# Foresight of EU sustainable food and nutrition security: the interplay between major challenges and policy responses at different spatiotemporal scales

## Deliverable No. 10.4

SUSFANS DELIVERABLES

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This deliverable reports on Task 10.4. Based on a quantif
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# DELIVERABLE SHORT SUMMARY FOR USE IN MEDIA

With EU food systems providing sufficient calories and other nutrients to meet the dietary needs of the European population, the past policy focus on quantity is shifting to a quality perspective. Nowadays, food systems in high income countries are judged based on their ability to provide healthy and nutritious diets without compromising sustainability in any dimension. Here we bring together different strands of SUSFANS research with a focus on demand side interventions targeting a change in consumer's behaviour towards healthy and sustainable diets.

We apply three state-of-the-art economic agricultural sector models to assess how EU food and nutrition security (FNS) may evolve in the future and quantify the effectiveness of supply and demand side targeted policies in improving overall performance of the food system with respect to sustainability issues focused around FNS. We explore different macro-economic developments and policy instruments targeting the production systems to assess sustainability impacts and the development of future EU FNS. Then we quantify the impacts of demand side policies, using different diet shift scenarios, on nutrition outcomes and diverse sustainability indicators.

Our simulations show that without policy interventions directed at consumer purchases and dietary habits, EU diets will neither become healthier nor more sustainable. Diet shifts based on food pattern changes are found to outperform the effects from changes in total calorie consumption and overall demand side interventions deliver co-benefits for the environment in the EU. The comparison between EU member states reveals that while the size of impact differs, the directions of change are in line with each other.

# TEASER FOR SOCIAL MEDIA

Without policy interventions directed at consumer purchases and dietary habits, model simulations indicate that EU diets will neither become healthier nor more sustainable. However, a shift in dietary preferences would yield substantial co-benefits for the environment.

Without policy interventions directed at consumers, model simulations indicate that EU diets will neither become healthier nor more sustainable. #Food #SDGs

# ABSTRACT

With EU food systems providing sufficient calories and other nutrients to meet the dietary needs of the European population, the past policy focus on quantity is shifting to a quality perspective. Nowadays, food systems in high income countries are judged based on their ability to provide healthy and nutritious diets without compromising sustainability in any dimension. Here we bring together different strands of SUSFANS research with a focus on demand side interventions targeting a change in consumer's behaviour towards healthy and sustainable diets.

We apply a number of state-of-the-art economic agricultural sector models to assess how EU food and nutrition security may evolve in the future and quantify the effectiveness of supply and demand side targeted policies to improve the performance of the EU food system with respect to sustainability.

We first explore different macro-economic developments and policy instruments targeting the production systems (decrease in livestock density, sustainable fishery policies, and climate change mitigation) to assess sustainability impacts and the development of future EU food and nutrition security. Then we quantify the impacts of demand side policies, using five diet shift scenarios, on nutrition outcomes and diverse sustainability indicators. We define diet scenarios based on a change in intake of different food groups (a shift towards fruit and vegetables and away from red meat, processed meat and sugar) and energy (reduction in total energy intake to halt the increase in body weight) in line with recommendations of nutritionists and judged feasible given past trends in European diets.

Our analysis shows that without policy interventions directed at consumer purchases and dietary habits, model simulations indicate that EU diets will neither become healthier nor more sustainable. Diet shifts based on food pattern changes are found to outperform the effects from changes in total calorie consumption. Demand side interventions deliver co-benefits for the environment in the EU, while EU agricultural production decreases slightly due to the drop in demand. The comparison between EU member states reveals that while the size of impact differs, the directions of change are in line with each other.

# INTRODUCTION

With European food systems in the beginning of the 21st century providing sufficient calories and other nutrients to meet dietary needs of the EU population (Berners-Lee et al., 2018), the discourse has shifted from a quantity to a quality perspective. Nowadays, food systems in high income countries are judged based on their ability to provide healthy and nutritious diets without compromising sustainability in any dimension (Rutten et al, 2018; Gustafson et al., 2016). This is a demanding challenge as researchers are still facing great difficulties in assessing nutrition and sustainability in a comprehensive and integrated way. An integrated assessment, however, is a prerequisite in order to make a robust statement about the performance of the food system and to develop policies targeting improvements in both food quality and sustainability of the food system.

Within the course of the SUSFANS project, research has been conducted in various domains with the aim of assessing the current and potential future state of EU food and nutrition security (FNS). Nutritionists elaborated on healthy diets and nutrition for the European population considering regional differences while coping with the challenge of aggregating across consumers (Mertens et al. 2018, Mertens et al. 2016 (D2.2)). Their outcomes reveal the directions of desired changes with respect to intakes of certain nutrients and food groups.

The SUSFANS toolbox was set up based on various models differing in scope, methods and strengths complementing each other. The toolbox was improved and applied for the assessment of impacts on sustainability and nutrition derived from potential macro-economic developments (Frank et al. 2018 (D10.2)) and supply side policies (Latka et al. 2018 (D10.3)).

Food system impacts were investigated with respect to three dimensions of sustainability: environmental (planet), social (people) and economic (profit). Moreover, sustainability impacts have not only been identified, but even quantified, aggregated, and visualized in an easily accessible way for a large number of sustainability indicators (Zurek et al. 2017 (D1.3), Kuiper and Zurek 2017 (D1.4), and Achterbosch et al. 2019 (D6.3)).

In the present deliverable, we bring together these different strands of SUSFANS work with a focus on demand side interventions (chapter 4) targeting consumers' behaviour. We implement the diet scenarios on top of the contextual scenarios shaped by differences in macro-economic developments and presented in chapter 2 (based on D10.2). In chapter 3 we assess three possible supply side instruments (decrease in livestock density, sustainable fishery policies, and climate change mitigation) focused on improving the sustainability of the EU food system and assess the impact on consumer purchases and thus diets (based on D10.3). In chapter 4, we focus on demand side policies targeting healthier diets, using five diet scenarios, analysing nutrition outcomes and diverse sustainability indicators and presenting the aggregated effects using the SUSFANS visualizer. We define diet scenarios based on a change in intake of different food groups and energy in line with recommendations of nutritionists (D2.2). Since nutrition research is based on individual food intakes, nutrition data are translated to fit the consumer representation of macro models, which is an average national consumer for each country (see D1.4). The approach for linking individual intake data to macro-level consumption data comes with strong assumptions and caveats for the interpretation of results (Box 1).

We conclude the deliverable by comparing the supply and demand side interventions across scales and discuss efficient policy solutions for advancing the EU food and nutrition security.

**Box 1 "SHARP data" on individual food intake in the EU: explanation and a disclaimer on their use**

*Disclaimer*

For use in the SUSFANS project, national dietary survey data were standardized based on populations' age and sex distributions (year 2010), daily energy intake (2000 kcal for women and 2500 kcal for men), and number of dietary assessment days. Therefore, data presented here may differ from national dietary survey data published elsewhere.

*National survey data (we refer to these "SHARP data")*

For the assessment of dietary intakes on the national level, individual-level data were obtained from four EU Member States representing the diversity of food habits in the Europe, i.e., Denmark (2005-2008), Czech Republic (2003-2004), Italy (2005-2006), and France (2006-2007). These countries were selected to capture a wide range of food and agricultural commodities that are incorporated in the dietary patterns to supply the required nutrients, not as a representative sample of the EU as a whole. They illustrate the geographical diversity of dietary patterns in Europe (Mertens, 2018). Furthermore, these four countries participate in the emerging pan-European Nutrition Surveillance, and have their survey data included in the FOODEX2 system by EFSA. The dietary assessment in these four countries was done by either food records or 24-hour recalls, all aiming at a complete picture of food and nutrient intake, and covering at least two non-consecutive days per individual.

*Use of national survey data in scenario analysis*

We assessed food consumption based on national dietary surveys from four countries. In these surveys detailed information on food intake is collected at individual level, e.g., FoodEx2 classification with ~1000 food items. Based on this detailed information two performance metrics related to 'balanced and sufficient EU diets' are constructed, e.g., a food based and nutrient based performance metric.

In the diet scenarios for 2020 to 2050, presented in section 4, changes in food consumption patterns expressed as a percentage change for each FoodEx2 code are generated as an output from the MAGNET model. To be able to apply this change to the baseline year 2010, we needed for each country a baseline in g/d for each food item. However, the national surveys that we use are from different years. Therefore, we constructed in each country four subgroups based on age (<50 years vs ≥50 years) and sex (male vs female). These subgroups were used to standardize the national dietary surveys of the four countries, to the baseline year 2010 based on these demographics.

# FORESIGHT IN SUSFANS – IMPACTS OF MACRO ECONOMIC DRIVERS

To explore sustainability implications and identify challenges for EU FNS, three contextual scenarios were quantified along with four key macro-economic dimensions that were recognized as vital for future EU FNS:

- Demographic and income trends: One important driver of future food demand and consequently FNS are socio-economic developments. These were identified as a key scenario component and quantified in Task 10.1 (Havlík et al., 2018) in the scenario database.
- Technological change: The speed of change and character of technical change (adaptation of new technologies or technology transfer) is important for future FNS but also for reducing environmental impacts of the agricultural production system.
- Policy context: The European agro-food sector develops within a complex policy framework. A prominent example examined here is international trade policy, being of utmost importance when considering the environmental and social objectives.

The three contextual scenarios were developed along these drivers and span from i) a future based on ongoing global developments (REF0), ii) a future with high challenges for sustainable global food and nutrition security (REF-), and iii) a future with comparably low challenges for sustainable food and nutrition security at global scale (REF+). A detailed description of the underlying macro-economic drivers is provided in D10.1 (Havlík et al., 2018). This chapter represents a summary of results across contextual scenarios based on D10.2 (Frank et al., 2018) however with enhanced details for the four case study countries and food consumption related indicators such as household expenditures or food purchases. The presented results in this chapter do not consider dietary interventions on the demand side.

## Planet

Due to limited agricultural production expansion in the EU across most scenarios and models combined with productivity gains related to technological change, fertilizer use and nitrogen/phosphorous surplus are projected to slightly decrease by 2050 with potential benefits for the environment. Across EU member states quite diverse environmental effects can be observed (Figure 2 provides country level results for 4 national case studies) ranging from modest decreases in fertilizer use and modest increases in other natural vegetation, up to doubling of other natural vegetation area in the case of the Czech Republic. Agricultural greenhouse gas (GHG) emissions are projected to remain rather stable across contextual scenarios until 2050 again related to the modest increase in agricultural production levels in the EU and continuous improvement in GHG efficiency through technological change. In contrast to the rather modest changes with respect to environmental sustainability within the EU, at global scale fertilizer demand as well as agricultural GHG emissions are projected to grow significantly by 2050 (Figure 1 provides results at the EU28 and global scale).

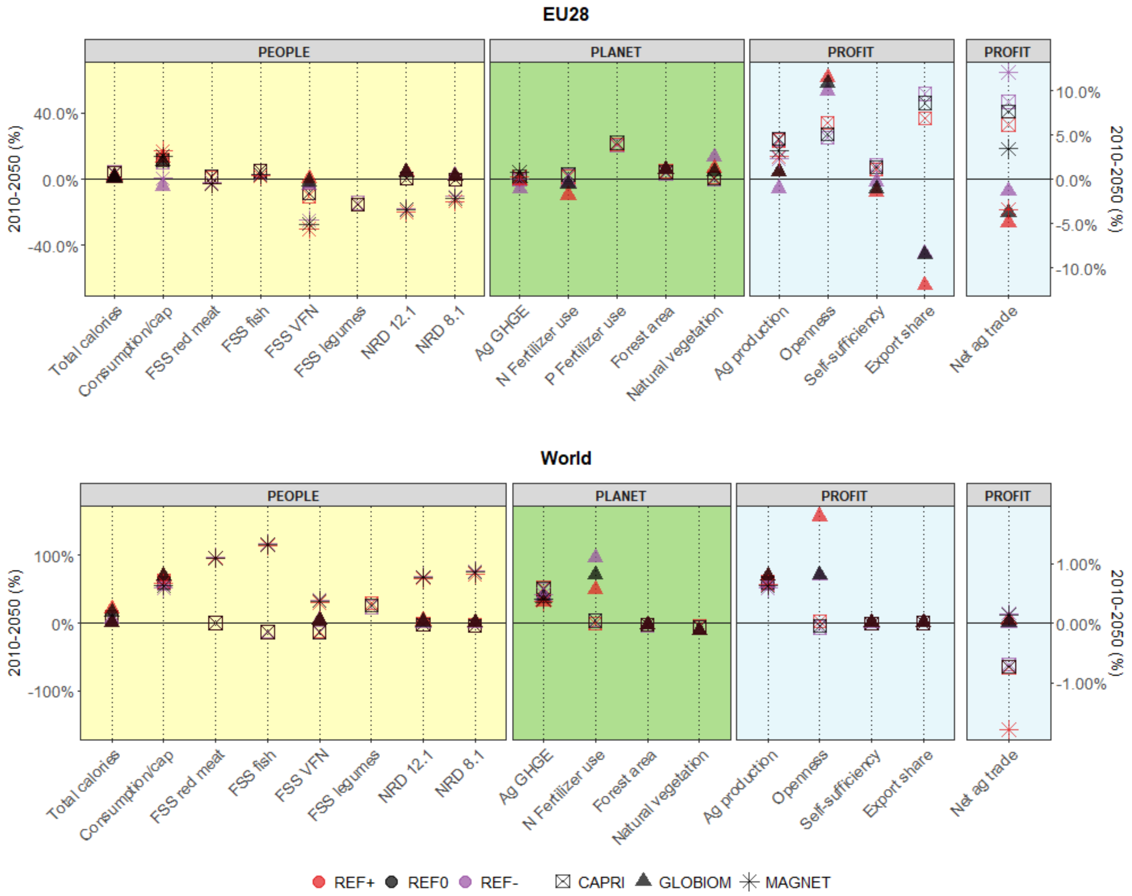


*Figure 1. Development of sustainability indicators for people, planet, and profit at EU and global level by 2050 compared to 2010 across contextual scenarios. Total calories – total calorie consumption per capita, Consumption/cap – per capita food consumption, FSS red meat –red meat consumption, FSS – fish consumption, FSS VFN – fruits, vegetables and nuts consumption, NRD 12.1 nutrient rich dietary score for 12 qualifying and 1 disqualifying micro-nutrients, NRD8.1 - nutrient rich dietary score for 8 qualifying and 1 disqualifying micro-nutrients, Ag GHG – agricultural GHG emissions, N fertilizer use – nitrogen fertilizer use, Forest area – total forest area, natural vegetation – other natural vegetation area, Ag production – total agricultural production, Openness – ratio of export plus imports in total agricultural production, Self-sufficiency – agricultural self-sufficiency ratio, Export share – agricultural exports in total production, Net ag trade – agricultural net trade.*

## Profit

Stabilization of agricultural commodity demand and modest yield growth explain the continued decrease in agricultural areas inside the EU while at global scale rapid demand growth drives the steady expansion of agricultural areas. Crop yields are projected to grow only moderately in the EU while they increase much stronger on global average by 2050. Consequently, regions outside the EU are able to increase their competitiveness. As developing and emerging countries continue to catch up in terms of crop- and livestock productivities, other regions outside Europe become increasingly competitive, thereby limiting the opportunities for EU farmers to continue expanding production by increasing export shares. Hence, despite substantial growth in food demand outside Europe, agricultural production and net exports in the EU do not benefit across all models from these developments at higher level (Figure 1). Individual countries like Denmark, may experience more substantial increases in production/exports as consistently anticipated across models (Figure 2).

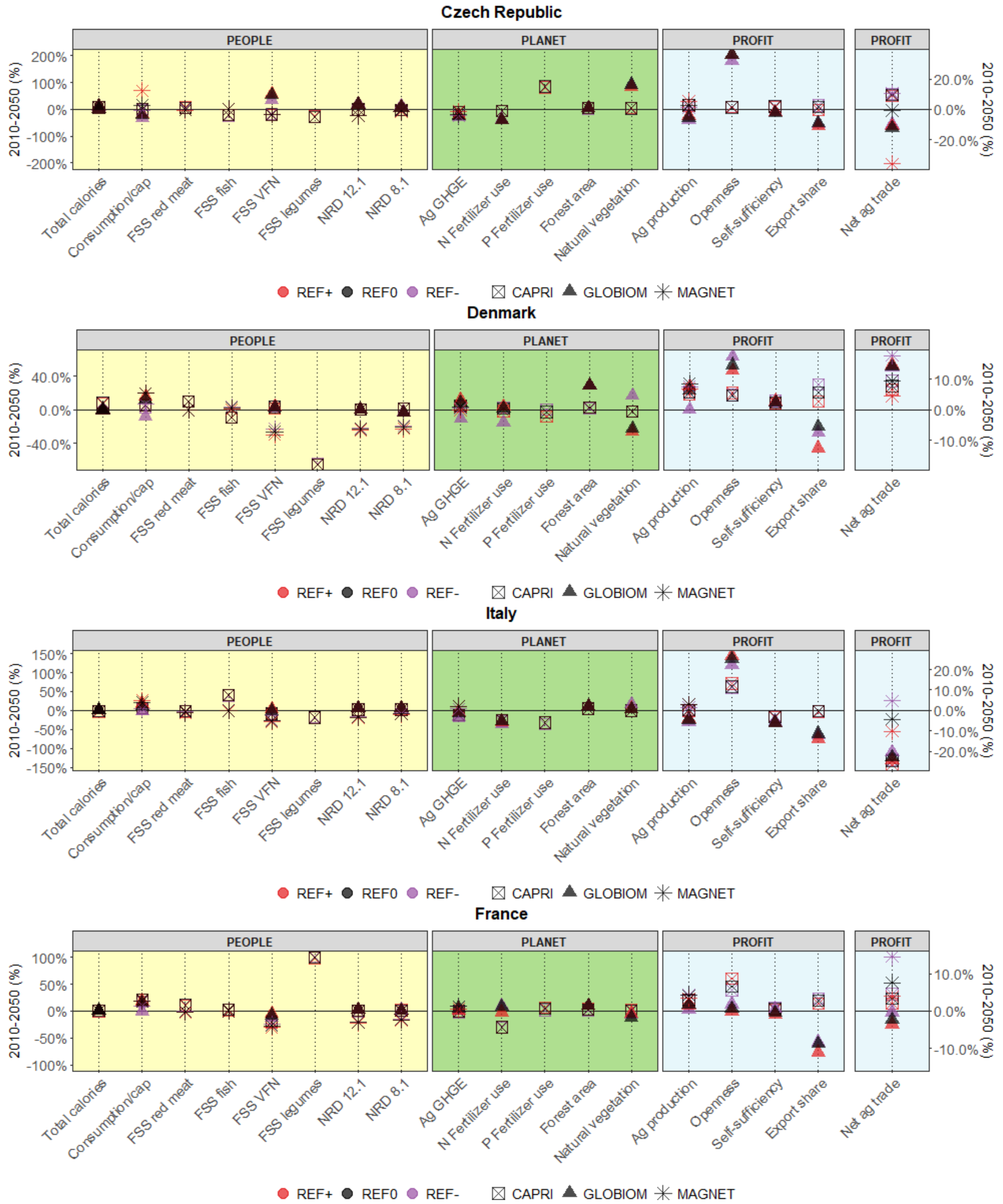


*Figure 2. Development of sustainability indicators for people, planet, and profit for 4 EU member state case studies by 2050 compared to 2010 across contextual scenarios. Total calories – total calorie consumption per capita, Consumption/cap – per capita food consumption, FSS red meat –red meat consumption, FSS – fish consumption, FSS VFN – fruits, vegetables and nuts consumption, NRD 12.1 nutrient rich dietary score for 12 qualifying and 1 disqualifying micro-nutrients, NRD8.1 - nutrient rich dietary score for 8 qualifying and 1 disqualifying micro-nutrients, Ag GHG – agricultural GHG emissions, N fertilizer use – nitrogen fertilizer use, Forest area – total forest area, natural vegetation – other natural vegetation area, Ag production – total agricultural production, Openness – ratio of export plus imports in total agricultural production, Self-sufficiency – agricultural self-sufficiency ratio, Export share – agricultural exports in total production, Net ag trade – agricultural net trade.*

## People

EU food consumption will not stay unaffected from macro-economic drivers, as GDP per capita is one of the determinants regarding consumer food purchases and food intake. Figure 3 displays GDP per capita growth until 2050 for the EU28 in the REF0 scenario. While GDP per capita is projected to grow by 68% until 2050 in comparison to 2010 levels on average for the EU28, per capita income for the average of the rest of the world is expected to grow much stronger by 184% until 2050. Starting from different income levels, this implies a convergence of incomes and food consumption between the EU average and the rest of the world in this respect. However, even within the EU there remain considerable differences between member states with respect to per capita income growth, as indicated by the light blue shadow in Figure 3. EU members with below EU average incomes in 2010 (notably Eastern European countries and the Baltics) are projected to slowly converge toward the Western European countries income levels, reflected in higher per capita growth rates. In comparison to the business as usual reference case (REF0), GDP per capita grows more strongly (about 80% until 2050) in the low challenges scenario (REF+) while the growth is weaker (50% compared to 2010) if challenges for sustainable FNS in the EU are high (REF-).

