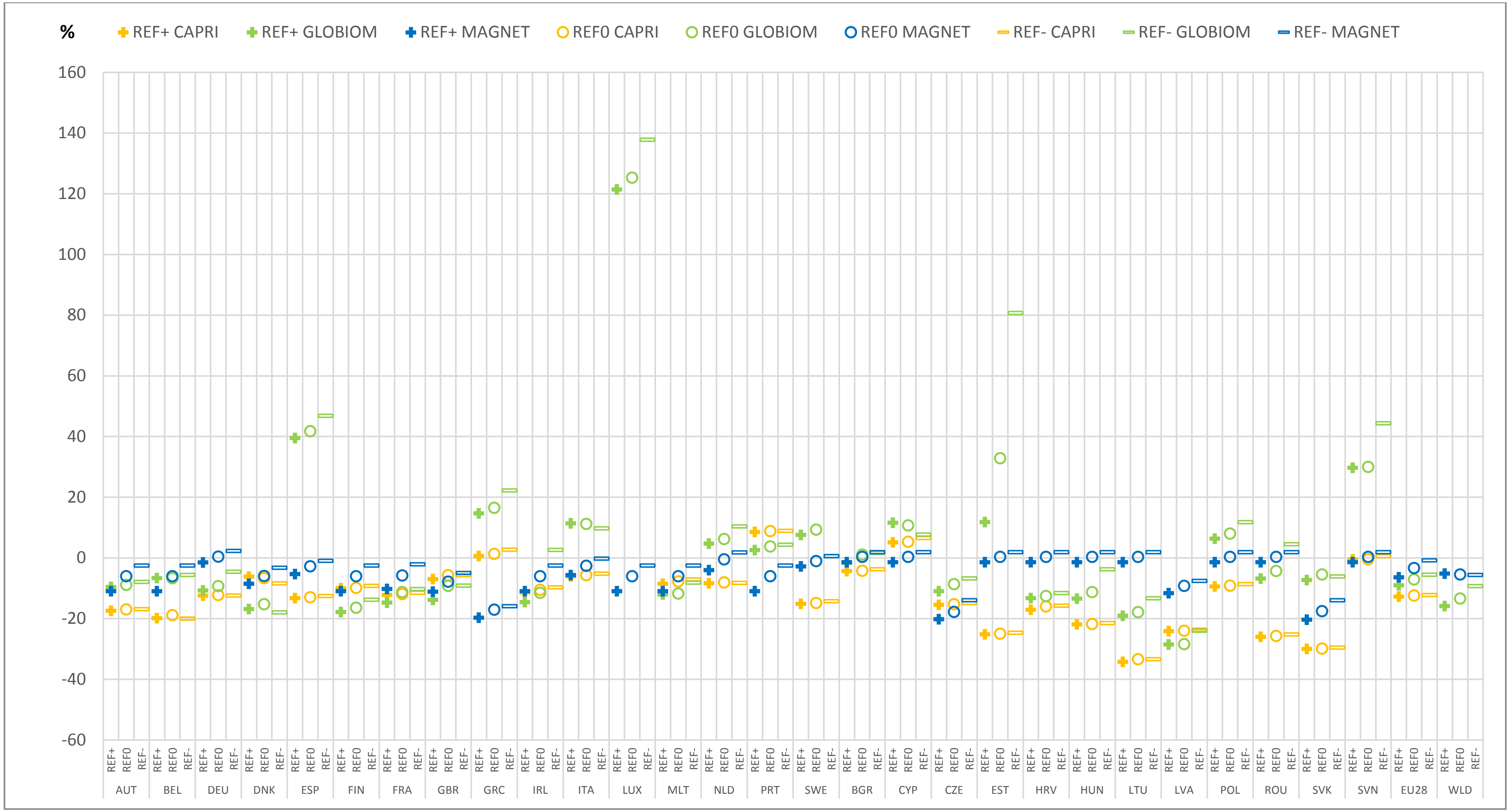


Figure A.3. 5 Changes in agri-food GHG emissions per calorie produced 2010-2030