Food Systems True Cost Accounting

Report

May 2025

Food Impact Map

Synthesis report on food impact pathways

PLAN'EAT

(TMG) ThinkTankforSustainability Töpfer Müller Gaßner

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Contents

List of Figures

List of Tables

Abbreviations

CO2	Carbon dioxide
DALYs	Disability-Adjusted Life Years
E/MSY	Extinctions per million species years
EFSA	European Food Safety Authority
EU	European Union
FAO	Food and Agriculture Organization
GHG	Greenhouse gas
MD	Mediterranean diet
MSC	Marine Stewardship Council
N	Nitrogen
NCD	Non-communicable diseases
NH3	Ammonia
P	Phosphorus
PHD	Planetary health diet
QALYs	Quality Adjusted Life Years
SSBs	Sugar-sweetened beverages
T2DM	Type 2 diabetes
UPF	Ultra-processed food
WHO	World Health Organization

Executive Summary

Moving toward sustainable food systems is not straightforward, as sustainability is multidimensional. Healthy and sustainable diets aim to: achieve optimal growth and development of all individuals and support functioning and physical, mental and social well-being at all stages of life for present and future generations; contribute to the prevention of all forms of malnutrition (i.e. undernutrition, micronutrient deficiencies, excessive bodyweight and obesity); reduce the risk of diet-related non-communicable diseases (NCDs); and support the conservation of biodiversity and the health of the planet.[1] A food systems approach is a way of thinking and doing that considers the food system in its totality, considering all dimensions of sustainability, their relationships and related effects.[2] It is important to recognize that environmental, health and social systems are interrelated, and that progress focused on the goals of one system may have implications for the goals of other systems.

An important component of sustainable food systems is healthy and sustainable diets. Achieving such diets requires a thorough understanding of the environmental, health and social impacts of food production and consumption. Given the goal of the EU Horizon Europe project PLAN'EAT to support a dietary transition towards sustainable diets, this synthesis report aims to summarize key evidence of the sustainability challenges associated with European diets, in relation to health, the environment and social issues, and to provide overarching recommendations of what can be done in these domains to move towards more sustainable diets. It integrates key findings from the contributions of several working groups and three project internal reports (IR2–4) based on a series of literature reviews and modelling studies with regional details, while also integrating international dietary recommendations for human and planetary health. The reports provide country-specific analyses of environmental and health impacts and outline the linkages between food consumption and social sustainability in EU member states.

The overarching goal is to provide a holistic picture of the impacts of prominent dietary patterns in the EU and to provide guiding principles for healthy and sustainable diets, helping to create clearer direction for consumers, policymakers and food professionals for the necessary dietary transition. The report is part of the project's efforts to enable European stakeholders to identify hidden positive and negative impacts along the food value chain and transform economic systems in the long term by providing (policy) recommendations on how to reduce and eventually internalize negative externalities (True Cost Accounting).

Guiding Principles to Achieve Healthy and Sustainable Diets: from Macro to Micro

Macro level: food system

Far-reaching action is needed to shift consumer diets to greater reliance on plant-based foods and less consumption of animal-based foods and highly processed foods, notably those high in added fat, salt or sugars.

The following actions by policymakers and businesses can help to make healthy and sustainable food available, accessible, affordable and safe:

- **Create financial access to healthy and sustainable foods.**

  Implementing fiscal policies, such as taxing products that have a greater impact on human health and the environment and targeting food subsidies and incentives on fruits and vegetables, whole grains, legumes, nuts and seeds to increase the affordability of healthy and sustainable food.

- **Encourage and support the consumption of plant-based foods and a reduction of foods high in added sugars, fats, salt and/or ingredients not found at home, as well as meat and dairy products.**

  Enable food sector stakeholders to integrate country-specific guidelines for healthy and sustainable diets based on the PLAN'EAT project.

- **Shape healthy and sustainable food environments for consumers.**

  Integrate sustainable and plant-based meals and appropriate portion sizes into community catering, especially for children and adolescents in day-care centres, school catering and university canteens. Take further action to restrict the advertising and marketing of unhealthy and unsustainable foods targeted at children, adolescents and other vulnerable groups.

Meso level: food environment

A sustainable approach to food retail and service is more important than ever to make food environments less harmful for people and the planet.