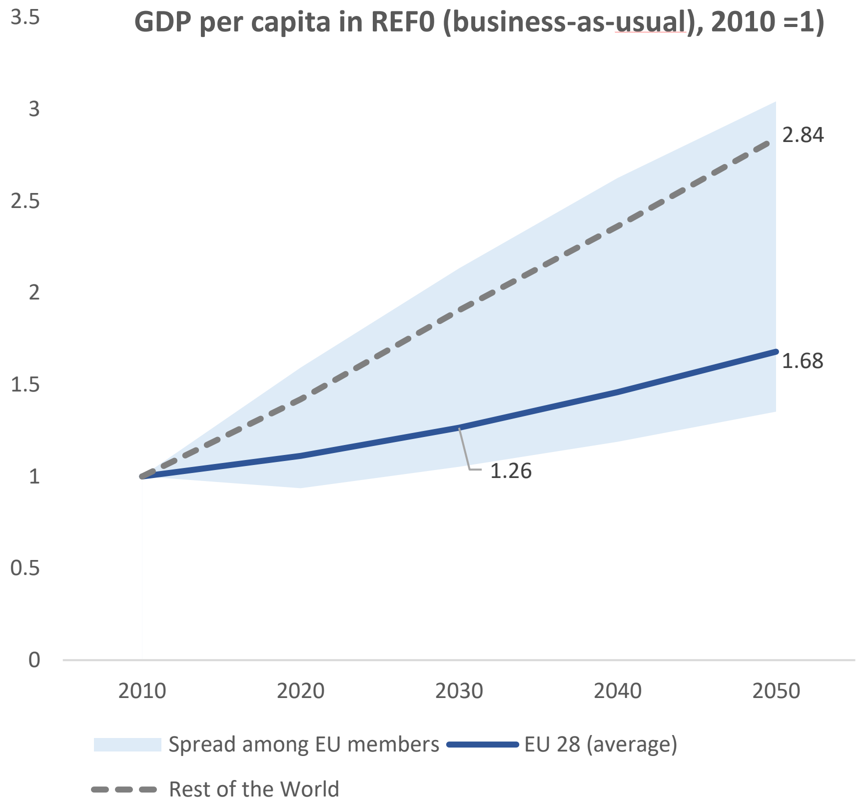


*Figure 3. Income per capita growth projection at EU28 average and spread among EU members in REF0 (2010 =1).*

The increase in income in the EU does not necessarily imply an equally strong increase in food expenditures. Being a high-income region food forms only a modest part of total household expenditures and the elasticities that govern household responses to income and price are low. Inelastic demand coupled with productivity increases achieved in the past decades has translated in decreasing relative cost of food for European citizens. The decreasing importance of food in the average European household budget is projected to continue in the future in all contextual scenarios, dropping to as low as 6% of average EU28 household expenditures in REF+ by 2050 (Figure 4). The declining share of food expenditures with rising incomes is also illustrated by the relatively high shares in Czech Republic, the poorest among the case study countries. However, being based on one single representative household per country, the household expenditures cannot measure within country differences in food access due to internal income distribution.

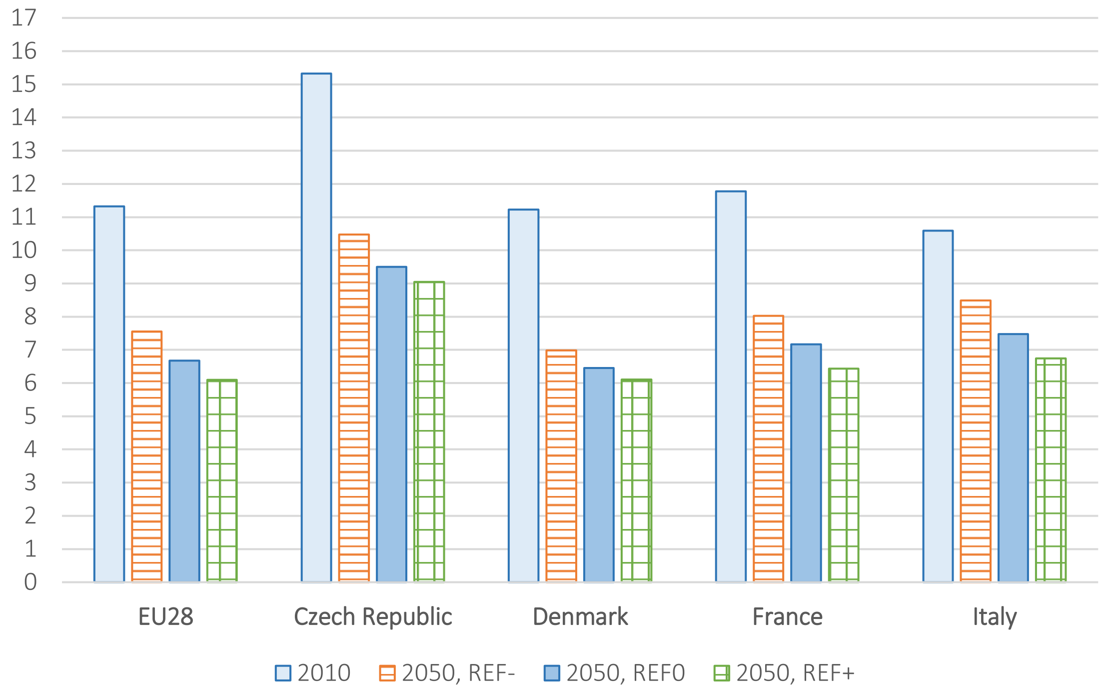


*Figure 4. Food share in total private household expenditures for the EU 28 and the four case study countries (% for 2010 and for 2050 by contextual scenario). Source: MAGNET simulations.*

The interplay of income and price changes determines in our models household purchases of food and non-food items. While Figure 4 shows a declining share of food expenditures, it does not yet provide insight in the purchased quantities of food.

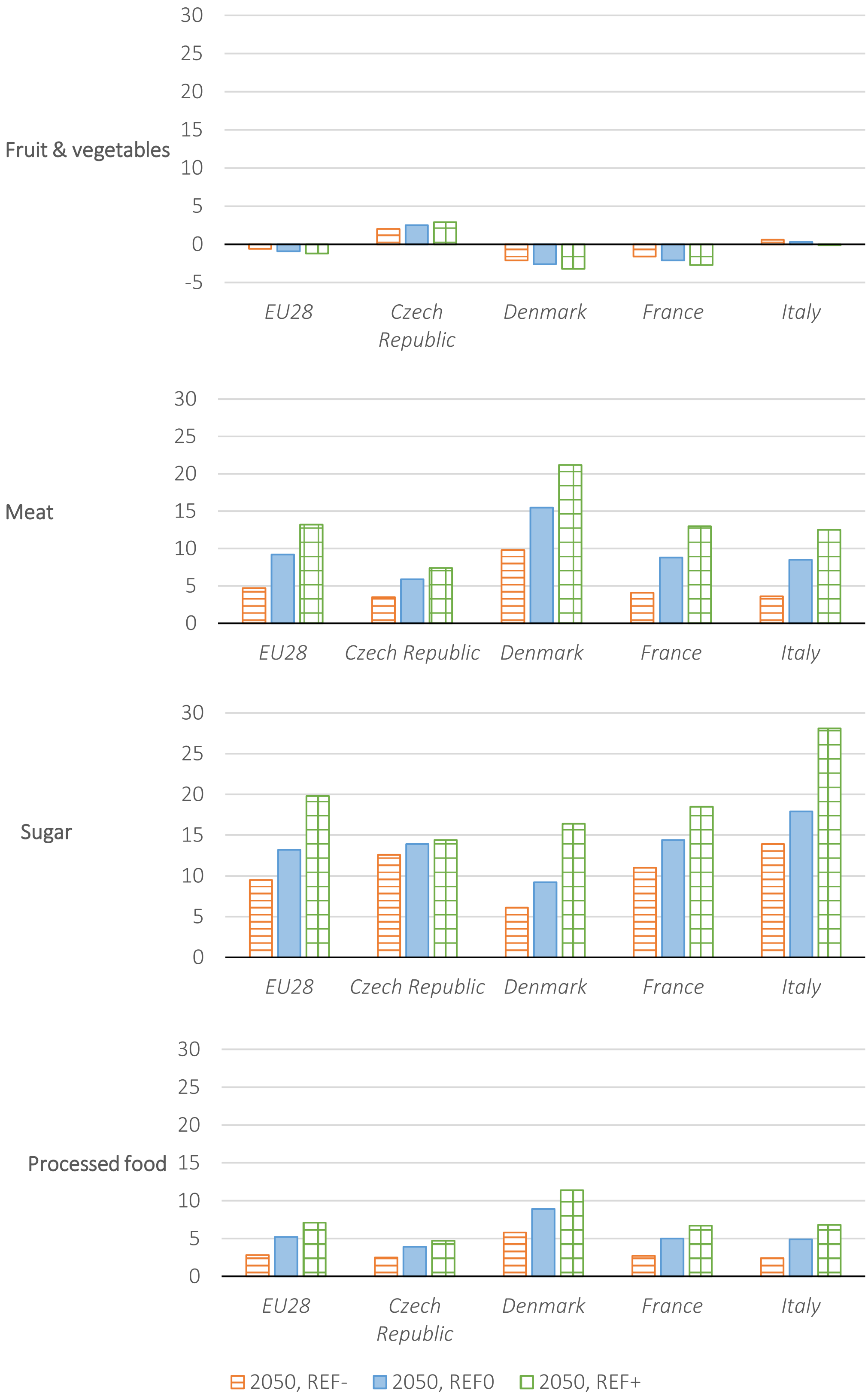


*Figure 5. Changes in household food purchases of key food groups for EU and case study countries (% change from 2010 by contextual scenario). Source: MAGNET simulations.*

From a nutritional point of view, aggregate food purchases in a high-income setting like the EU are not very relevant. We therefore focus on distinct food groups which, based on the currently observed diet patterns in the four case study countries (Mertens et al., 2018), are important markers of changes in diet quality: fruit and vegetables, meat, sugar and processed food are of key importance. Figure 5 presents the changes in purchases for the EU as a whole and by case study country.

For meat and sugar, a consistent increase is projected across the countries as well as across the scenarios, while from a nutritional point of view intake of these groups should decrease to move towards healthier diets. In case of processed foods, the desired direction of change from a nutritional point of view is less clear, as this category encompasses a wide range of products from canned vegetables to sugar sweetened beverages. Whereas preserved fruit and vegetables, depending on their salt and sugar content, may contribute to a healthier diet, sugar sweetened beverage intake should be reduced. In case of REF+, technological progress is highest, thus price drops stimulating demand, together with the high income growth result in the strongest increase in household food purchases.

The changes for fruit and vegetables hover around zero for the EU28, which appears driven by a more diverse pattern in changes across the regions than for the other food groups judged by the variability across the case study regions. While the pattern in prices is the same (a drop from 2010 to 2050, most strongly in REF+), in Denmark and France purchases drop. The price elasticity of fruit and vegetables (and hence households' response) is much lower than for the other commodities (see footnote 1 in Chapter 4 for a more in depth discussion). For high-income EU regions, it is also practically zero and the decline in fruit and vegetable purchases signals a shift towards more preferred (but less nutritious) food items like meat as well as non-food expenditures. Czech Republic has a relatively high price response, being the poorest among the case study countries, and here we observe a modest increase in fruit and vegetables (which is in part helped by the lack of response in the higher income regions, which will push prices of imports from other EU regions down). This increase, however, is dwarfed by the increases in the other food groups.

Overall little improvement can thus be expected for FNS related to macro-economic developments inside the EU (Figure 1) as consumption of livestock products is expected to remain at high level until 2050 while consumption of healthy but rather under-consumed food groups like vegetables, fruits or legumes tend to decrease across scenarios (at best marginally increasing in the EU members with lower per capita income) and hence the nutrient rich diet composition (NRD indicators).

## Discussion

Overall, all models implemented in the SUSFANS toolbox agree that with respect to the considered sustainability indicators, only minor FNS improvement can be expected within the EU until 2050. Even though the stabilization of EU population and moderate GDP growth result in a marginal growth in EU food consumption and production, it does not result in substantial change in dietary patterns towards more healthy diets. As other regions become increasingly competitive, opportunities for EU farmers to continue expanding production by increasing export shares are limited at the same time and slight increases in production levels can only be expected in the livestock sector since domestic demand for animal products is still projected to continue to increase.

Despite these economic challenges for EU farmers, some co-benefits for the environment are anticipated. Fertilizer demand and emissions are projected to stabilize or even slightly decline while other natural vegetation area is expected to increase related to abandonment of agricultural land. Sustained yield growth results in continued decline in agricultural areas with potential co-benefits for biodiversity or climate change mitigation i.e. through afforestation.

With respect to FNS, the contextual scenarios reveal that without direct demand side interventions EU diets tend to worsen in the long run. Foods, such as red meat, that should be reduced to meet dietary recommendations rather tend to increase as consequence of macro-economic developments while healthy foods like fruits, vegetables, and legumes tend to decrease in food purchases. Furthermore, the scenario that shows the lowest challenges for FNS based on macro-economic developments (REF+) in terms of economic and environmental sustainability, is projected to deviate most from healthy dietary recommendations, which clearly illustrates that macro-economic developments are not sufficient to advance the EU FNS.

# IMPROVING SUSTAINABILITY OF THE EU FOOD SYSTEM THROUGH SUPPLY SIDE INTERVENTIONS

In this chapter, we assess the sustainability impact of three possible supply side targeted policies and investigate if they are capable of advancing EU FNS and pushing consumers towards changing their purchase and dietary habits. We explore the impacts of:

1. Common fisheries policy
2. Restriction of livestock density
3. Land based climate mitigation efforts

## Fishery policy

Seafood production and consumption play an ambivalent role with respect to sustainable FNS. On the one hand, aquatic food production has the potential to contribute to ensuring sufficiently available food for a growing world population (Merino et al., 2012). On the other hand, seafood production relates to several sustainability issues. Uncontrolled capture tends to deplete wild fish stocks. This overfishing endangers future fishery production and the income basis of people working in this sector (Allan et al., 2005; Quaas et al., 2012).

Aquaculture production may have a direct negative impact through influxes into the ocean from coastal production sites in terms of nutrients, antibiotics or invasive species (Frankic and Hershner, 2003). Indirect environmental effects arise from agricultural production of fish feed. Competition for feed and land with land animal production systems may have far-reaching consequences on the future agricultural sector (Froehlich et al., 2018). Nevertheless, aquaculture production likely increases the competitiveness of the EU fishing industry (Hornborg et al., 2016).

The present common fisheries policy (CFP) assessment includes three scenarios that were implemented on top of the REF0 scenario:

1. MSY - this scenario introduces the rule that stocks in EU waters are harvested in a way that maintains them at levels producing the maximum sustainable yield (MSY);
2. MEY - also the maximum economic yield (MEY), a presumably more profitable harvesting approach that also leads to lower

environmental impacts, is inspected regarding its effects on seafood production and various sustainability indicators;

3. AQUA – here we examine the effects of implementing EU member states national aquaculture growth plans and the effectiveness of these policy scenarios for ensuring future yields and seafood supply.

The two models used for the CFP scenario estimations are GLOBIOM and CAPRI. A comparison of the CAPRI and GLOBIOM fish models reveals some differences in the calibration of the two models in the reference runs, and also some differences in the magnitude of the effects and the reactions to shocks. Generally, however, it is possible to draw several conclusions, supported by both models.

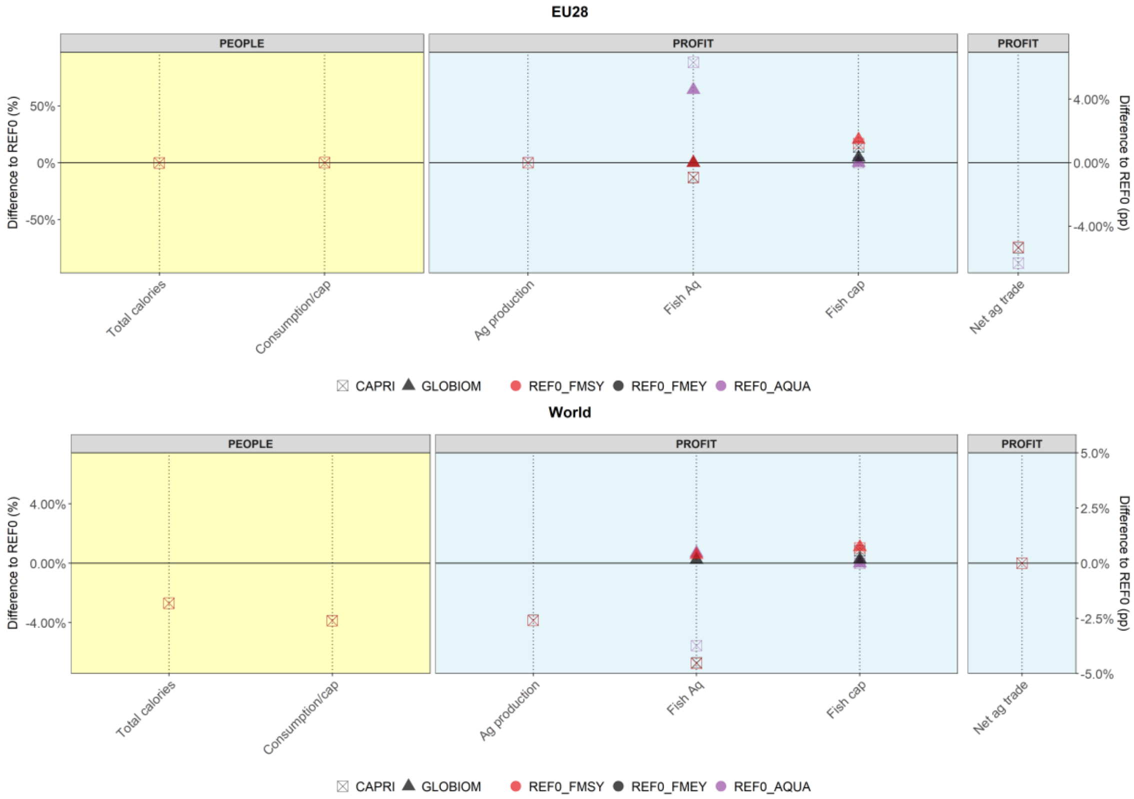


*Figure 6. Development of sustainability indicators for people, planet, and profit at EU and global level by 2030 compared to 2010 across the common fisheries scenarios. Total calories – total calorie consumption per capita, Consumption/cap – per capita food consumption, Ag production – total agricultural production, Fish Aq – fish production aquaculture, Fish cap – fish production capture, Net ag trade – agricultural net trade.*

First, the size of the fish sector in the EU relative to the rest of the agri-food sector in the EU is small, and fisheries and aquaculture scenarios therefore have little effect on the rest of the agricultural system in the EU (Figure 6).

Second, while EU seafood consumption has a major global impact due to EU's seafood import dependency (Swartz et al., 2010), and this is also reflected in the modelling results presented above, the EU fisheries and aquaculture production sector is very small relative to the rest of the world. Therefore, the scenarios of EU policies tested here, which are focused on the production side, only have small impacts globally.

Finally, fishmeal and fish oil aquaculture feed markets provide a strong link between the capture and aquaculture sector. Carnivorous aquaculture production increases the pressure on wild fish stocks (Naylor et al., 2000). Therefore, secondary effects are observable from capture policies on the aquaculture sector and vice versa. This could suggest that EU aquaculture and capture policies be better thought of as a coordinated and integrated policy affecting a common seafood sector. One suggestion of a combined policy approach would be a restriction of growing aquaculture species that rely on fishmeal and fish oil from capture fish. Besides assessing the distance to maximum sustainable yields, no environmental indicator for the CFP scenarios is composed, or rather, due to the limited size of the fish sector, quantifiable agricultural pollution indicators would hardly change. However, pollution coverage from capture and aquaculture production in the models is deficient and maybe extended in the future. Only then, suggested measures for reaching an environmentally sustainable fish sector in the EU like fishing technologies or management systems (Hornborg et al., 2016) can be assessed with the models.

## Livestock density

To achieve sustainable food production as aimed for in "SDG 2: Zero hunger" and in the objectives of the future CAP, reducing nitrogen surpluses and agricultural GHG emissions is inevitable. In the present analysis we investigate whether a restriction of livestock density under consideration of soil nutrient needs can contribute to reaching this goal. The reduction of animal density in nitrogen hotspot areas has the potential to address various sustainability determinants at once: reducing over-fertilization and nitrogen surpluses, increasing space per animal which potentially improves animal welfare, and decreasing agricultural greenhouse gas emissions.

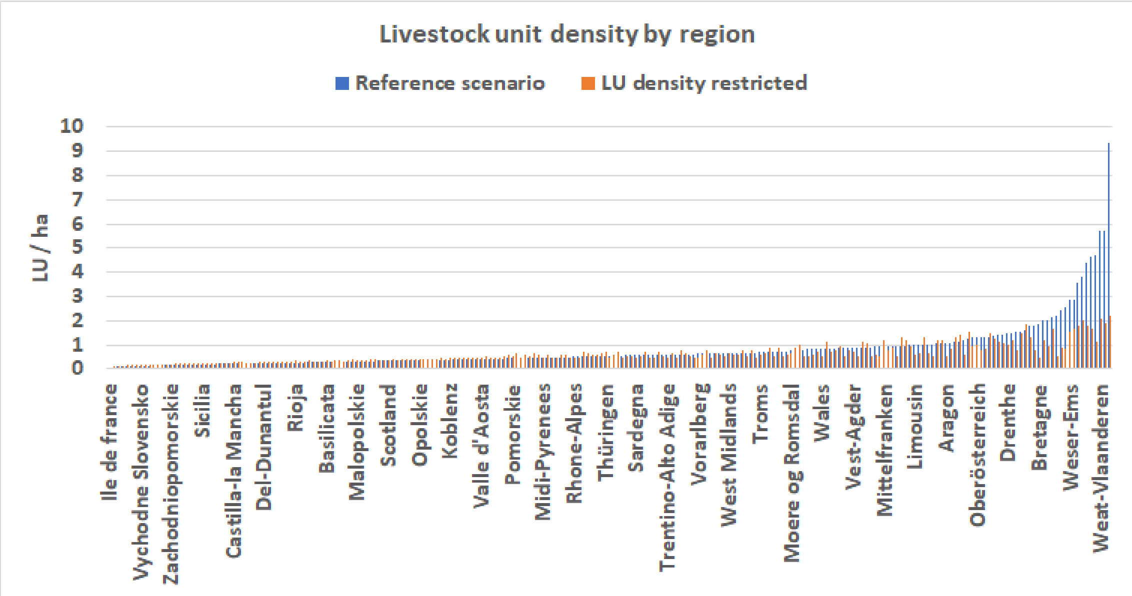


*Figure 7. Livestock density (LU/ ha) in the reference scenario (baseline) and after the policy shock by region (only selected region names displayed).*

The livestock density restriction scenario is set up in the following way: The nutrient need for reaching baseline yield levels is calculated. Livestock density is restricted so that the derived manure output could cover those soil nutrient needs. For those regions for which this calculation results in very low estimated animal densities, a safety maximum bound is set higher, to 0.5 livestock units (LU)/ ha. This gives flexibility for fertilization increases in regions that may lack sufficient nutrients in soils. The scenario definition allows for locally defined livestock density boundaries under consideration of environmental thresholds in the respective locality. Scenario results are compared for 2030 in contrast to a business as usual contextual scenario (REF0).

The scenario analysis reveals that a policy that restricts livestock density dependent upon regional soil nutrient needs will likely reduce soil nutrient surpluses in livestock dense hotspot areas. Overall such a policy is expected to reduce negative environmental impacts, e.g. model results indicate that agricultural GHG emissions could decrease by 9% as consequence of the livestock density policy compared to the reference case in 2030 (Figure 8). The livestock density policy also reveals progress on the way to clean water as nitrogen leaching and run-off from fertilizers and manure can be reduced.

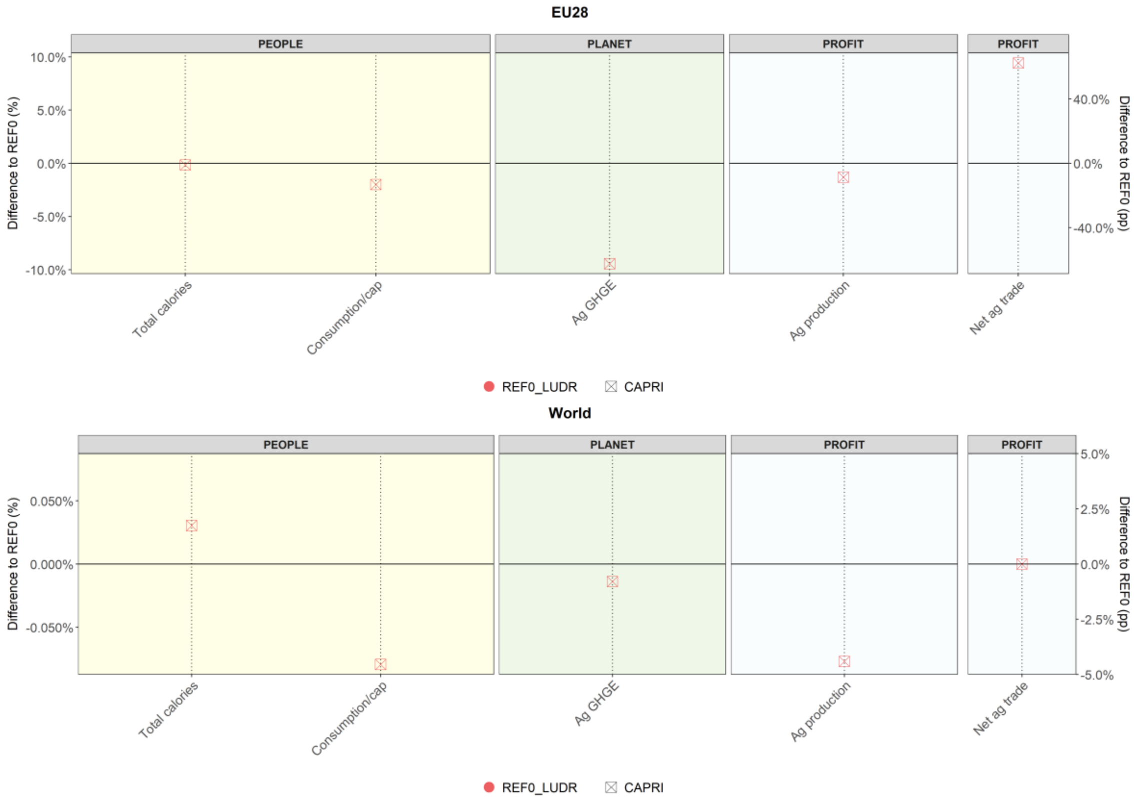


*Figure 8. Development of sustainability indicators for people, planet, and profit at EU and global level by 2030 compared to 2010 across the livestock density scenario. Total calories – total calorie consumption per capita, Consumption/cap – per capita food consumption, Ag GHG – agricultural GHG emissions, Ag production – total agricultural production, Net ag trade – agricultural net trade.*

# Climate change mitigation policy

In order to achieve the Paris Agreement climate target of limiting global warming to 1.5 °C by the end of the century, all sectors of the economy, including agriculture, will have to reduce GHG emissions substantially. Agricultural mitigation efforts may yield co-benefits for future FNS through the consumption decrease of GHG intensive food products such as beef. However, as European farmers are amongst the most GHG efficient producers, coordinated global mitigation efforts in agriculture may result in reallocation of food production across regions e.g. to the EU with domestic environmental knock-on effects. Here we assess the implications of applying a global uniform carbon price in agricultural production that would allow achieving a 1.5 °C (240 USD/t$CO_2$eq by 2050, "MTG1p5C") and 2 °C (50 USD/t$CO_2$eq by 2050, "MTG2p0C") climate stabilization target if adopted across all economic sectors.

Applying a global carbon price on agricultural GHG emissions to achieve the 1.5 °C stabilization target would result in global and EU calorie consumption reduction due to agricultural price increases driven by the carbon tax compared to the contextual scenario REF0. Even though EU consumers would react less sensitive to the food price increase as compared to less developed regions, still total calorie consumption is projected to be lower than in the contextual scenario REF0 without mitigation efforts (Figure 9). Also with respect to FNS indicators such as beef consumption and nutrient rich diet scores, actually some improvement can be observed in response to the mitigation policy. A carbon price is found to deliver also synergies with other environmental indicators, such as fertilizer use and other natural area expansion where substantial improvements are projected inside the EU but also at global scale.

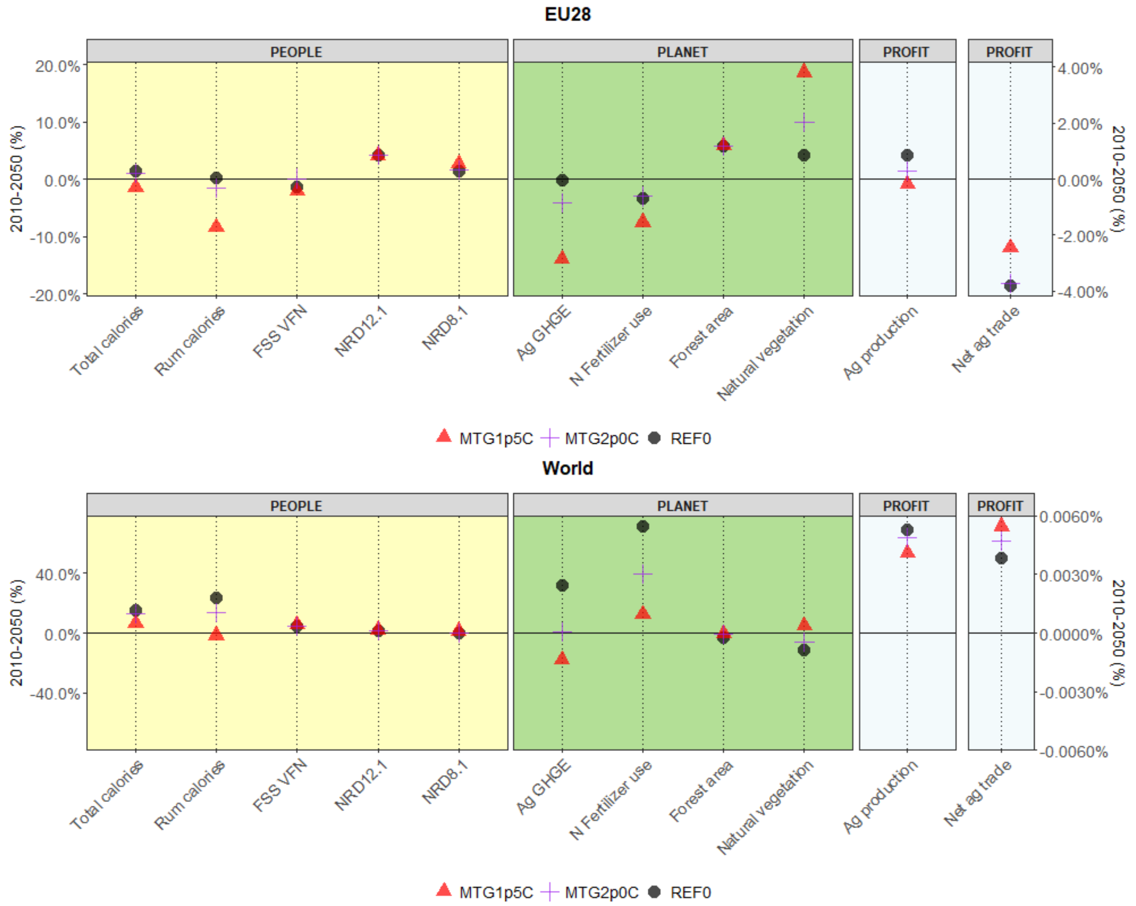


*Figure 9.* Relative change for people, planet, and profit indicators across climate impact and climate mitigation scenarios compared to the baseline (REF0) scenario by 2050. *Total calories – total calorie consumption per capita, Rum calories – ruminant meat consumption, FSS VFN – fruits, vegetables and nuts consumption, NRD 12.1 nutrient rich dietary score for 12 qualifying and 1 disqualifying micro-nutrients, NRD8.1 - nutrient rich dietary score for 8 qualifying and 1 disqualifying micro-nutrients, Ag GHG – agricultural GHG emissions, N fertilizer use – nitrogen fertilizer use, Forest area – total forest area, natural vegetation – other natural vegetation area, Ag production – total agricultural production, Net ag trade – agricultural net trade.*

If the climate change mitigation policy is applied consistently across the world, the EU agricultural sector would be less impacted as compared to other regions because of its relatively high GHG emissions efficiency, which would allow it to increase its exports and reduce imports. However, unilateral EU climate mitigation policy would have exactly the opposite effect, potentially even increasing global GHG emissions rather than decreasing.

## Discussion

The analysis performed in chapter 3 highlights that the selected supply side policies do not advance significantly future FNS in the EU. Even though synergies with in particular environmental sustainability can be observed in particular from the livestock density and climate change mitigation policy, overall FNS synergies remain limited. This shows that in order to achieve sustainable FNS in the EU, supply side policies will need to be complemented by more consumer oriented policies which we will assess in the subsequent chapter 4.

# IMPROVING EU DIETS THROUGH CONSUMER SIDE INTERVENTIONS

Considerable challenges have been overcome in order to bridge the gap between micro-level nutrition and macro-level economic research especially regarding modelling attempts in the SUSFANS toolbox. As part of the SUSFANS project, nutritionists have investigated current EU diets at population level based on individuals' intakes of a wide array of products. Despite valid concerns when averaging intake recommendations across individuals they came up with national level healthy diet recommendations that can be addressed by large-scale macro models (D2.2). To operationalize the toolbox some major challenges linked to definition of food consumption had to be resolved to the extent possible in the context of the SUSFANS project (see discussion on methods for more detail).

A growing number of research deals with potential and implemented interventions targeted at changing consumer food purchases and intake (D10.3). Not all instruments are equally suitable to be implemented in macroeconomic models. The range of potential instruments and the selection for scenario implementation are reflected in the following section. Figure 10 provides an overview of the linkages between targets defined by nutrition research, instruments suggested by consumer research and their macro model representations and implementation possibilities.

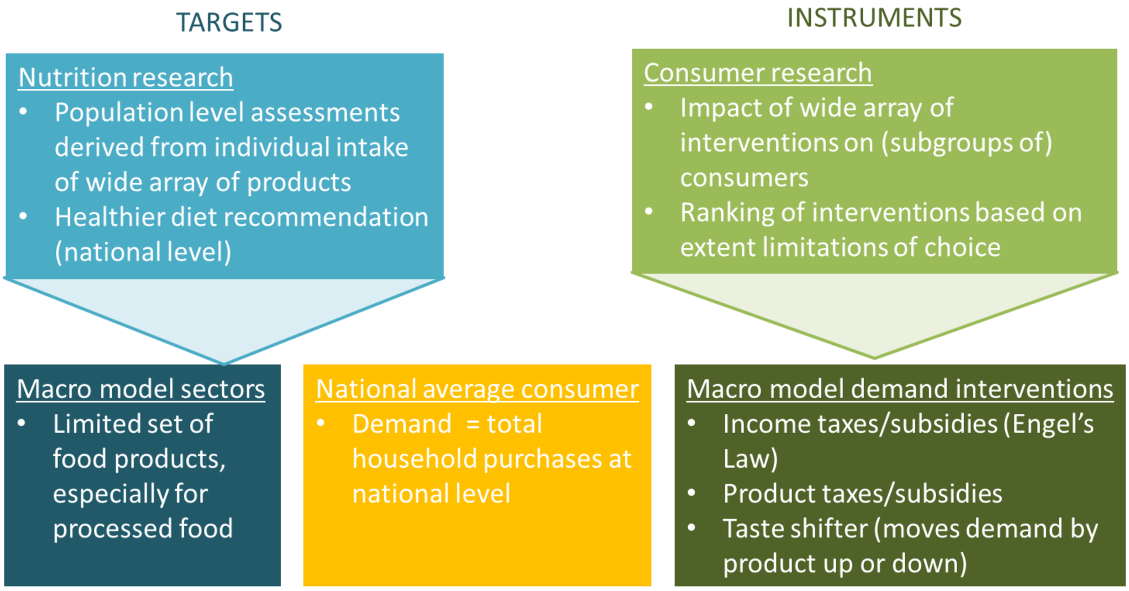


*Figure 10. Research targets and policy instruments implemented in macro models.*

# Methods

Based on nutritional and health considerations a shift towards fruit and vegetables and away from red meat, processed meat and sugar is needed (see D10.3, D2.2). In addition, total energy intake needs to be reduced to halt the increase in body weight. The dietary targets are set in a way that they are deemed feasible given past trends in European diets and achievable based on observed current diets of subgroups in the population. In other words, these diet shifts (see Table 1) would contribute to making European diets healthier without requiring radical and unlikely shifts.