Micro level: individual

Changing our diets to include healthy, high-quality foods and more plant-based is an effective way to protect our planet and improve our health. This does not necessarily mean turning vegan or even vegetarian but eating less and better animal-based foods and focussing on unrefined, minimally processed foods, healthy fats and healthy sources of protein.

How consumers can change their diets for the better:

- Lower the overall intake of meat and dairy products and instead eat more legumes, nuts and seeds.
- Avoid eating more than needed.
- Buy seafood from sustainably managed stocks by looking out for certifications and third-party labels and increase intake of seaweed and bivalves.
- Base the diet on a variety of vegetables, fruits, legumes, nuts, whole grains and roots, preferably when in season.
- Choose organic products to reduce pesticide use.
- Choose meat from extensive grazing systems that help preserve biodiversity.
- Reduce foods with cosmetic, non-culinary ingredients not commonly used at home and/or those with too much added fat, sugar or salt.
- Limit consumption of products grown in tropical regions, such as coffee, tea and cocoa.
- Avoid household food waste, especially of foods with a high environmental impact (e.g., meat, dairy, fish, tropical products, etc.).

1 Environmental Impacts

1.1 Environmental impacts of the European food system

Significant environmental impacts occur along the food supply chain, threatening the environment by contributing to global warming, resource depletion and loss of habitat and biodiversity. Food is a vital part of our lives, but its impacts are far-reaching and require urgent attention.

Land use change

One of the main drivers of the environmental impacts of food production is the conversion of natural ecosystems to agricultural land.[3] Global deforestation, often caused by the expansion of agricultural activities such as livestock grazing and crop cultivation and driven by consumption in the EU and other high-income regions of the world, results in the loss of biodiversity and contributes to the release of carbon dioxide (CO2) into the atmosphere, exacerbating climate change.[4]

Water use in agriculture

The agricultural sector requires intensive use of water resources. Irrigation for crop production accounts for a significant proportion of global freshwater consumption. Excessive withdrawals from rivers and underground aquifers can lead to the depletion of water sources, altering ecosystems and affecting aquatic species.[5] Inefficient irrigation practices are at risk of causing water waste and water contamination from agricultural chemical runoff.

Greenhouse gas emissions

The food system is a major contributor to global GHG emissions, accounting for about one third of total GHG emissions globally.[6] GHG emissions contribute to climate change and associated impacts, such as rising temperatures, extreme weather events and sea level rise. Along the supply chain, large GHG contributions occur from land use changes and farm activities such as cropping activities that emit nitrous oxide (e.g., as fertilizer application) and manure storage and management.[6] Relatively little emissions arise from transport (except air transport). Regarding products, most GHG emissions come from livestock production; red meat in particular is a major source of methane, one of the most potent GHGs.

Chemical inputs

Intensive agriculture can also result in high environmental costs related to increased use of chemical inputs such as fertilizers and pesticides. Excessive and inappropriate use of these substances can contaminate soils, water sources and ecosystems, harming terrestrial and aquatic life.[7] Pesticides have been linked to the decline of pollinators such as bees, which play a critical role in maintaining biodiversity and ensuring food security through their role in crop pollination.[3]

1.2 Case Study: Environmental performance of baseline diets from the living lab countries

The objective of this study was to evaluate the environmental performance of Living Labs' baseline diets, here exemplified by Ireland, Hungary and Greece, using footprinting and life cycle assessment (LCA) data. Different population groups and age groups were used as target groups for the individual countries. The baseline diets were benchmarked against the boundaries in the report from the EAT-Lancet commission[17] in line with Moberg et al.[18] This means that the global targets for the food system suggested by Willett et al.[17] were divided by the global population (7.5 billion in 2016) to establish per capita boundaries.

In total, the environmental performance of 1426 food products was assessed, using the following indicators: carbon footprint, cropland use, new input of nitrogen (N) and phosphorus (P), blue water use, pesticide use, biodiversity impact and ammonia emissions. All indicators are expressed per kg of food and then used to calculate the performance on an aggregate level for the complete diet. Environmental assessment of diets is associated with major uncertainties associated with modelling complex biological processes (e.g., nitrous oxide emissions from soils), variation in production parameters like yields and manure management systems and uncertainty in assessing the intake of foods in self-reported dietary surveys.