*Table 1: Nutrition-based SUSFANS national average diet scenarios for EU member states (% change compared to the 2010 consumption levels).*

| SCENARIO I: Food pattern | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|
| *Fruit, vegetables (nuts)* | +25 | +50 | +75 | +100 |
| *Red meat & meat products* | -12.5 | -25.0 | -37.5 | -50.0 |
| *Sugar* | -12.5 | -25.0 | -37.5 | -50.0 |
| *Energy (isocaloric)* | 0 | 0 | 0 | 0 |

| SCENARIO II: BMI under 25 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|
| *Energy* | -2.5 | -5.0 | -7.5 | -10.0 |

*Source: adapted from Table 6 in D10.3*

Establishing a direction of change is one part of the puzzle, designing policies to achieve these changes is another. While the ambition here is not to design full-fledged policies, the choice of implementation method affects the impacts on the food system. Technically the macro models are all three able to impose a desired consumption pattern i.e. imposing the shift in diet exogenously. The way in which this is done, however, matters and varies across models.

CAPRI and GLOBIOM are partial equilibrium (PE) models implying there is no feedback loop from changes in the agri-food system to household incomes and the PE models focus on food related household expenditures only. Within the given total food expenditure, choices between products are driven by changes in product prices and consumer preferences. MAGNET has a similar demand system where prices and preferences govern choices but being a general equilibrium (GE) model total household income is affected (though changes in factor payments like labour and capital) by changes in the agri-food system. Furthermore, MAGNET explicitly models processed food and non-food expenditures which are also endogenous. In the context of the diet scenario it should be noted that CAPRI and GLOBIOM express demand in primary equivalents (i.e. food processing is not modelled explicitly).

With all three models having a demand system driven by prices and preferences there are two mechanisms to impose change in diets from the consumer side, taxes /subsidies and taste or preference shifts. Given the ambition to harmonize across models we implement the scenarios through price shifts with clearly envisaged dietary targets. In D10.3 evidence on interventions targeting consumer purchases and intake has been reviewed. Since the reviewed studies were hard to compare, only the most suitable studies have been summarized in a table with diet changes and costs of intervention (see Table 2).

All interventions geared at changing consumer decisions (1-7) would be captured by a preference or taste shift in the macro models. Note that the macro models are not able to distinguish between different motives underlying a change in consumer response to price and income changes. Therefore, we cannot assess the effectiveness of individual measures under intervention 1-7 in Table 2. Intervention 8 and 9 would be captured by subsidies and taxes, respectively. Finally, the last two measures amount to production and trade interventions reducing the products available for consumers. Due to missing data on this type of intervention, it is not further considered in the scenario design.

There is a major difference between tax/subsidies and preference shifts in terms of costs which, if not addressed, makes preference shifts seem the easy way out of the diet change policy discussion. Preference shifts are modelled as costless changes in consumer behaviour which means that the parameters in the demand system are exogenously changed to impose the desired behaviour. Taxes and subsidies on the other hand come at a cost, a so-called deadweight loss of consumer surplus and in the case of GE model like MAGNET an explicit need to define the use/source of the money involved. For example, in the case of a subsidy either a countervailing tax on other products would be imposed (making the measure budget neutral) or the subsidy would drain resources from other government expenditures (like on health care). Therefore Table 2 includes an estimate of costs of interventions to at least gauge the costs of a preference shift based on literature findings (D10.3).

Sub-scenarios aid in the interpretation of results. From Table 1 we therefore derive a set of diet scenarios varying in contextual scenario describing the expected changes in the food system (REF0, REF- and REF+) combined with only a target on food groups, only a target on energy or combined constraints on food groups and total energy intake to zero change or a decrease relative to 2010 levels (Table 3).

*Table 2: Size of change and cost by measure (selection from entries in Table 2 in D10.3).*

| | Intervention | Size of diet change | Cost of intervention | Model instrument |
|---|---|---|---|---|
| 1 | Provide information a) General population | 0.2% obesity reduction / 0.2-0.77 increase in fruit an veg servings | 1.8 $ PPP/capita (whole population) in OECD countries | Consumer taste shifters |
| 2 | b) Targeted subgroup | Adult reduced intake of energy (-6.3%, cholesterol (-9.2%), total fat (-12.2%), saturated fat (-15.6%) and increase in fibre intake (7.6%) | | |
| 3 | Compulsory information on products | Decreased average daily intake of fat (-6.9%), saturated fat (-2.1%), cholesterol (-6.9mg), sodium (29.58mg), increased average intake of fibre by 7.51g | 2.16 $ PPP per capita (whole population) in OECD countries | |
| 4 | Nudge through changing default policy | Shelf-product placement and visibility can affect choice but results between studies vary strongly (0-44%) and are hardly comparable | No data | |
| 5 | Ban marketing aimed at agents with limited decision-making capacity (e.g. children) | Food advertising regulations can reduce obesity by 5% across the whole population | 1.4 $ PPP per capita (whole population) in OECD countries | |
| 6 | Ensure healthy choices are available | 13% increase of fruit consumption among adolescents and a 6.3% decrease in sweet beverages | 2.59 $ PPP per capita (whole population) in OECD countries | |
| 7 | Enable choice by behavioural change programs | Decrease in obesity rates of 6.5%, | 7.16 $ PPP per capita (whole population) in OECD countries | |
| 8 | Guide choices through incentives | Subsidies ranging from 1.8% to 50% increased purchases of targeted foods between 1.5% and 25%; however, some studies find that the effect of subsidies (10%-30%) increased overall food consumption and calorie intake by 1%-17% | A 10% food subsidy would cost $734 million a year in the US | Taxes & subsidies |
| 9 | Guide choices through disincentives | Nutrient taxes (fat, sugar, or salt) of about 5% to 40% reduce intake of the respective nutrient by 0-8%, substitution of low-fat for high- fat options are likely, sugar tax of 1€/ kg could reduce 23% of sugary food consumption | Fiscal revenue of 0.28 $ PPP per capita (whole population) | |
| 10 | Restrict choice through regulation | Seems effective but no evidence on size of impact | No data | Production / trade quota |
| 11 | Eliminate choice | Effective but no evidence on size of impact | No data | |

*Source: Table 4 in D10.3*

The energy target is set-up in line with reaching an average Body Mass Index (BMI) of under 25 in order to reduce the prevalence of overweight and obesity (WHO, 2000). In the analysis at hand, we focus on tax/subsidy based instruments to achieve the diet changes because (i) prices consistently appear in studies as one of the important drivers of consumer behaviour; (ii) our review of cases indicates limited impact and generally only for subgroups of the population of non-price interventions (information, nudging etc.) while a national and large shift in diets is required; (iii) envisaging a restriction or even full elimination of choice of what are all healthy foods if consumed at appropriate levels is hard to envisage (in contrast to for example smoking, which is banned in indoors restaurants); (iv) costs (and revenues) are explicit when implementing subsidies or taxes; (v) food taxes are already in place, for example through different VAT taxes depending on the type of food commodity, which will ease the implementation. The novelty of our approach is to combine the implementation of a dietary target derived from nutritional insights on what is required for both diet patterns and BMI and what is deemed feasible given past changes in diet patterns with forward looking models able to incorporate the overall socio-economic context and food systems implications of such diet policies. Furthermore, we abstain from costless taste shifters which lack clear guidance to which policies or interventions are able to bring about the large national level shifts required to move Europe to healthier (and hopefully more sustainable) diets.

*Table 3: Tax-based diet scenarios (targets steps are identical for each of the four 10-year periods from 2010 to 2050).*

| | **REF0 contextual scenario** | | | | **REF- contextual scenario** | | | | **REF+ contextual scenario** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *DP_T_R0* | *DEm_T_R0** | *DPE0_T_R0* | *DPEm_T_R0* | *DP_T_Rm* | *DEm_T_Rm** | *DPE0_T_Rm* | *DPEm_T_Rm* | *DP_T_Rp* | *DEm_T_Rp** | *DPE0_T_Rp* | *DPEm_T_Rp* |
| ***Macro drivers*** | REF0 | REF0 | REF0 | REF0 | REF- | REF- | REF- | REF- | REF+ | REF+ | REF+ | REF+ |
| ***Fruit, vegetables (nuts) consumption*** | +25 | n.c. | +25 | +25 | +25 | n.c. | +25 | +25 | +25 | n.c. | +25 | +25 |
| ***Red meat & meat product consumption*** | -12.5 | n.c. | -12.5 | -12.5 | -12.5 | n.c. | -12.5 | -12.5 | -12.5 | n.c. | -12.5 | -12.5 |
| ***Sugar consumption*** | -12.5 | n.c. | -12.5 | -12.5 | -12.5 | n.c. | -12.5 | -12.5 | -12.5 | n.c. | -12.5 | -12.5 |
| ***Energy (calories)*** | n.c. | -2.5 | 0 | -2.5 | n.c. | -2.5 | 0 | -2.5 | n.c. | -2.5 | 0 | -2.5 |
| ***Tax limit*** | n.c. | n.c. | n.c. | n.c. | n.c. | n.c. | n.c. | n.c. | n.c. | n.c. | n.c. | n.c. |

*Remarks: targets are % change of 2010 consumption levels and increase in identical steps, i.e. for fruit and veg consumption by 25, 50, 75 and 100% of 2010 levels in 2020, 2030, 2040 and 2050 respectively; targets are identical for each of the four 10-year periods from 2010 to 2050; n.c. = not constrained; *DE0_T_R0/m/p as DEm_T_R0/m/p but Energy set to 0*

*Table 4: Scenario coding and labelling.*

| Scenario code | Scenario label | Global & EU food system outlook | Imposed shifts in European diets |
|---|---|---|---|
| **REF0** | REF0 (R0) | "Business-as-usual" food system outlook (REF0) | Diet changes freely in response to income and price changes |
| **REF-** | REF- (Rm) | Negative sustainability outlook regarding macro drivers | Diet changes freely in response to income and price changes |
| **REF+** | REF+ (Rp) | Positive sustainability outlook regarding macro drivers | Diet changes freely in response to income and price changes |
| **DP_T_R0** | Food pattern | REF0 | By 2050 the average diet of the EU population has moved towards a recommended diet composition in terms of fruit and vegetables, red and processed meat, and sugar |
| **DE0_T_R0** | Fixed calories | REF0 | By 2050 diet changes freely in response to income and price change while calories remain at 2010 levels |
| **DEm_T_R0** | BMI under 25 | REF0 | By 2050 calories are reduced to get the EU population average BMI under 25 |
| **DPE0_T_R0** | Food pattern & fixed calories | REF0 | By 2050 the average diet of the EU population has moved towards a recommended diet composition in terms of fruit and vegetables, red and processed meat, and sugar, while calories remain at 2010 levels |
| **DPEm_T_R0** | Food pattern & BMI under 25 | REF0 | By 2050 the average diet of the EU population has become healthier in terms of both food composition of main food groups and an energy intake to keep the average BMI under 25 |

In D2.2 the deviation of current average national diets from dietary recommendations is demonstrated. In the foresight study at hand, we assess future consumption patterns, economic developments and sustainability impacts. In order to follow a realistic attempt, we implement the achievement of the diet targets in a stepwise approach using a 10-year interval until 2050. Future projections are subject to uncertainties. Therefore, we compare the diet scenarios in three different future contexts.

We differentiate between a future based on ongoing global developments (REF0), a future with high challenges for sustainable global food and nutrition security (REF-), and a future with comparably low challenges for sustainable food and nutrition security at global scale (REF+) (see chapter 2 and D10.2 for more detail). Aiming at a comprehensive assessment of sustainable food and nutrition security in the EU, we apply the SUSFANS toolbox.

The interplay and data exchange between the three macroeconomic models CAPRI, GLOBIOM and MAGNET with the micro dietary model SHARP is shown in Figure 11. In the current application there is only a top-down link between MAGNET and the FoodEx intake data which feed the SHARP model, due to several challenges linked to the definition of food consumption in each of the models.

The two agricultural sector models (CAPRI and GLOBIOM) model household demand through primary equivalents, not explicitly addressing the processing of food (which forms a large part of diets in high income countries). Processing may affect the nutritional profile of diets considerably, for example through the addition of salt when preserving vegetables or nitrates when processing meat. MAGNET, being an economy wide model does capture the processing of food but in a very aggregate manner. While having dedicated sectors for meat processing, all other processed foods are lumped together in a single processed food sector. In contrast, the intake surveys register food items at a high level of detail. This implies that the best possible match of products was between the 17 food products (including processed foods) of MAGNET to the 955 FoodEx2 products used by SHARP. With data on food item prices or incomes lacking from the intake surveys we have no data to adjust intake data at FoodEx2 level beyond this coarse mapping.

A second issue in the mapping is the sizeable gap between the definition of food consumption in the macro models and those used by intake surveys and thus SHARP. The macro models refer to food demand based on average food purchases (or food availability) covering actual intake but also food waste by households and losses from retail. While there is a deduction of food losses, inedible parts of foods and approximate food waste shares, a substantial divergence between the available food and actual intake of food (which has its own biases, for example in the extent to which out-of-home consumption is covered).

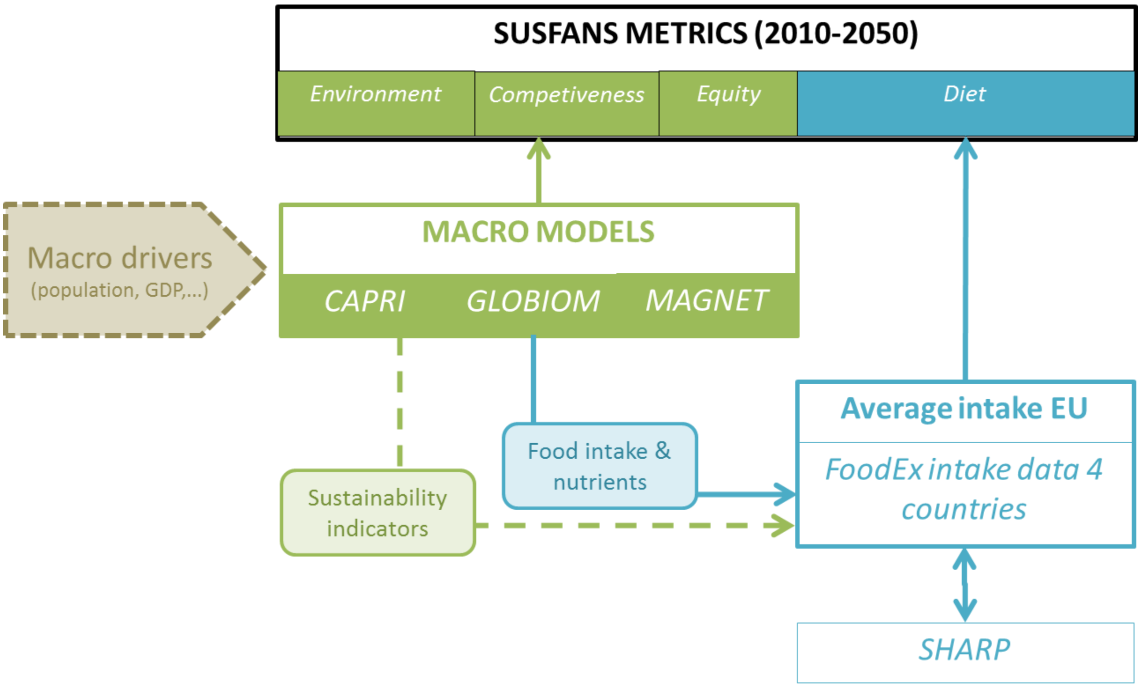


*Figure 11. Methodology for deriving SUSFANS metrics from the toolbox.*

In terms of assessing sustainability and profitability, the SHARP database (Mertens et al., 2017) addresses the former by fixed coefficients that do not capture food system changes in response to macro level diet shifts and has no data on profitability.

Given these considerations we rely on the macro models for changes in sustainability and profitability, while referring to the SHARP database for diet metrics. The macro models deliver several indicators on changes in diet and nutrition, but from availability data with all limitations discussed above. The SHARP database currently only covers four of the 28 EU regions and has no coverage outside of the EU. The macro models cover, however imperfectly, all EU member states as well as the rest of the world. We therefore deem it worthwhile to compare the macro model diet metrics to those from SHARP to compare similarities and differences in these results and assess the robustness of the nutritional outcomes.

Among the macro drivers, population and GDP developments have the most direct impact on consumer decisions simulated in the macro models (Figure 12). These drivers have a direct effect on consumer purchases via price and income elasticities representing consumer pereferences. Since high taxes will be imposed to achieve substantial changes in food purchases, these may exceed the validity range of price elasticities in the model. Therefore, resulting tax levels should be interpreted with caution focusing rather on the order of magnitude than the exact values. With respect to agricultural food supply, population growth and GDP affect per capita food availability and accessibility.

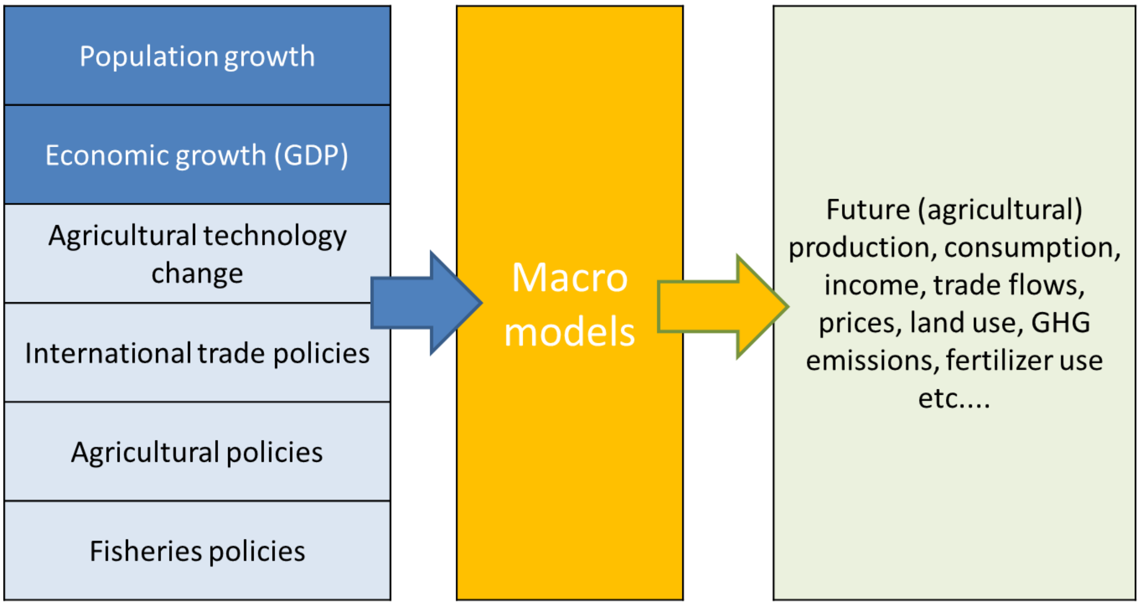


*Figure 12. Various drivers influence the context in which the diet scenarios operate.*

Further important drivers in the contextual scenarios underlying the diet shifts are technological change in agriculture, trade policies, agricultural and fisheries policies. For the sake of interpretability of the results, in the reference scenarios referred to in the study at hand agricultural and fisheries policies are not considered. An in-depth analysis of the drivers is already provided in D10.2 and D10.3 and summarized in Sections 2 and 3 above. Here we present how the diet scenarios change the results of the contextual scenarios, with particular focus on the "business-as-usual" scenario (REF0).

## Results

Without policy interventions directed at consumer purchases and dietary habits, model simulations indicate that EU diets will neither become healthier nor more sustainable, as discussed in chapter 2 and 3. In order to assess the impacts of price-based interventions targeted at consumer purchases, we simulate 15 diet scenarios (the scenario set-up is described in Table 3 and Table 4).

In the following we compare resulting tax/ subsidy levels and impacts on nutrition, environmental and competitiveness indicators for 2030 and 2050 for the following scenarios:

- The average EU diet pattern is stepwise aligned to recommendations regarding the intake of certain food groups while calories remain unrestricted (**Food pattern**)
- The EU average calorie intake is kept at 2010 intake levels in order to simulate the effects of dietary variations in response to income and price changes in an isocaloric scenario (**Fixed calories**)
- The average EU diet pattern is stepwise aligned to recommendations regarding the intake of certain food groups while calories are fixed at 2010 levels (**Food pattern & fixed calories**)
- The EU average calorie intake is reduced to meet intake levels in line with reaching a BMI of under 25 to reduce the occurrences of overweight and obesity in the population (**BMI under 25**)
- Combining the food pattern shift and the calorie reduction scenario (**Food pattern & BMI under 25**).

We furthermore compare differences in the results between

- Models
- EU member states (total, four SUSFANS case study countries), World
- Reference scenario settings (REF0, REF+, REF-).

## *Food price and expenditure changes*

The dietary changes are technically implemented in the models in form of a subsidy or tax, depending upon whether a purchase increase or decrease is aimed at. In some cases, notably the increase in fruit and vegetable consumption in MAGNET, the targeted increase could not be achieved through a subsidy and a taste shifter has been employed instead.[1]

[1] The technical reason is a low price elasticity for fruit and vegetables in the EU region (around 0.03 for lower income regions like Czech Republic to as low as 0.003 for the Netherlands). These elasticities are based on Reimer and Hertel (2004) estimating an implicit, directly additive demand system (AIDADS) first using cross-country data on consumer expenditures from the International Comparison Project (ICP) and then using GTAP data. While these appear low compared to other sources there is no immediate direction in which to change the elasticities without also

Figure 13 shows the changes in total EU household food expenditures from 2010 (normalized at 1) to 2050. The three contextual scenarios already show quite a spread with declining EU food expenditures in REF- while in both other contextual scenarios (REF0 and REF+) EU food expenditures increase in a quite similar way. The diet scenarios operate in a REF0 context and show a further increase in EU household food expenditures through the employment of taxes (and a taste shifter to achieve the fruit and vegetable target). The BMI under 25 scenario operates through a tax on calories, with the effective tax by product varying according to calorie content. Not targeting specific food groups, it allows most flexibility to change the diet pattern hence requiring the lowest price increase from all diet scenarios. Impacts from the diet pattern with and without an energy target are almost indistinguishable. Achieving two changes, diet pattern and energy reduction, is clearly most taxing for the model as indicated by the strongest increase in EU food expenditures.

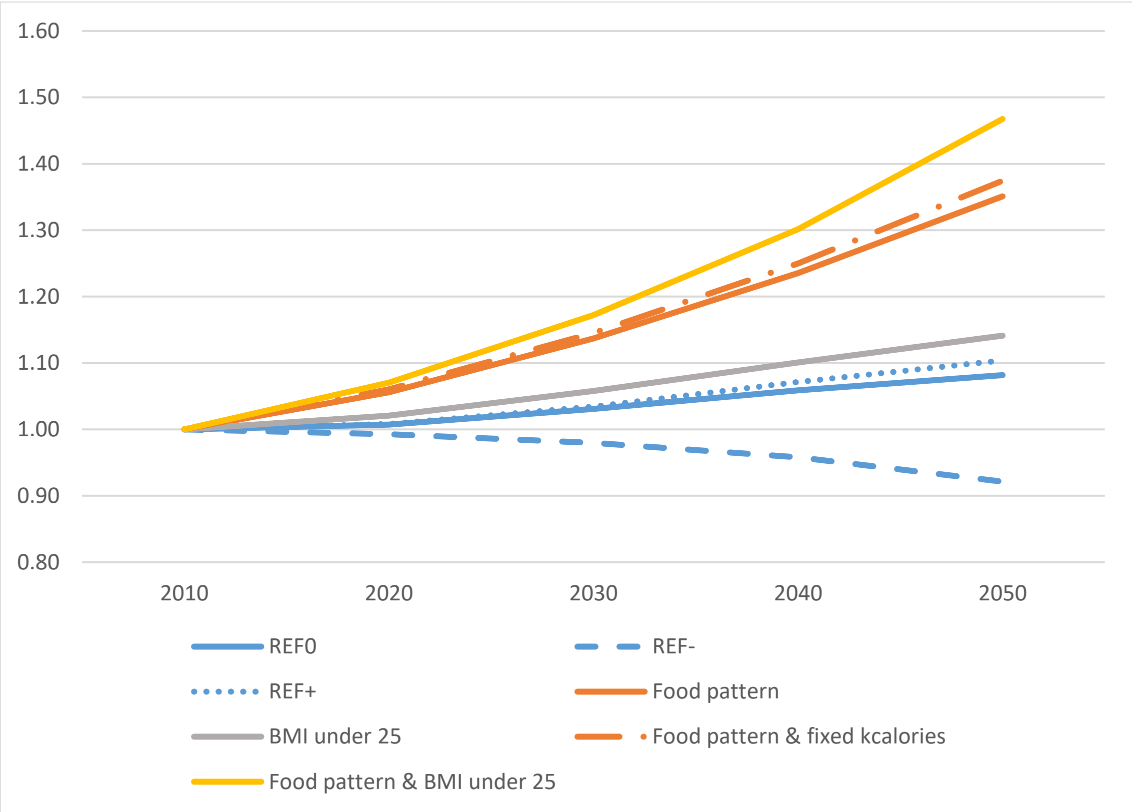


*Figure 13. Total EU household food expenditures by scenario and time period (2010 = 1), MAGNET results.*

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considering the flow of fruit and vegetables through other food (which has a high elasticity of up to 0.75). Ideally, we would separate the flow of vegetables from other processed foods to allow a targeted intervention, but this is beyond the scope of the current study.

Rising food expenditures and especially the notion of a food tax raises concerns with respect to the affordability of food. Food costs, however, need to be evaluated in relation to overall household expenditures. Furthermore, the diet shifts are not instantaneous but implemented over several decades in which the overall economic context changes as well. The first thing to note is that food is only a minor part (11.3%) in the total EU household budget, as one would expect in a high-income setting like Europe. As shown in Figure 14, this share of food expenditure in total EU household expenditures is projected to decrease further, even with implementation of taxes across all diet scenarios. In the absence of any diet specific interventions (REF0) the share of food in total expenditures is projected to halve by 2050 (6.7%). Enforcing the shift towards the recommended diet pattern increases food expenditures (Figure 13) as expected, but an overall increase in household expenditures (linked to the projected macro-economic growth) strongly mutes the impact in terms of the share of household budget needed for food which remains below the 2010 expenditure share (7.0 to 8.8 % by 2050). From a policy point of view, these two figures show the importance of accounting for the context in which the impact of the taxes is considered - in terms of food expenditures or the share of food in total expenditures, and in terms of expected income developments which can actually help soften the impact on actual household budgets compared to the current situation.

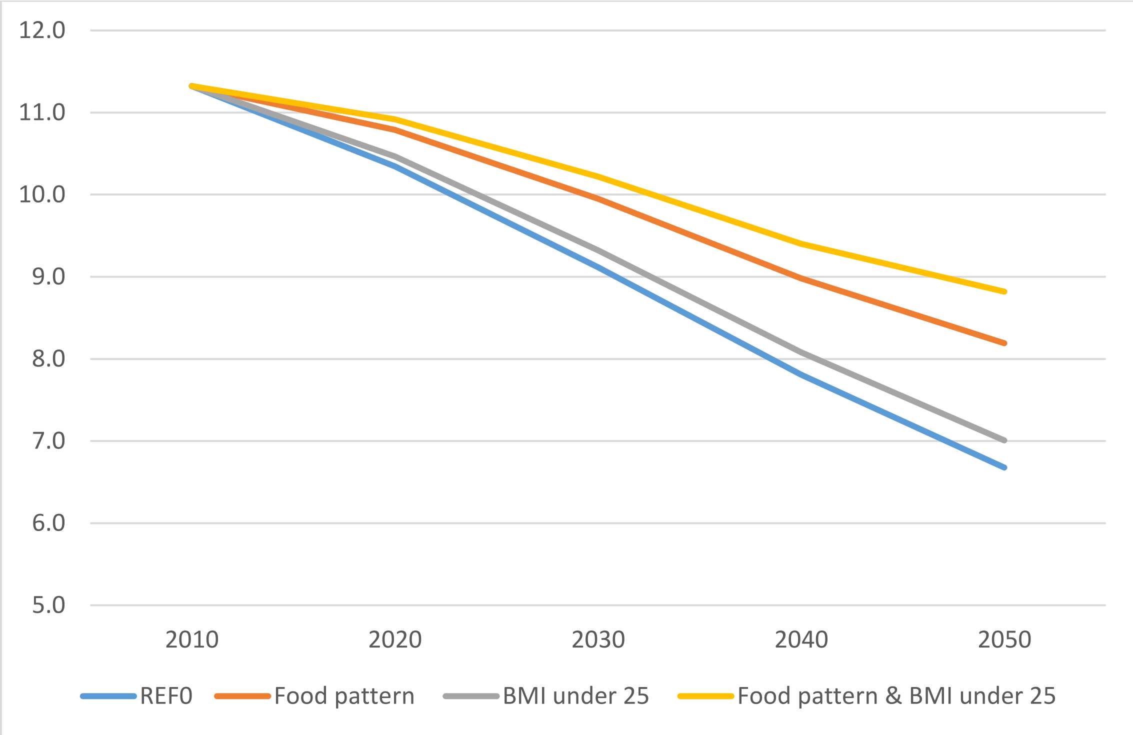



*Figure 14. Share of food in total household expenditure based on MAGNET results.*

It should be noted that the model relies on a single representative consumer for each country or region and thus cannot address the food accessibility of poor subgroups in the population. Additional assessments using micro level data would be needed to address these distributional issues, while also taking differences in diets and thus exposure to diet-related health risks into account. Unfortunately, the food intake surveys only register age, sex and education level but hold no further data on the socio-economic status or income level to address these distributional questions.

In Table 5 consumer price changes relative to 2010 are exemplified for different scenarios for EU-28 average beef prices based on MAGNET results. While beef consumer prices decrease slightly in all reference scenarios (up to -12% in 2050), they strongly increase in any of the diet scenarios until 2050 (+270 to +275%). These strong price increases incorporate the tax needed to enforce the envisaged dietary targets. Since the recommended diet patterns (reduction in average meat consumption) contradict to the consumption trends in the reference scenarios (increased meat consumption) the necessary trend reversal requires the observed strong changes.

*Table 5: Consumer price change (%) relative to 2010 for beef based on MAGNET results, diet scenarios based on REF0.*

| | 2030 | 2050 |
|---|---|---|
| REF0 | -3 | -9 |
| REF- | -2 | -5 |
| REF+ | -4 | -12 |
| | | |
| Food pattern | 74 | 270 |
| BMI under 25 | 75 | 275 |
| Food pattern & fixed kcalories | 74 | 271 |
| Food pattern & BMI under 25 | 75 | 275 |

In comparison, Springmann et al. (2017) estimate a 26.8% increase in beef prices by 2020 for high income countries in order to internalize external costs of the respective greenhouse gas emissions. The price changes that we estimate for 2030 are three times higher than the proposed shift in the analysis by Springmann et al. (2017). However, their analysis differs in various ways. First, the emissions to be reduced refer to domestic production whereas the consumption shock implemented in the study at hand also targets imported products. Second, high income countries are comparably less affected by the emission tax since these countries produce more emission efficiently (low tax rates in the "Springmann set-up"), whereas beef consumption levels are especially high in these countries (high tax rates in our set-up to target a healthy meat consumption level by region).

### *Impacts on sustainable food and nutrition security*

The price changes discussed in the previous section are the most direct impacts of the food taxes introduced. These price changes result from the enforcement of certain food demand shifts in the models in order to bring the average EU diet closer to dietary and nutrition recommendations. Besides this immediate impact on EU food and nutrition security, further effects on sustainability indicators arise from such an intervention.

In Figure 15 an overview of impacts on selected SUSFANS metrics is presented for the EU-28 in 2050 and also on a global level despite a few indicators that are only covered at a European scale. Intuitively the effects are smaller on a global scale, since the EU population makes up only a small share of the world population and spill-over and trade effects are limited in this scenario setting. Effect sizes and partly even directions vary between models, however, not all indicators are provided by several models. The strongest impacts are found for the “people” dimension capturing indicators for social sustainability and health explicitly. In the following subsection, a closer look is taken at the impacts related to the different sustainability dimensions.

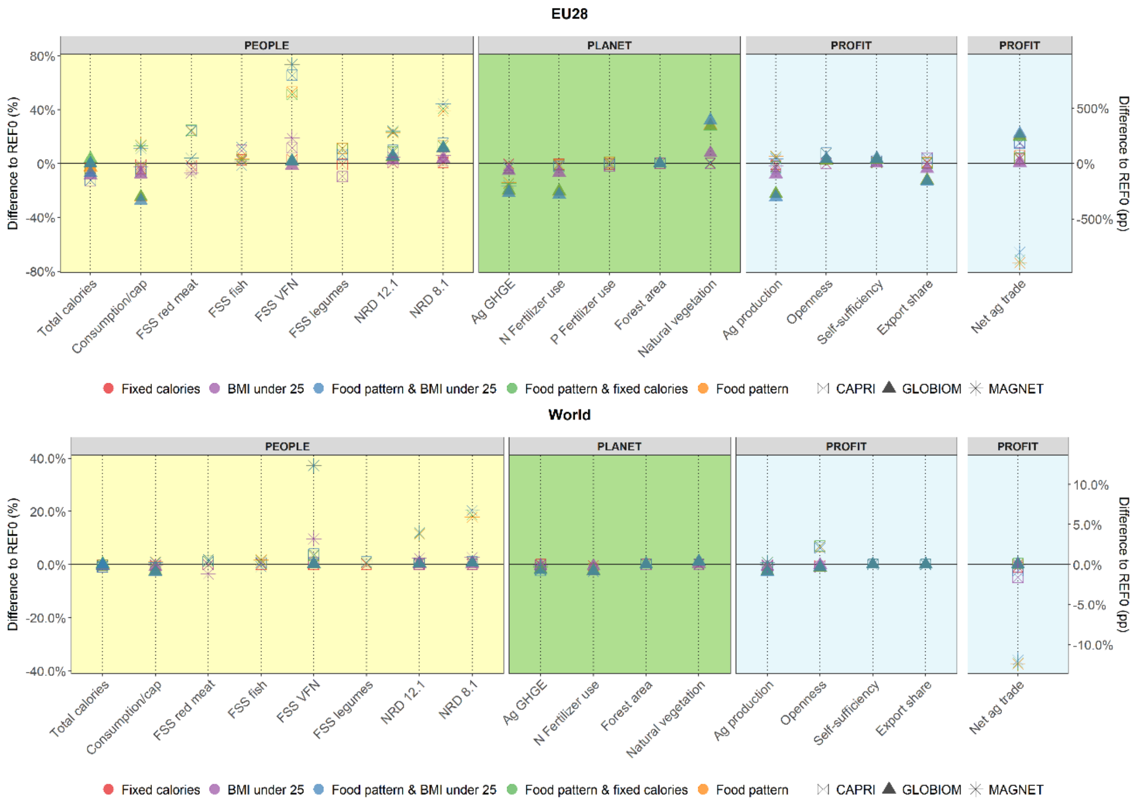



*Figure 15. Development of sustainability indicators for people, planet, and profit at EU and global level by 2050 compared to REF0 across diet scenarios. Total calories – total calorie consumption per capita, Consumption/cap – per capita food consumption, FSS red meat –red meat consumption, FSS – fish consumption, FSS VFN – fruits, vegetables and nuts consumption, FSS legumes – legumes consumption, NRD 12.1 nutrient rich dietary score for 12 qualifying and 1 disqualifying micro-nutrients, NRD8.1 - nutrient rich dietary score for 8 qualifying and 1 disqualifying micro-nutrients, Ag GHG – agricultural GHG emissions, N fertilizer use – nitrogen fertilizer use, Forest area – total forest area, natural vegetation – other natural vegetation area, Ag production – total agricultural production, Openness – ratio of export plus imports in total agricultural production, Self-sufficiency – agricultural self-sufficiency ratio, Export share – agricultural exports in total production, Net ag trade – agricultural net trade.*

## Planet

Impacts on environmental sustainability, the “planet dimension”, are assessed with respect to influences from agricultural production only. Thus, the displayed changes in agricultural greenhouse gas emissions (Ag GHGE) in Figure 15 reflect changes in crop and livestock production. Food related GHGE arising further along the food chain in transportation, processing, storage, or preparation are not covered here.

At EU-28 scale, agricultural greenhouse gas emissions are especially reduced when the food pattern is adapted but remain nearly unchanged when only calorie intake is targeted compared to the 2050 reference scenario (REF0). The comparably higher reduction of rather emission intensive products, like animal products, in the "food pattern"-scenarios explains this difference. While forest area remains nearly unchanged as consequences of all diet scenarios, natural vegetation area increases according to GLOBIOM results and again more strongly if the dietary pattern shift occurs. On a global level, the described trend for the available environmental indicators remains, however, to a much smaller extent of only up to 2%.

### *People*

The "people" dimension is most directly affected by the diet shifts. Total calorie availability presented by the macro models remains nearly unaffected by any of the diet shifts (see Figure 15 above). Since this measure is however based on calorie supply, the missing effect could represent a limited impact on domestic production and imports. Regarding per capita food consumption, the resulting scenario effects are more dispersed and vary between the models (see Figure 15 above). Scenarios including a shift of the food pattern show stronger effects than those in which just the calorie levels are changed. Interestingly, consumption increases are predicted by MAGNET whereas per capita consumption decreases are implied by the GLOBIOM results for the combined scenarios. Since the same relative changes are underlying each, further investigation regarding the supply and demand reactions in the models towards these shocks is needed. These reactions are likely to differ due to the household income feedback effects which are, scope of the demand system which in MAGNET also accounts for price and income effects of non-food items and the definition of food commodities which affect the technical implementation of an identical shock (see also the discussion on the flow of for example fruit and vegetables through processed food in MAGNET).

In Figure 16 below, a close up of the SUSFANS diet and nutrient indicators is provided. Despite the fact that the models deliver different versions of these indicators because of differences in model coverage, it can be seen, that the impact sizes differ much stronger between scenarios according to the macro models compared to the SHARP results derived based on MAGNET output (in the following referred to as SHARP-MAGNET). The food-based summary score (FSS) improves in nearly all scenarios that include the food pattern shift. If only the calorie intake is targeted (Fixed calories, BMI under 25) the FSS remains often unchanged. The strongest increases are found for the FSS for the aggregate of vegetables, fruits and nuts (VFN) showing strong differences between diet scenarios. All displayed nutrient rich diet indicators (NRD) improve as a result of the diet scenarios across all models. The food pattern shifts overlay the calorie changes, which themselves affect the NRD values only slightly.

Nutrition and dietary indicators based on macro-economic model outputs however need to be interpreted with caution. Due to their limited level of food product details, the high aggregation to average national and even EU consumers, and their strong reliance on food availability (in contrast to food intake) data, nutrition indicators calculated based on direct macro-model output can only show approximate and assumptive effects. The displayed nutrition rich diet indicators NRD12.1 and NRD8.1 must be seen as an approximation of the established NRD15.3 (D9.3) based on the nutrients available for the direct mapping to macro model outputs (with saturated fats being the only nutrient to limit and vitamin E D, and B12 missing in the row of nutrients to encourage).