1.2.1 Ireland

The Living Lab in Ireland focuses on young university students (18–30 years). The assessed diet was extracted from the National Adult Nutrition Survey conducted in 2008.

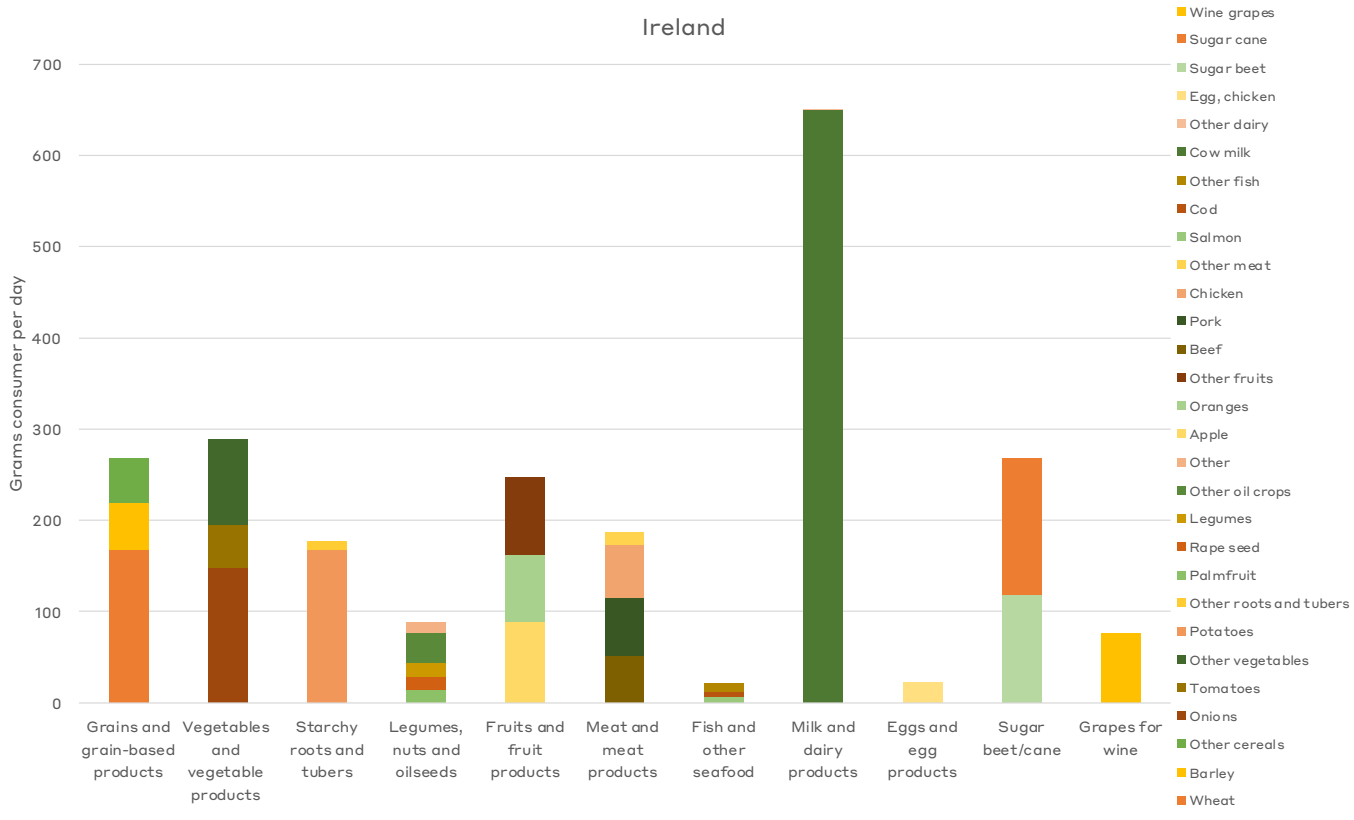
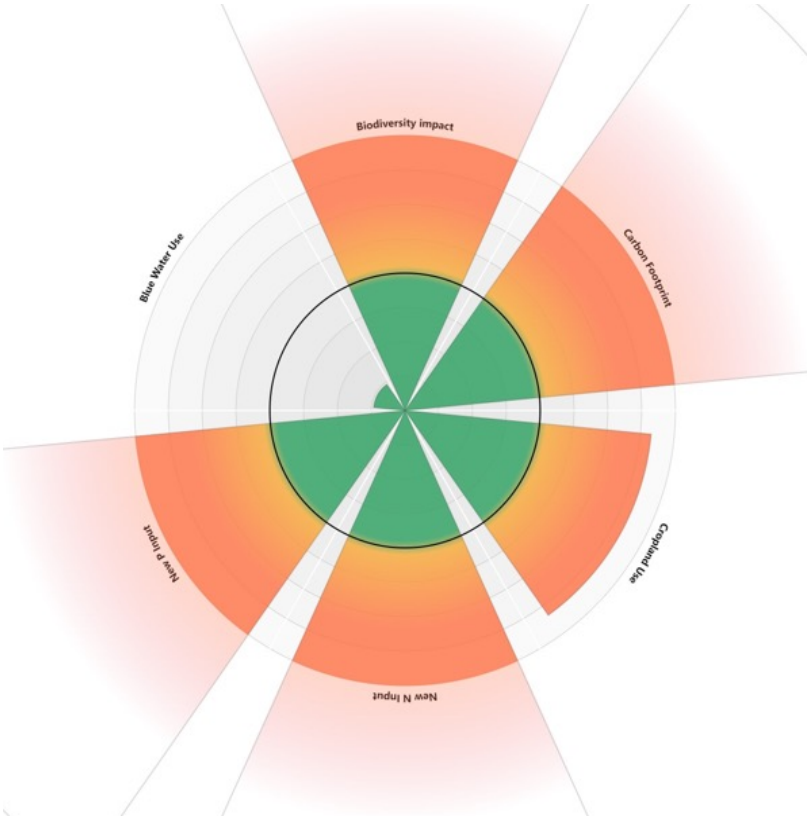