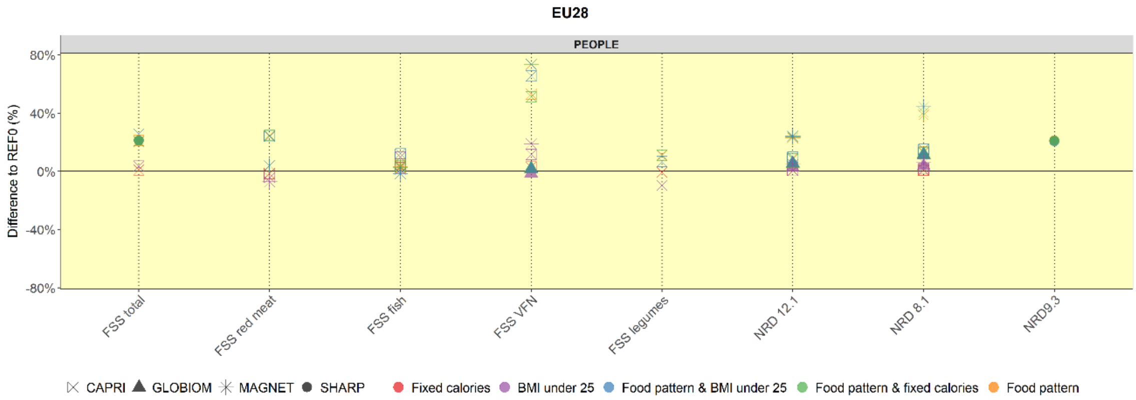



*Figure 16. Development of dietary and nutrition indicators at EU level by 2050 compared to REF0 across diet scenarios, SHARP representing SHARP-MAGNET. FSS total – total calorie consumption per capita, FSS red meat –red meat consumption, FSS – fish consumption, FSS VFN – fruits, vegetables and nuts consumption, FSS legumes – legumes consumption, NRD 12.1 nutrient rich dietary score for 12 qualifying and 1 disqualifying micro-nutrients, NRD8.1 - nutrient rich dietary score for 8 qualifying and 1 disqualifying micro-nutrients, NRD9.3 - nutrient rich dietary score for 9 qualifying and 3 disqualifying micro-nutrients.*

In Figure 16 just one SHARP-MAGNET value is shown for the respective indicators (not normalized to 0-1) across all scenarios, since the percentage changes are comparably limited. The nutrition indicators presented in the following are based on combining food intake survey data for four EU countries (in FoodEx2 classification and which are used by the SHARP model) with projected changes in food purchases from MAGNET. This set-up is a rather rough approximation of the changes in diets due to the different food details in MAGNET and SHARP. Effectively we map 17 MAGNET sectors to 955 FoodEx2 products. Lacking sufficient socio-economic information at the individual level in SHARP we also have to apply the same change in purchases to all population subgroups. SHARP-MAGNET results representing EU-28 intakes are derived based on results for the SUSFANS case study countries, Denmark, France, Italy and Czech Republic.

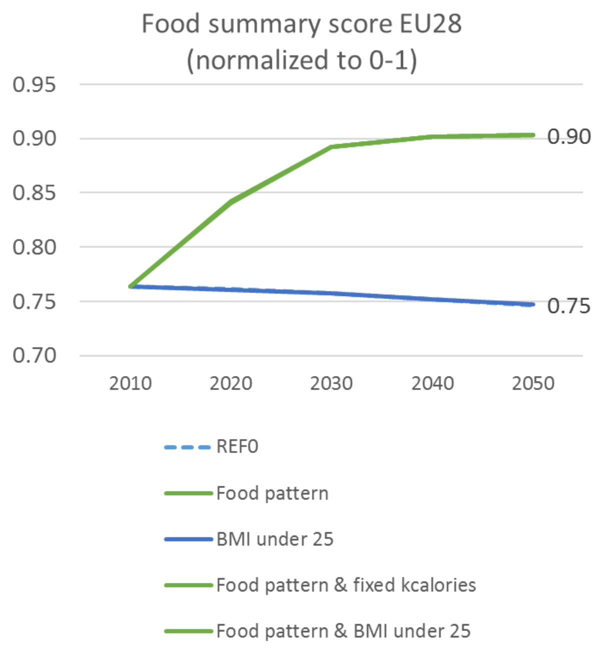



*Figure 17. Food summary score (normalized to 0-1) based on SHARP-MAGNET output.*

In Figure 17 the food summary score is presented for the REF0 scenario and four diet scenarios. The Food summary score remains unaffected when enforcing only the calorie target (BMI under 25) in comparison to the REF0 scenario. All diet scenarios that include a change in the food pattern score perform higher than the REF0 scenario on this indicator. Fixing or reducing the calories on top of this does not create an additional improvement for the food summary score at EU-28 level. Furthermore, while we observe basically no improvement (and even a small deterioration) in the food summary score in the reference scenario, the score considerably improves, as expected, after changing the food pattern.

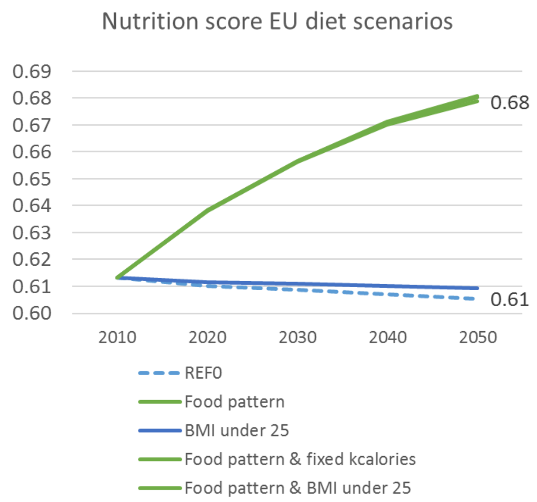



*Figure 18. Nutrition score NRD9.3 based on SHARP-MAGNET output.*

The nutrition score moves in a similar direction as the food summary score. The calorie reduction improves the nutrition score only marginally compared to the reference scenario (REF0) which remains basically unchanged compared to 2010 score levels. In contrast to that, the nutrition score (Figure 18) is visibly improved in all scenarios that include a change in food patterns in line with dietary recommendations. This emphasizes that the food pattern change dominates with respect to nutrition performance. Nevertheless, the absolute improvement is rather small with only 0.07 nutrition score points in comparison to 2010 and the reference scenario in 2050.

As shown in Mertens et al. 2018 (also see Mertens et al. 2017 (D7.1)), there is a considerable divergence with respect to dietary patterns across EU member states. In Figure 19 we show the diet and nutrition indicators for the two case study countries Czech Republic and France. Despite similar tendencies in the directions how dietary indicators are affected, the impact sizes are in tendency larger for Czech Republic.


*Figure 19. Development of dietary and nutrition indicators at national average level for Czech Republic and France by 2050 compared to REF0 across diet scenarios, SHARP representing SHARP-MAGNET. FSS total – total calorie consumption per capita, FSS red meat –red meat consumption, FSS – fish consumption, FSS VFN – fruits, vegetables and nuts consumption, FSS legumes – legumes consumption, NRD 12.1 nutrient rich dietary score for 12 qualifying and 1 disqualifying micro-nutrients, NRD8.1 - nutrient rich dietary score for 8 qualifying and 1 disqualifying micro-nutrients, NRD9.3 - nutrient rich dietary score for 9 qualifying and 3 disqualifying micro-nutrients.*

### Profits

Economic sustainability is summarized in the “profit” dimension. The drop in demand arising from the implemented diet shifts results in a reduction in agricultural production and net agricultural trade on EU level for most diet scenarios based on CAPRI and GLOBIOM results (Figure 20). While CAPRI and GLOBIOM suggest reductions of agricultural imports into the EU due to most diet shocks, by MAGNET a large increase of almost 40% in imports compared to the reference scenario (REF0) is projected. For agricultural exports, differences between models vary less strongly but are still opposing.

In addition, we assess three further metrics for competitiveness: Openness, self-sufficiency and export share. The calculation of these metrics is described in detail in SUSFANS D1.3. These profit indicators remain nearly unchanged at EU level compared to the REF0 scenario in 2050.

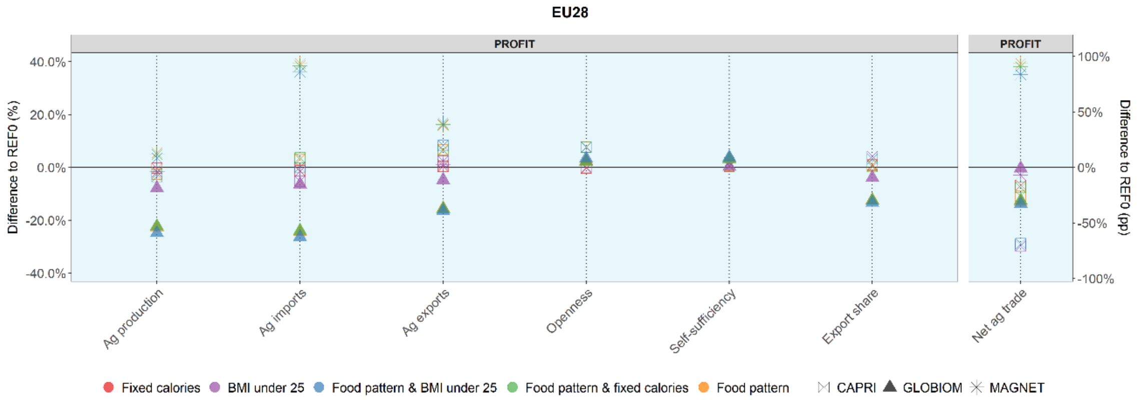



*Figure 20. Development of competitiveness indicators at EU level by 2050 compared to REF0 across diet scenarios. Ag production – total agricultural production, Ag imports – agricultural imports, Ag exports – agricultural exports, Openness – ratio of export plus imports in total agricultural production, Self-sufficiency – agricultural self-sufficiency ratio, Export share – agricultural exports in total production, Net ag trade – agricultural net trade.*

Since intra-EU trade is quite relevant for the trade of agricultural products of EU member states, below an indication of trade effects is given for two SUSFANS case study countries, France and Czech Republic.

In the member state comparison, stronger differences between diet scenarios become apparent. Competitiveness indicators show some variation and even antagonism when comparing the two EU member states. Based on MAGNET results, agricultural imports increased considerably stronger in France than in Czech Republic. GLOBIOM results support improvements in openness especially in the food pattern scenarios for France, while these show deteriorations for Czech Republic compared to REF0 in 2050. Also the values for net agricultural trade are partly opposing when comparing them for these two countries, even across models.

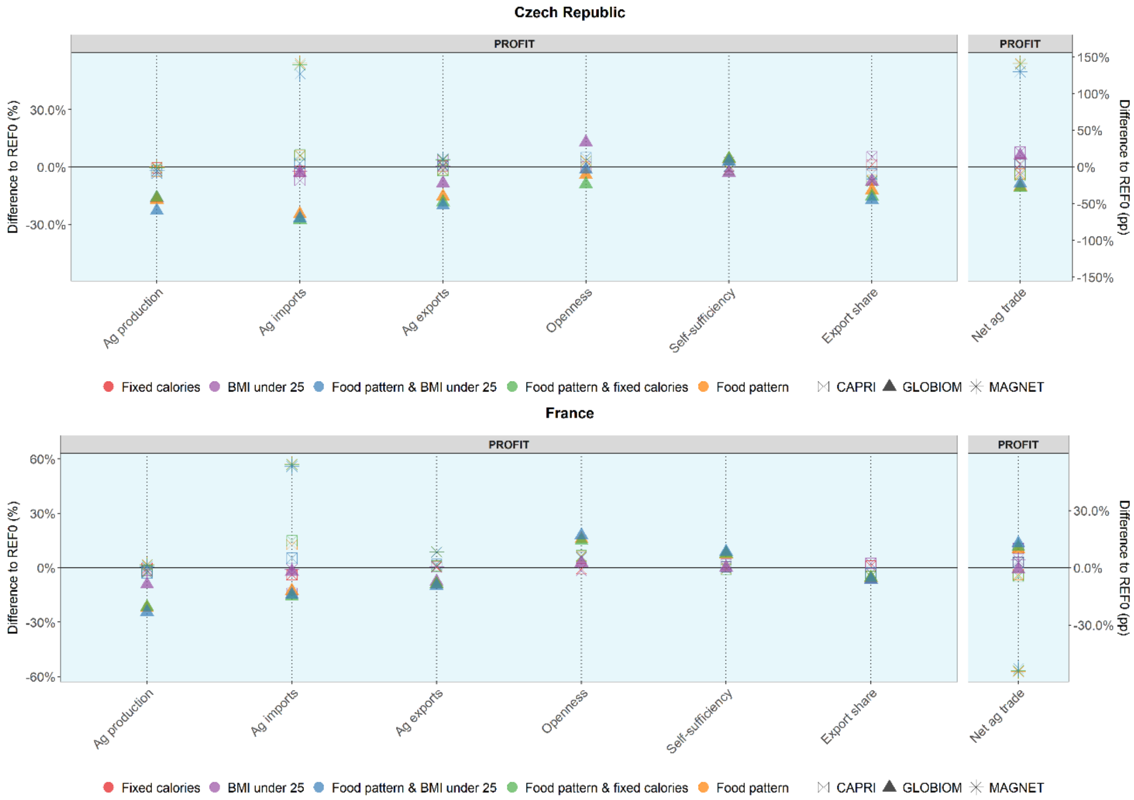



*Figure 21. Development of competitiveness indicators at national average level for Czech Republic and France by 2050 compared to REF0 across diet scenarios. Ag production – total agricultural production, Ag imports – agricultural imports, Ag exports – agricultural exports, Openness – ratio of export plus imports in total agricultural production, Self-sufficiency – agricultural self-sufficiency ratio, Export share – agricultural exports in total production, Net ag trade – agricultural net trade.*

### *Impacts vary by macro drivers*

So far, scenario related impacts on SUSFANS indicators were assessed in contrast to the REF0 scenario, the business-as-usual future development.

In Figure 22 the REF0 developments are contrasted to the scenario results, in which the REF+ and the REF- contextual scenarios are underlying the diet scenarios. Size and direction of the impacts are very similar and not strongly influenced by whether low challenges for EU food and nutrition security are assumed (REF+) or whether these challenges are expected to be high (REF-).

Only one indicator reveals opposing effects across all models, which is the net agricultural trade. While net trade increases over REF0 in almost all diet scenarios if REF+ is underlying, it decreases for all diet scenarios based on REF-. The contextual scenarios overlay the diet scenarios, which explains the only minor differences in the other SUSFANS metrics when comparing the upper and the lower diagram in Figure 22.

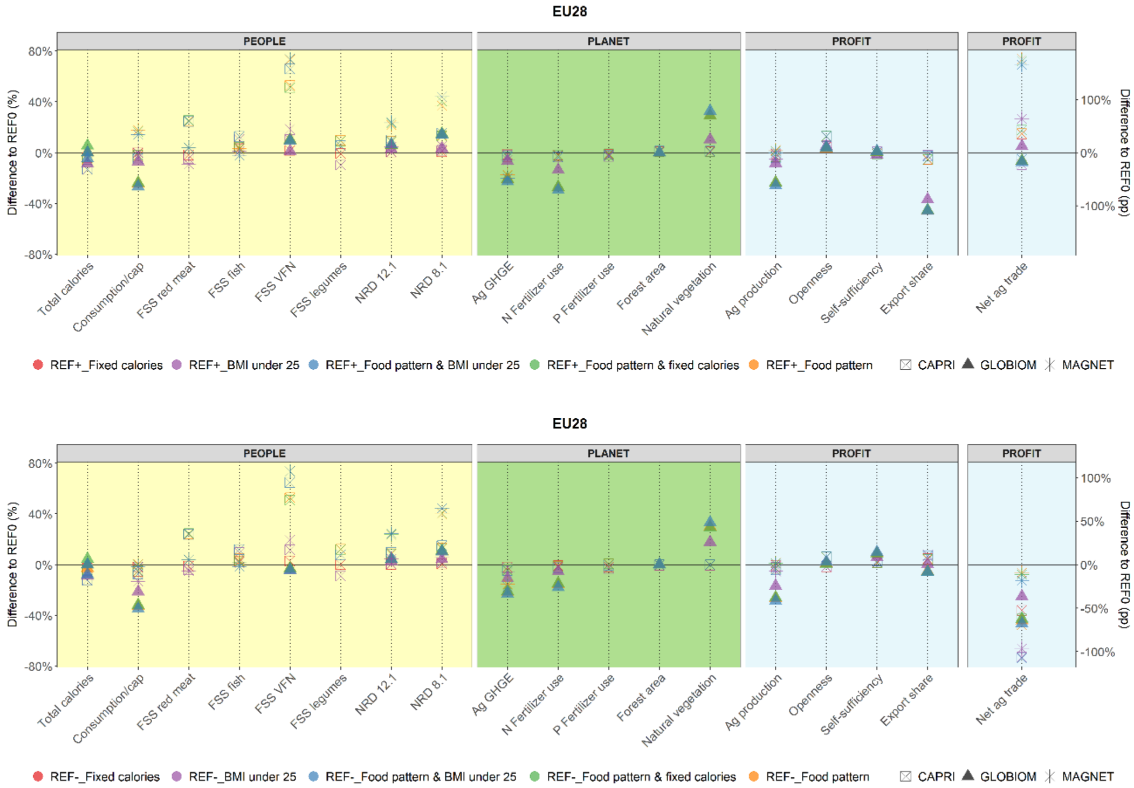



*Figure 22. Development of sustainability indicators for people, planet, and profit at EU and global level by 2050 compared to REF0 across diet scenarios and contextual scenarios. Total calories – total calorie consumption per capita, Consumption/cap – per capita food consumption, FSS red meat –red meat consumption, FSS – fish consumption, FSS VFN – fruits, vegetables and nuts consumption, FSS legumes – legumes consumption, NRD 12.1 nutrient rich dietary score for 12 qualifying and 1 disqualifying micro-nutrients, NRD8.1 - nutrient rich dietary score for 8 qualifying and 1 disqualifying micro-nutrients, Ag GHG – agricultural GHG emissions, N fertilizer use – nitrogen fertilizer use, Forest area – total forest area, natural vegetation – other natural vegetation area, Ag production – total agricultural production, Openness – ratio of export plus imports in total agricultural production, Self-sufficiency – agricultural self-sufficiency ratio, Export share – agricultural exports in total production, Net ag trade – agricultural net trade.*

### Impacts vary between regions

As already indicated in the course of the diet and profit indicator assessments, when averaging across the EU differences based on regional food cultures, agricultural production specializations and established trade relations can get lost. In Figure 23 below we compare impacts on SUSFANS indicators due to the various diet scenarios based on REF0 in 2050 for the four case study countries. Despite similar trends, some differences become apparent. Diet and nutrition indicators show a similar tendency across the four countries, however, being less strong for Italy. CAPRI and MAGNET suggest strong improvements in the food-based summary score related to vegetable, fruit and nut intake (VFN) for Czech Republic. In contrast to the results for the other three countries, profit-related indicators react only slightly for Czech Republic as a result of different diet scenarios.

Agricultural GHGE are reduced stronger in Denmark than in the other assessed countries, whereas environmental sustainability indicators show nearly no changes for Czech Republic. Natural vegetation area is increased strongly for Denmark relative to the REF0 scenario in 2050. These effects are lower for the other countries. While N fertilizer use is reduced considerably for Denmark, P fertilizer use is suggested to increase based on CAPRI results due to the diet shifts.

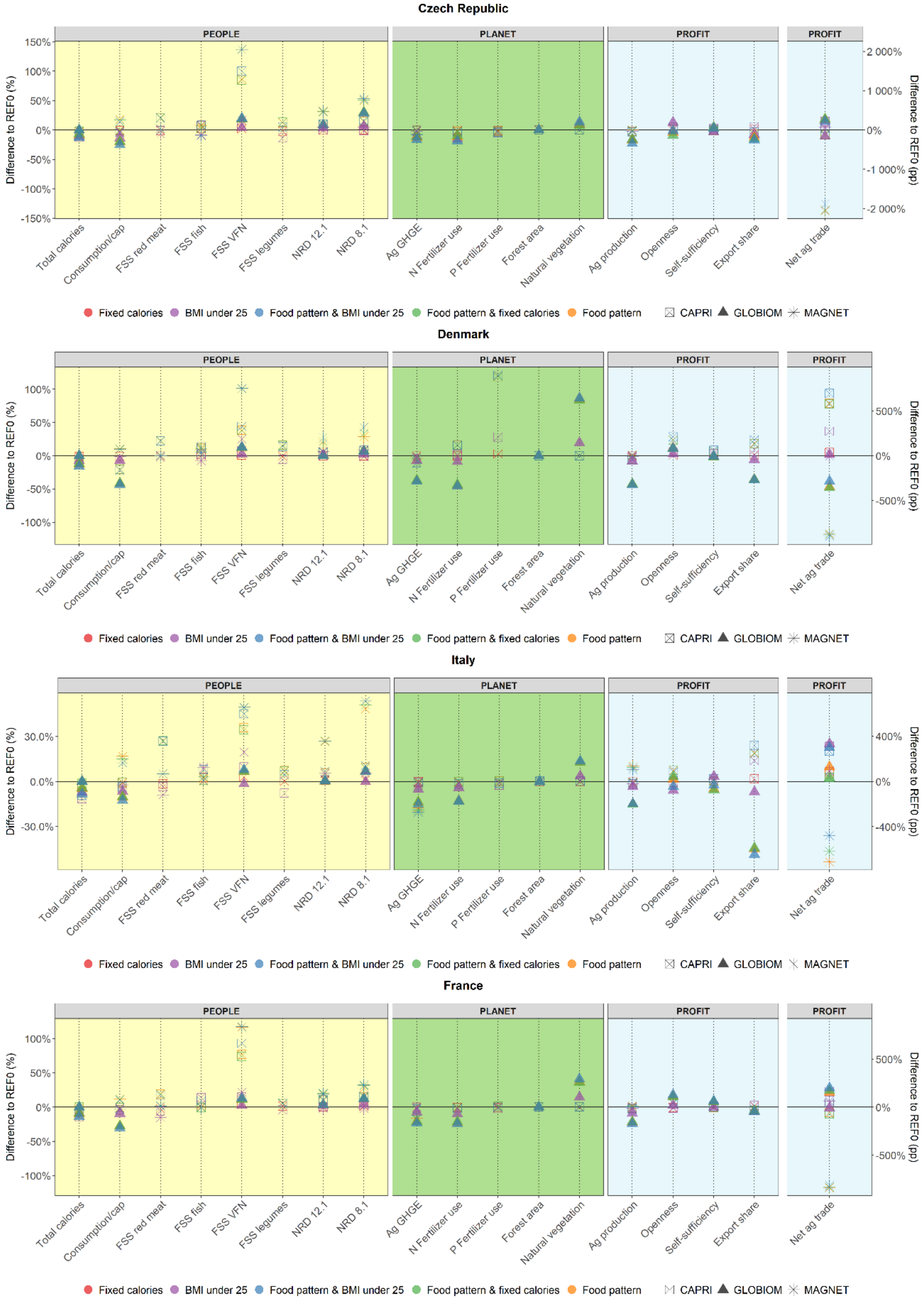



*Figure 23. Development of sustainability indicators for people, planet, and profit for the four SUSFANS case study countries Czech Republic, Denmark, Italy and France by 2050 compared to REF0 across diet scenarios. Total calories – total calorie consumption per capita, Consumption/cap – per capita food consumption, FSS red meat –red meat consumption, FSS – fish consumption, FSS VFN – fruits, vegetables and nuts consumption, FSS*

*legumes – legumes consumption, NRD 12.1 nutrient rich dietary score for 12 qualifying and 1 disqualifying micro-nutrients, NRD8.1 - nutrient rich dietary score for 8 qualifying and 1 disqualifying micro-nutrients, Ag GHG – agricultural GHG emissions, N fertilizer use – nitrogen fertilizer use, Forest area – total forest area, natural vegetation – other natural vegetation area, Ag production – total agricultural production, Openness – ratio of export plus imports in total agricultural production, Self-sufficiency – agricultural self-sufficiency ratio, Export share – agricultural exports in total production, Net ag trade – agricultural net trade.*

Regional differences become apparent not only at member state level. In Figure 24 below the relative changes in N surplus per hectare compared to the reference scenario (REF0) in 2050 based on CAPRI results are displayed at NUTS2 level. Despite the fact that N surpluses vary by region already in the reference scenario, also the responses to the diet scenarios differ. While the changes in N surpluses are rather moderate (mostly within -/+ 3%) a few regions show extreme N surplus reductions. Across regions however, strong N surplus reductions are nearly absent when only the calorie levels are targeted while these become apparent once the food pattern is changed in line with dietary recommendations. Keeping total calorie intake fixed at 2010 levels shows a slight increase in N surplus in many regions. In some of these regions, beef meat production increases and other livestock production activities remain nearly unchanged in comparison to REF0 in 2050 which are strongly reduced as consequence of food pattern changes.

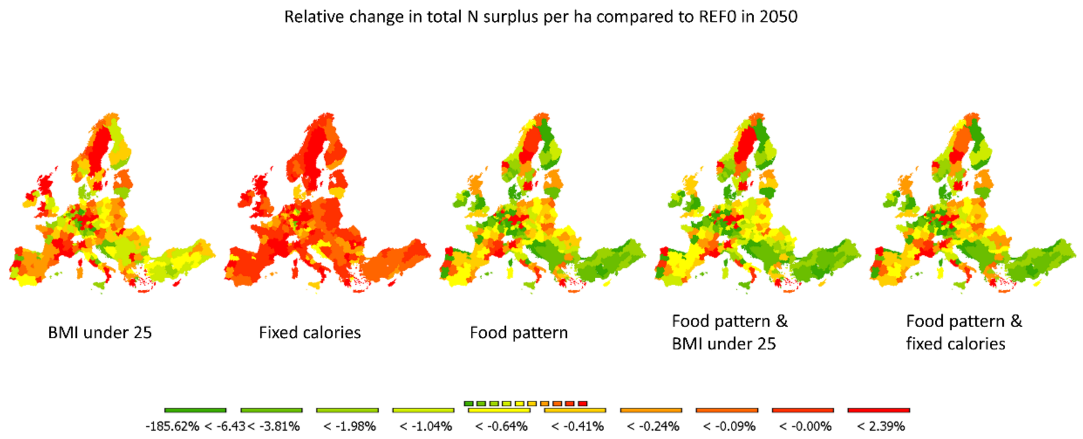



*Figure 24. Relative change in total N surplus per ha compared to REF0 in 2050 shown at NUTS2 level, CAPRI results.*

## Discussion

Our demand side analysis reveals that diet shifts based on food pattern changes show impacts that outperform the effects from calorie shifts. Also in the combined scenarios, the type of total calorie restriction does not add much of a difference to the impact sizes. Effects at global scale are minor compared to EU level or EU member state level impacts, which was expected as the diet restrictions were only implemented for the EU population. Dietary and nutrition effects are stronger compared to changes in other sustainability dimensions, being directly addressed with the scenario setting. Nevertheless, these solely demand side interventions result in visible environmental improvements or, at least in no deteriorations. EU agricultural production decreases slightly due to the drop in demand. Also trade opportunities to compensate this are limited at the aggregated EU level. At member state level however, the case study country comparison shows stronger and varying effects on imports and exports. The comparison between EU member states reveals that impact sizes differ while effect directions are in line with each other.

# EFFICIENT POLICY SOLUTIONS

The SUSFANS modelling toolbox was applied in order to test the effects on sustainable EU food and nutrition security of i) global macro drivers, ii) supply-side policies, and iii) demand-side policies.

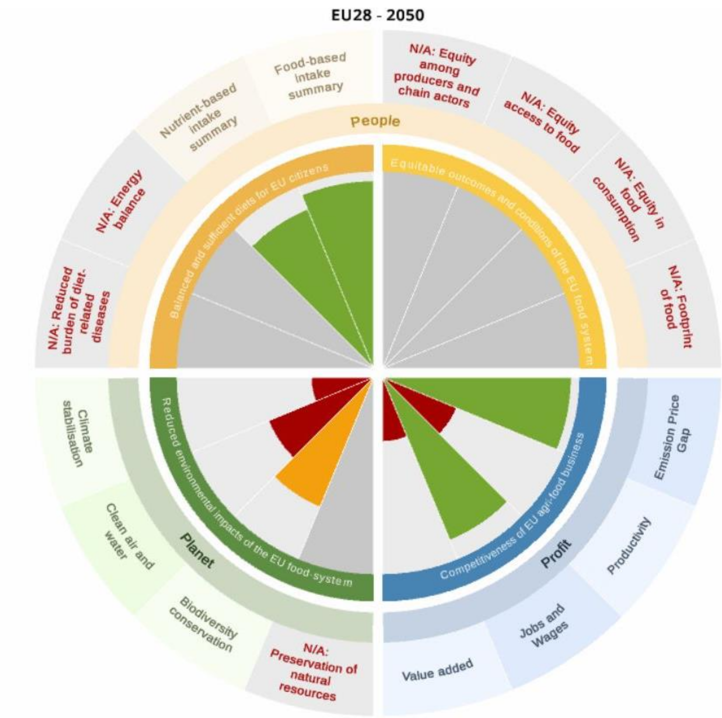
This assessment has shown that global developments of population and GDP growth, trade relations and technological progress will influence EU agricultural net trade but not considerably contribute to improvements in EU average diets nor to sustainable food systems. Future socio-economic developments will rather increase the need for policy interventions in the EU in order to reach sustainable food and nutrition security.

Due to its limited importance for the overall EU agricultural sector, the common fishery policy scenarios targeted at changes in aquaculture production and directing capture towards achieving maximum sustainable yields do not show strong effects in the sustainability indicators displayed in this report. Nevertheless, fisheries policy should be included as an important component of an integrated policy set-up for sustainable EU food systems due to the growing importance of this sector and related potentially huge environmental impacts (Diana, 2009). A need for extending model coverage of environmental sustainability indicators that better represent the impacts from capture and aquaculture production could be identified. Otherwise, sustainable policy recommendations remain biased and deficient in this respect.

The introduction of the carbon price is a special case of supply side policy, as it was experimentally implemented as a scenario at the global scale. Thus, improvements in social and environmental sustainability indicators are mainly driven by increases in emission efficiencies of agricultural production for which the EU performs already at a comparably high level. The results from this scenario show, that the greenhouse gas emission reductions achieved by introducing a carbon price alone are also not sufficient for reaching sustainable EU food systems in all dimensions but would deliver co-benefits both in terms of environmental sustainability and improved diets.

The supply-side scenario in which livestock density was restricted leads to a considerable reduction in greenhouse gas emissions from EU agricultural production. However, due to compensating trade effects, EU diets are hardly affected and emission improvements partly offset due to carbon leakage.

On the other hand, demand-side policies captured in the diet scenarios result in dietary improvements, and partly also achieve comparable environmental improvements as the livestock density restriction. In this case however, adjustment in international trade and increasing EU exports, dampens impacts on domestic agricultural production and thus prevent further greenhouse gas emission reductions. Figure 25 presents aggregated sustainability and FNS indicators in the SUSFANS visualizer (see Achterbosch et al. 2019) for reasoning, aggregation, and derivation of displayed metrics in the SUSFANS visualizer as well as the Annex of this deliverable). Results highlight the need for integrated and efficient policies beyond demand side interventions as even under favourable macro-economic conditions and dietary preference change towards healthier diets, these are not enough to ensure sufficient progress on all indicators considered in this assessment.



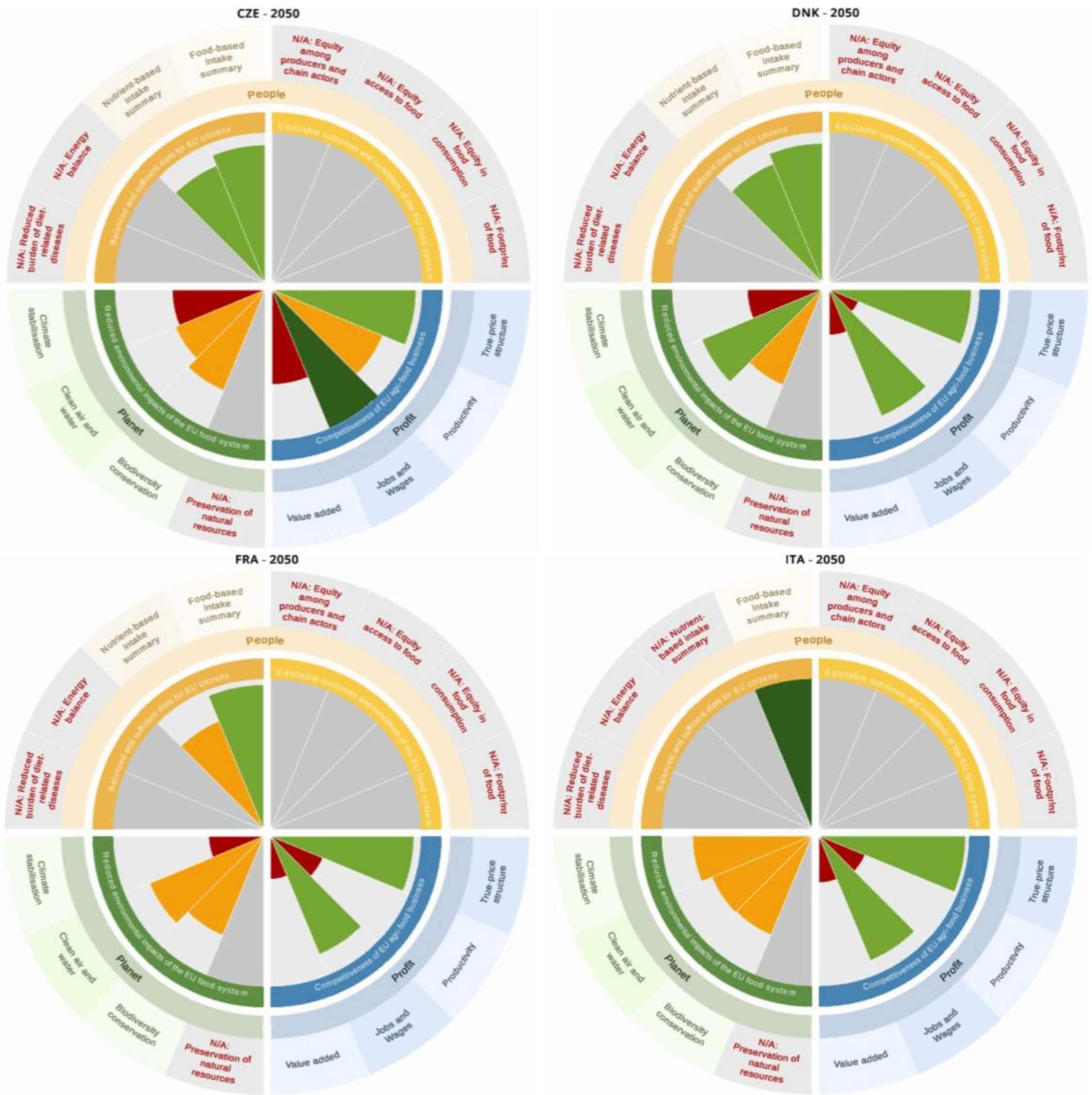



*Figure 25. Visualizer results for EU28 and 4 selected case-study countries in 2050 for the REF+ scenario with changing food patterns & BMI under 25.*

Another important aspect in order to create an efficient policy set-up to reach sustainable EU food and nutrition security is the consideration of heterogeneity within the EU at various scales. The preceding analysis has taken up differences at member state level in terms of policy impacts for all sustainability dimensions (Figure 25) and has shown that impacts across sustainability indicators and member states were quite heterogeneous. When comparing EU-level results, the underlying diversity regarding food demand, consumer prices, expenditure levels, or agricultural production practices gets easily lost. As an example, in the figures below (Figure 26, Figure 27) the absolute changes in total N surplus per ha compared to the reference levels are shown for the livestock density restriction scenario and the various diet scenarios. Despite limited comparability due to different reference years, the comparison of these figures stresses the heterogeneity in sub-regional (NUTS2) impacts arising from the assessed policies. Furthermore it shows, that supply- as well as demand-side policies have the potential to reduce N surpluses – however, improvements are likely not to prevail uniformly nor in every region. Hence, policies should address local conditions as "one-size-fits-all" approaches will not deliver efficient solutions.

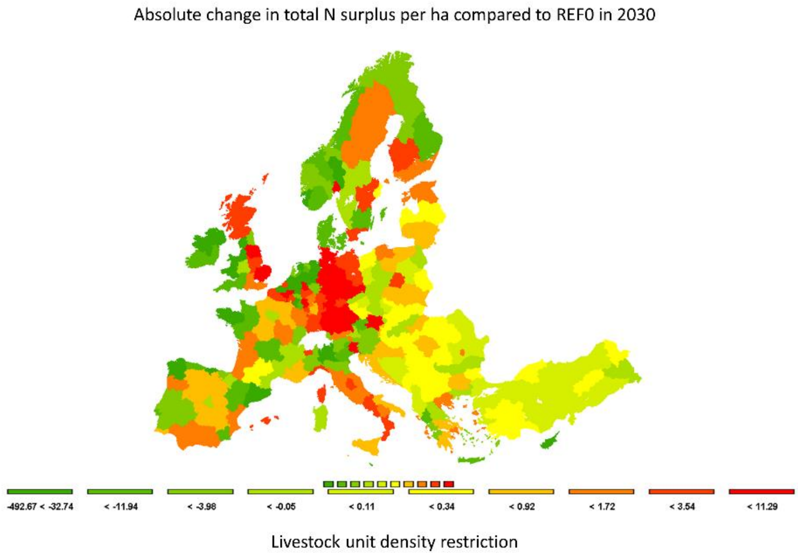



*Figure 26. Absolute change in total N surplus per ha compared to REF0 in 2030 shown at NUTS2 level, CAPRI results.*

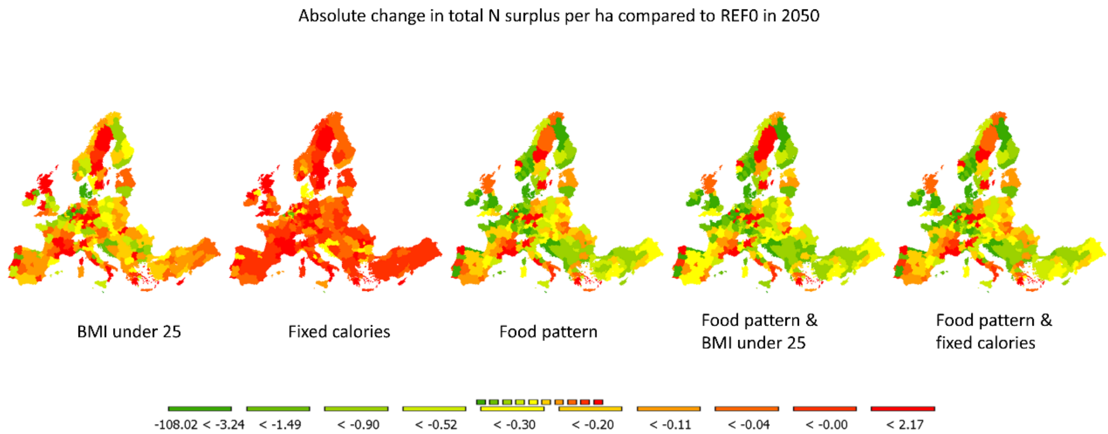



*Figure 27. Absolute change in total N surplus per ha compared to REF0 in 2050 shown at NUTS2 level, CAPRI results.*

Differences at farm, household and individual level do in fact determine whether sustainable food and nutrition security can be reached. Especially diet and nutrition indicators are strongly influenced by socio-demographic characteristics (Mertens et al. 2018). While this differentiation could not be captured in the present analysis due to a limited model coverage, it needs to be considered in designing efficient and successful food system policies. (see Latka et al., 2019 (D9.6) for a full discussion of the limitations of the SUSFANS toolbox.)