Figure 1: Food groups in the baseline diet for the Irish Living Lab.

Presented as raw commodities; e.g., "Milk and dairy products" also includes, e.g., cheese and butter.



Environmental indicators	Amount
Carbon footprint	2.0 t CO_2e year^{-1}
Cropland use	0.26 ha year^{-1}
New N input	53 kg N year^{-1}
New P input	3.5 kg P year^{-1}
Blue water use	67 m^3 year^{-1}
Biodiversity impact	5.6 x 10^{-7} E/ MSY year^{-1}
Pesticide use	445 kg a.s. year^{-1}
Ammonia emissions	9.1 kg NH_3 year^{-1}

Figure 2: Environmental performance of the baseline diet in the Irish Living Lab.
Benchmarked against the EAT-Lancet boundaries.[17]

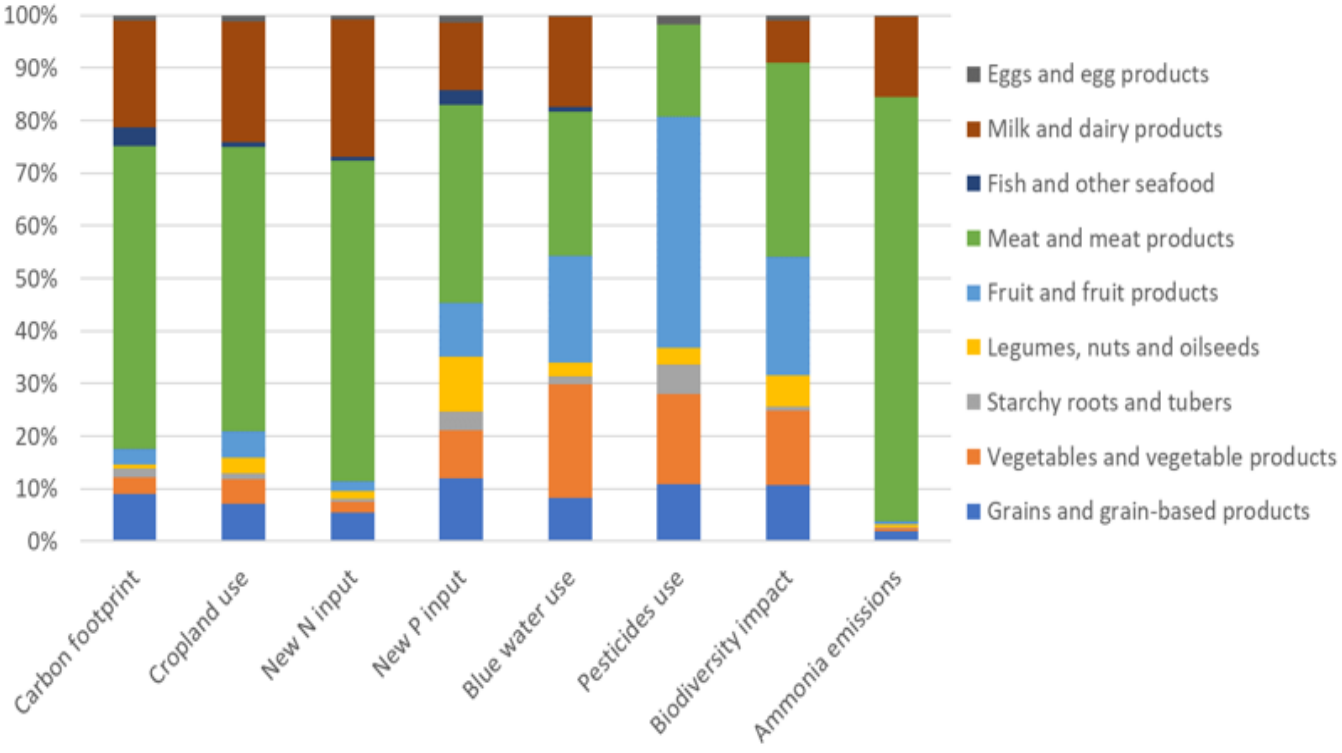


Figure 3: Relative contributions from different food groups of the baseline diet in the Irish Living Lab.

1.2.2 Hungary

The Hungarian Living lab targets single young parents (18–34 years). To assess their diet, a baseline diet was extracted from the Hungarian national food consumption survey conducted in 2018.