The analysis has shown that a policy framework that aims at improving the sustainability of the EU food system and nutrition security of EU citizens must be integrating across policy domains and intervention levels, and cannot rely on a single instrument only. Supply- and demand-side policies can complement each other and should be coordinated so that they contribute to the same policy target.

Besides policies, food system innovations can play a decisive role in order to improve the sustainability of the EU food system. The establishment of new protein sources like insects in animal feed and of circular food system strategies can reduce the resource dependency of agricultural production and contribute to increasing the sustainability of the overall system (van Zanten et al. 2019, (D5.4)).

The potential of a policy for promoting research and innovation (R&I) that uses food systems approaches to catalyse such systems innovation was not explored in this study. Currently, food, agriculture and nutrition R&I spending in the EU is mainly dedicated to sector-specific challenges (SCAR SWG FOOD, 2018).

While the studied supply and demand side measures showed substantial direct and indirect positive effects on the nutritional value of diets and environmental sustainability in the EU, and demonstrated a non-negligible degree of complementarity, they left partly out the economic sustainability in the agri-food sector. In particular the change in dietary patterns combined with a decrease in overall consumption further strengthening some of the baseline trends, would reduce the market opportunities for some of the traditional products. Similarly, supply side measures such as climate mitigation policies, depending on the implementation, could lead to reduced volumes and increased cost of production. However, also these developments provide opportunities which should be explored in follow-up studies. For instance, the diet shifts in the EU, would increase the domestic markets for fruits and vegetables, aquaculture, and the reduced demand for certain conventional products, such as beef, would allow for extensification of the remaining production with environmental and animal welfare benefits, which the more and more affluent EU population could be ready to compensate for through increased prices.

There are also yet untapped opportunities for the EU agri-food sector outside of the EU borders with the global humanity becoming more and more conscious about sustainable development under 2030 Agenda of achieving the Sustainable Development Goals. In this context, the highly efficient and safe EU agri-food production, should find its place on the international markets contributing at the same time to global food and nutrition security, as well as to the solution of some of the environmental challenges, including climate stabilisation or biodiversity conservation.

# CONCLUSIONS

We apply a number of state-of-the-art economic agricultural sector models to assess how EU food and nutrition security may evolve in the future and quantify the effectiveness of supply and demand side targeted policies to improve the performance of the EU food system with respect to sustainability in the following dimensions:

- Balanced and sufficient diets, for EU citizens;
- Viable agri-food business, in the EU;
- Reduced environmental impact, in the EU and from EU food production and consumption;
- Equitable outcomes and conditions, in the EU and beyond under a global sustainable development agenda.

Results clearly highlight the need for targeted consumer policies in addition to policies targeting the supply side in order to advance the future performance of EU food systems towards delivering sustainable European food and nutrition security (FNS). In the absence of such demand policies, only minor FNS improvement can be expected in the EU. Still, macro-economic developments and supply side policies may yield some co-benefits for the environment such as reduced fertilizer demand and emissions in the EU. Results show that without direct demand side interventions EU diets tend to worsen in the long run and that supply side policies may only be effective in resolving particular environmental sustainability issues.

In contrast, diet shifts based on food pattern changes may yield substantial advancements in FNS and outperform the sustainability effects from total calorie reduction. While impacts are minor at global scale, substantial impacts can be observed in the EU. Dietary and nutrition effects are stronger opposed to changes in other sustainability dimensions, which highlights the need for complementary measures on the supply side. Nevertheless, some environmental improvements can also be achieved through demand side interventions.

Across scenarios, EU farmers are likely to experience economic challenges as farmers outside the EU are anticipated to increase their economic competitiveness. Hence, trade opportunities to compensate the limited or even decreasing domestic growth in food demand are limited. At member state level however, the case study country comparison shows stronger and varying effects on imports and exports.

In the analysis at hand, we could not incorporate all facets of SUSFANS insights in the modelling work. For example, consumer level acceptance studies and intra-population differences are only reflected in the modelling work to a limited extent. Furthermore, future research could take up the idea of combined scenarios based on monetary interventions and preference shifts to limit the implied consumer price increases to a realistic extent. In addition, current research (e.g. Brown et al. 2019, IPCC 2018) argues that urgent change is needed for addressing climate change in order to limit global warming. The time horizon underlying this report is chosen comparably long with a full implementation of diet shifts only by 2050. Further analysis may consider more substantial dietary changes and faster behavioural adaptations.

While individual supply and demand side policies as well as food system drivers show potential to improve performance of certain sustainability and FNS aspects, these single policy approaches are not sufficient to move the agro-food system towards higher food and nutrition security with respect to all its dimensions. This calls for integrated policy solutions across sectors and actors that could allow to realize synergies of individual policies and amplify benefits for the overall sustainability of the food system.

# ANNEX - SUSFANS VISUALIZER

This annex describes how the metric scores are calculated (including some aggregated indicators) for presentation in the SUSFANS visualizer. The following chapters describe the process for calculating aggregated indictors, the targets (where applicable) and the performance metrics as described in D6.3. The targets are based on the targets mentioned in D1.3 (Zurek et al, 2017). In some cased these targets already changed which is indicated in the text.

## Diets (People)

### *Targets and aggregated indicators*

**Policy vision**: nutritious and healthy diets for the EU population (implemented for the average national consumer by 2050).

**Policy targets**: policy targets are 1 for each year (2010, 2020, 2030, 2040, 2050)

**SHARP aggregate indicators**: optimal (or maximum) scores are 5 for the food based intake score for 5 food groups (G7NS) and 900 for the nutrient recommended score based on 9 food groups (NRD9.3). The measured scores are between 0 and 5 for G7NS and between -300 and 900 for NRD9.3. Therefore these scores are divided by 5 and 1200 respectively to come to the metrics and aggregated indicators. Minimal scores are 0, maximum (optimal) scores are 1.

**Aggregate indicators from other models**: optimal scores are 10 for the food based intake score (G7NS) and 100 for the nutrient recommended intake scores NRD8 and NRD12. They are divided by 10 and 100 respectively to come to the metrics and aggregated indicators. Minimal scores are 0, maximum (optimal) scores are 1.

The aggregate indicator scores from SHARP and other models are not comparable as SHARP scores are based on food intake while other models use data on food availability. In addition, food products are rather aggregated in the macro models' representations, which limits the interpretability of diet indicators based on results from these models. The respective NRD computations are restricted to the nutrients available in the macro models.

## *Performance metrics*

### *Food based dietaryguidelines*

The performance metric is equal to the aggregated indicator for G7NS

### *Nutrient recommendations*

The performance metric is equal to the aggregated indicator for NRD9.3, NRD8 and NRD12

### *Energy balance*

No data

# Environment (Planet)

## *Targets and aggregated indicators*

### *Climate stability*

**Policy vision**: net zero GHG emissions from food supply chain in 2100 as described in D1.3. However in the meanwhile the new EU Long-Term Strategy set the net zero emission goal for 2050 instead of 2100. This is not included in the visualizer yet.

**Policy targets**: refer to reductions in emissions required to realize the levels associated with the low carbon road map, in 2050 (European, C, 2011). The reductions in this document are defined relative to the emissions in 1990. The policy target is set as a reduction of 80% of total GHG emissions (including emissions other than methane, CO2 and N2O and for all sectors) relative to 1990. To be able to get there, sub goals or mile-stones are set to: 20% reduction by 2020, 40% reduction by 2030, and 60 % reduction by 2040 (new reduction goals would be 25% for 2020, 50% for 2030, 75% for 2040 and 100% for 2050).

Regarding the policy targets/ visions no differentiation is made between the relative changes required from ETS vs non-ETS sectors (see also Annex I)

The target emission-reductions are recalculated as emission reductions relative to 2010 (See Annex I). The redefining of emission targets, relative to 2010 instead of 1990, has been done to have the same reference year (2010) for all policy goals. It could also be decided to keep 1990 as a reference year, in which case there will be results and associated metric score available for 2010 as well.

The **aggregated indicator** is calculated as

$$(\text{emission}_t - \text{emission}_{2010})/(\text{emission-target}_t - \text{emission}_{2010}).$$

With t = year

To get the value between 0 and 1, the indicator is rescaled as follows

- If the aggregated indicator is >0 and < 1

    Rescaled Aggregated indicator = aggregated indicator

- if aggregated indicator is > 1

    Rescaled Aggregated indicator is 1 (more reduction in emission then target)

- if aggregated indicator is < 0

    Rescaled Aggregated indicator = 0 (there's no reduction in emission but an increase)

*Clean air and water*

*Reduction of N surplus*

No targets are set as they are captured by the reduction of N emissions to atmosphere and water

*Reduction of N emissions to the atmosphere*

**Policy targets**: We used the National Emissions Ceilings Directive for the country specific emission reductions (2016). They are defined for NOx and NH3 and are relative to 2005. These target emission reductions are recalculate with respect to 2010. Therefore we used emissions for both gases from the EDGAR databased (Annex II, table) and recalculated the reductions for N relative to 2010 and also the reduction in total N accounted for by the two gases (NH3 and NOx). The total N emissions are calculated as the sum of N emissions (N- NOxNH3) coming from NOx (N-NOx) and those coming from NH3 (N-NH3). Hereby we have to take into account that the emission reductions are national reduction levels and not specific for agriculture. Furthermore, the used database consists of emissions of all sectors. It would be preferable to emission data for 2010 for NH3 and NOx.

Step 1: calculate the absolute emissions for the years 2020, 2030 and 2050 using the targets (emission reductions) and the emissions of 2005. NB we did a linear interpolation for the year 2040.

$t \in \{2020, 2030, 2050\}$

$N\text{-}NOx_t = N\text{-}NOX_{2005} * (1\text{-}NOxred_t)$

$N\text{-}NH3_t = N\text{-}NH3_{2005} * (1\text{-}NH3reduc_t)$

Step 2: calculate the sum of the emissions expressed in for the scenario years and for 2010

$N\text{-}NOxNH3_t = N\text{-}NOx_t + N\text{-}NH3_t$

$N\text{-}NOxNH3_{2010} = N\text{-}NOx_{2010} + N\text{-}NH3_{2010}$

Step 3: recalculate the emission reductions for N

$Nreduc_t = (N\text{-}NOxNH3_{2010} - N\text{-}NOxNH3_t) / N\text{-}NOxNH3_{2010}$

The **aggregated indicator** is calculated as

$(emission_t – emission_{2010})/(emission\text{-}target_t – emission_{2010})$.

With t = year

To get the value between 0 and 1, the indicator is rescaled as

- If the aggregated indicator is >0 and < 1

Rescaled Aggregated indicator = aggregated indicator

- if aggregated indicator is > 1

Rescaled Aggregated indicator is 1 (more reduction in emission then target)

- if aggregated indicator is < 0

Rescaled Aggregated indicator = 0 (there's no reduction in emission but an increase)

*Reduction of N emissions to the hydrosphere.*

**Policy vision**: zero emissions (leaching and runoff) in 2030

**Policy target**: no emissions in 2030.

This results in the emission reductions of 50% by 2020, and 100% by years 2030 onwards.

The **aggregated indicator** is calculated as

$(emission_t – emission_{2010})/(emission\text{-}target_t – emission_{2010})$.

With t = year

To get the value between 0 and 1, the indicator is rescaled as

- If the aggregated indicator is >0 and < 1

  Rescaled Aggregated indicator = aggregated indicator

- if aggregated indicator is > 1

  Rescaled Aggregated indicator is 1 (more reduction in emission then target)

- if aggregated indicator is < 0

  Rescaled Aggregated indicator = 0 (there's no reduction in emission but an increase)

*Reduction of P surplus*

**Policy goal**: no emissions in 2100.

**Policy target**: linear interpolation is done to get targets between the reference year and 2100.

This results in the reduction targets of 12% by 2020, 23% by 2030, 35% by 2040 and 46% by 2050.

The **aggregated indicator** is calculated as

$(emission_t – emission_{2010})/(emission\text{-}target_t – emission_{2010})$.

With t = year

To get the value between 0 and 1, the indicator is rescaled as

- If the aggregated indicator is >0 and < 1

  Rescaled Aggregated indicator = aggregated indicator

- if aggregated indicator is > 1

  Rescaled Aggregated indicator is 1 (more reduction in emission then target)

- if aggregated indicator is < 0

Rescaled Aggregated indicator = 0 (there's no reduction in emission but an increase)

*Reduction of toxic substances use*

No data available

*Biodiversity*

*Reduction of the contribution of the agrifood chain to loss of Mean Species Abundance (MSA).*

**Policy goal**: no further increase of land used for agricultural production relative to 2010.[2]

**Policy target** = policy goal.

We assume the same goal to be applicable for 2020, 2030, 2040 and 2050.

**Aggregated variable**: the aggregated variable cannot be calculated according the formula from page 12 D1.3 as the denominator would be 0. Just the relative difference between the two gives the distance between desired level and current level.

Therefore, aggregated indicator = agri land t / agri land 2010.

Then the derived **aggregated indicator**

- If aggregated indicator < 1

  Rescaled Aggregated indicator = 1

- If aggregated indicator – 1 < 1

  Rescaled Aggregated indicator = 1 - aggregated indicator

- If aggregate indicator -1 >= 1

  Rescaled Aggregated indicator = 0

*Agricultural land use diversity*

**Policy vision**: Increase of the Shannon index (LDIV) by two points by 2050.

[2] To be able to reach the target of a maximum of 2 degrees temperature increase, area is needed for energy crops and afforestation. Part of this area should come from agriculture (D1.3). Unfortunately energy crops are often considered as agricultural production (also in the models)(pers. P. Havlik).An option would be to return the target in an increase of natural vegetation. However for the moment it is not clear of such targets exists (pers.med. C. Latka)

**Policy target**: linear interpolation of the Shannon index is done between the reference year and 2050.

Therefore targets for the intermitting years are as follows:

Target 2020 = $LDIV_{2010}$+ 0.5
Target 2030 = $LDIV_{2010}$+ 1
Target 2040 = $LDIV_{2010}$+ 1.5
Target 2050 = $LDIV_{2010}$+ 2

**Aggregated indicators** are then calculated as

$CLDI_t = (LDIV_t - LDIV_{2010})/(Target_t - LDIV_{2010})$

With t = year

And rescaled as below

- If the aggregated indicator is >0 and < 1

  Rescaled Aggregated indicator = aggregated indicator

- if aggregated indicator is > 1

  Rescaled Aggregated indicator is 1 (more increase in Shannon index than target)

- if aggregated indicator is < 0

  Rescaled Aggregated indicator = 0 (there's a decrease in Shannon index instead of increase)

*Preservation of natural resources*

No data available

## Performance metrics

### Climate stability

The performance metric is equal to the rescaled aggregated indicator.

### Clean air and water

The performance metric is calculated as the unweighted average of the aggregated indicators for emission to air and hydrosphere and phosphorus surplus.

*Biodiversity*

The performance metric is calculated as the unweighted average of the aggregated indicators for land use for agricultural activities and the SHANNON-index

*Preservation of natural resources*

No data available

# Competitiveness (Profits)

## *Targets and aggregated indicators*

Targets for competitiveness are relative and can be best defined as scoring like the best performer on a variable.

The competitive aggregated indicators are calculated according to table 7 in D6.3.

These values range between 0 and 1.

## *Performance metrics*

Performance metrics are calculated as the unweighted average of the underlying aggregated indicators as defined in table 7 of D6.3.

# Visualizer

Table 1 shows the availability of scenarios (see Table 3 and 4 in D10.4 for scenario descriptions).

| Scenarios |
|---|
| REF- |
| REF-_DEM_T |
| REF-_DP_T |
| REF-_DPE0_T |
| REF-_DPEM_T |
| REF+ |
| REF+_DEM_T |
| REF+_DP_T |
| REF+_DPE0_T |
| REF+_DPEM_T |
| REF0 |
| REF0_DEM_T |
| REF0_DP_T |
| REF0_DPE0_T |

| REF0_DPEM_T |
| --- |

## Diets

SHARP data is used in the visualizer.

Only the four countries for which food intake ptake is measured are included (CZE, DNK, ITA and FRA) and an estimation is done for EU28.

The estimate for EU28 is the population weighted average of all 28 EU- countries whereby EU countries for which this data is not available, are mapped to one of the four selected countries for which the data is available (table 2).

Table 2 Mapping Countries to representative countries

| **Denmark** | **France** | **Italy** | **Czech Republic** |
| --- | --- | --- | --- |
| Sweden | Austria | Cyprus | Estonia |
| Finland | Belgium | Malta | Hungary |
| | Germany | Spain | Latvia |
| | United Kingdom | Greece | Lithuania |
| | Ireland | Portugal | Croatia |
| | Luxembourg | | Poland |
| | Netherlands | | Romania |
| | | | Slovakia |
| | | | Slovenia |
| | | | Bulgaria |

## Environment

CAPRI and GLOBIOM deliver environmental data. We choose the CAPRI data for the visualizer as the advantage of CAPRI is that the model calculates he Shannon index, which makes the performance metric for biodiversity more complete. On the other hand the advantage of using GLOBIOM is that this model calculated data for 2020 and 2040 and CAPRI not. Regarding the environmental indicators, EU results are based on the performance of all 28 EU member states and do not only refer to the case study countries.

## Competitiveness

The competitiveness metrics included in the visualizer are calculated using the MAGNET model results.

Results for all EU28 member countries are not available at country-level from the MAGNET scenarios. Country specific results and therefore metrics are available for CZE, DEU, DNK, ESP, FRA, GBR, GRC, ITA, LVA, NLD, SVK, SWE and for EU28 as an aggregate.

CYP, EST, HUN, LTU, POL, SVN, BGR, HRV,ROU are clubbed together as a group. AUT, BEL, FIN, IRL, LUX, MLT, PRT form another such aggregate regional group.

The group specific results from MAGNET are assumed to be applicable for all the members of the associated group. For example, to look for metrics for POL, metrics from the first group should be used; for PRT, metrics from the second group should be used. Note however that results for countries within a group are non-distinguishable.

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