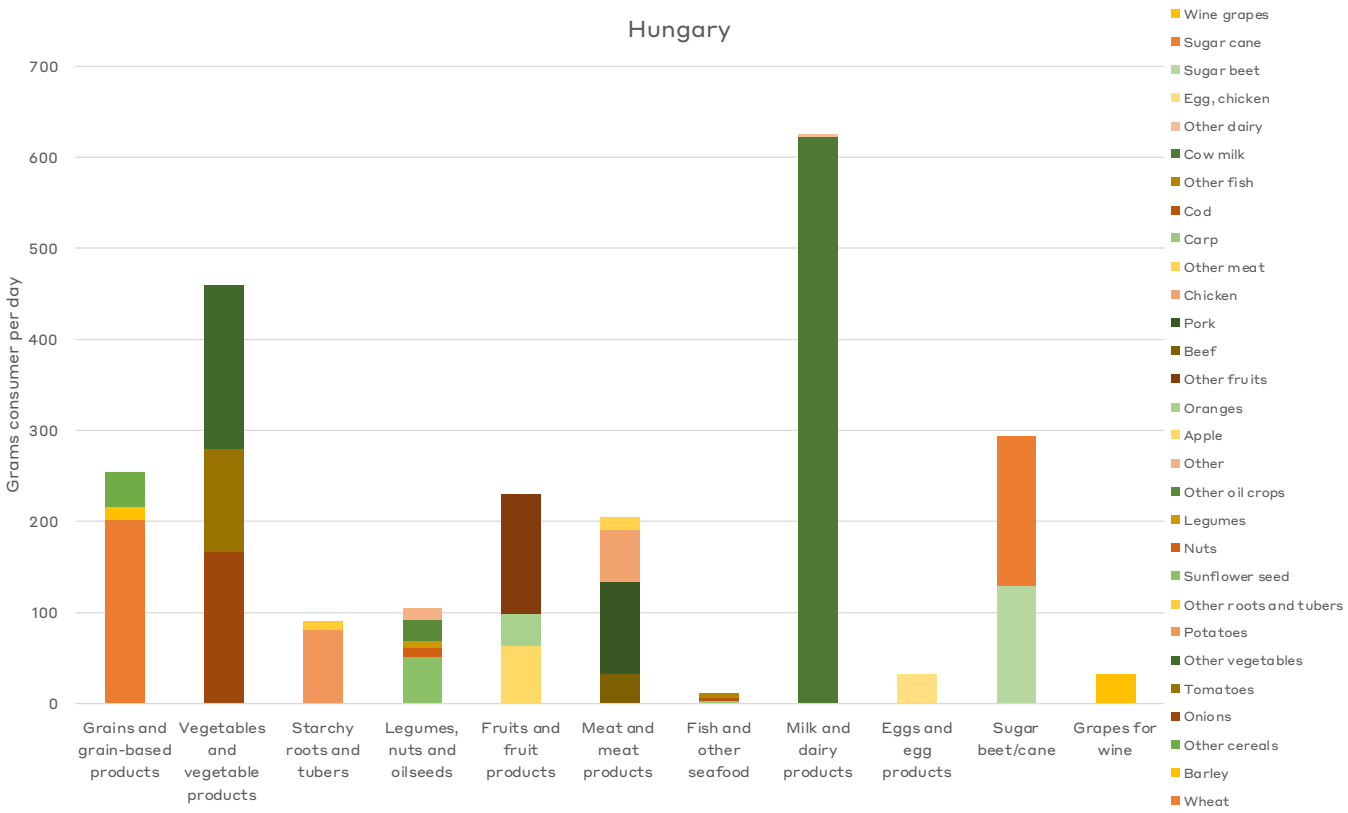
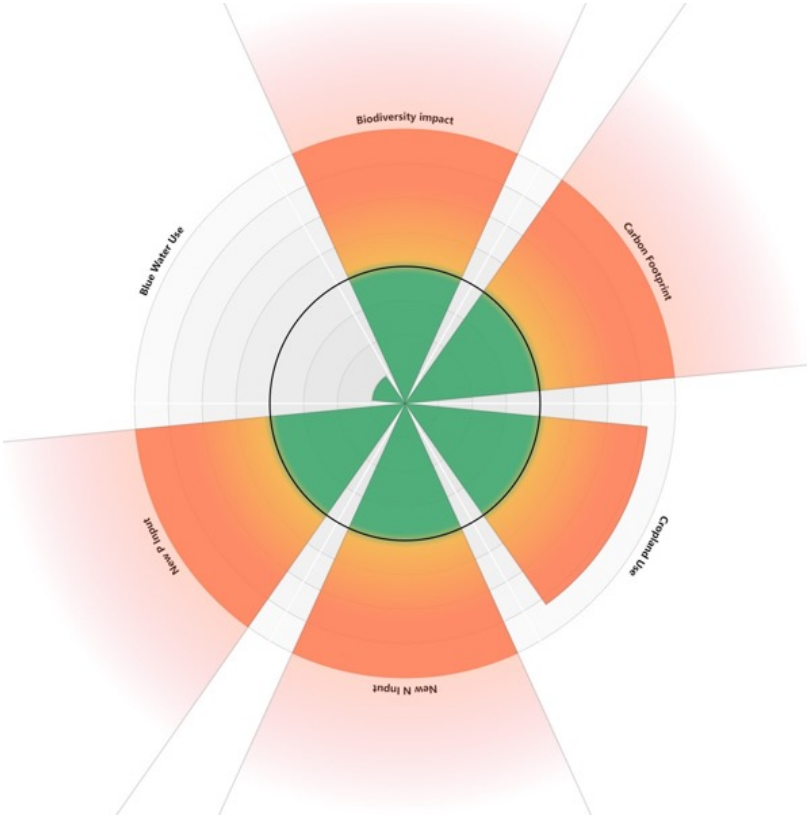


Figure 4: Food groups in the baseline diet for the Hungarian Living Lab.

Presented as raw commodities; e.g., "Milk and dairy products" also includes, e.g., cheese and butter.



Environmental indicators	Amount
Carbon footprint	1.07 t CO_2e year^{-1}
Cropland use	0.27 ha year^{-1}
New N input	43 kg N year^{-1}
New P input	3.7 kg P year^{-1}
Blue water use	73 m^3 year^{-1}
Biodiversity impact	5.7 x 10^{-7} E/ MSY year^{-1}
Pesticide use	357 kg a.s. year^{-1}
Ammonia emissions	8.2 kg NH_3 year^{-1}

Figure 5: Environmental performance of the baseline diet in the Hungarian Living Lab.

Benchmarked against the EAT-Lancet boundaries.[17]

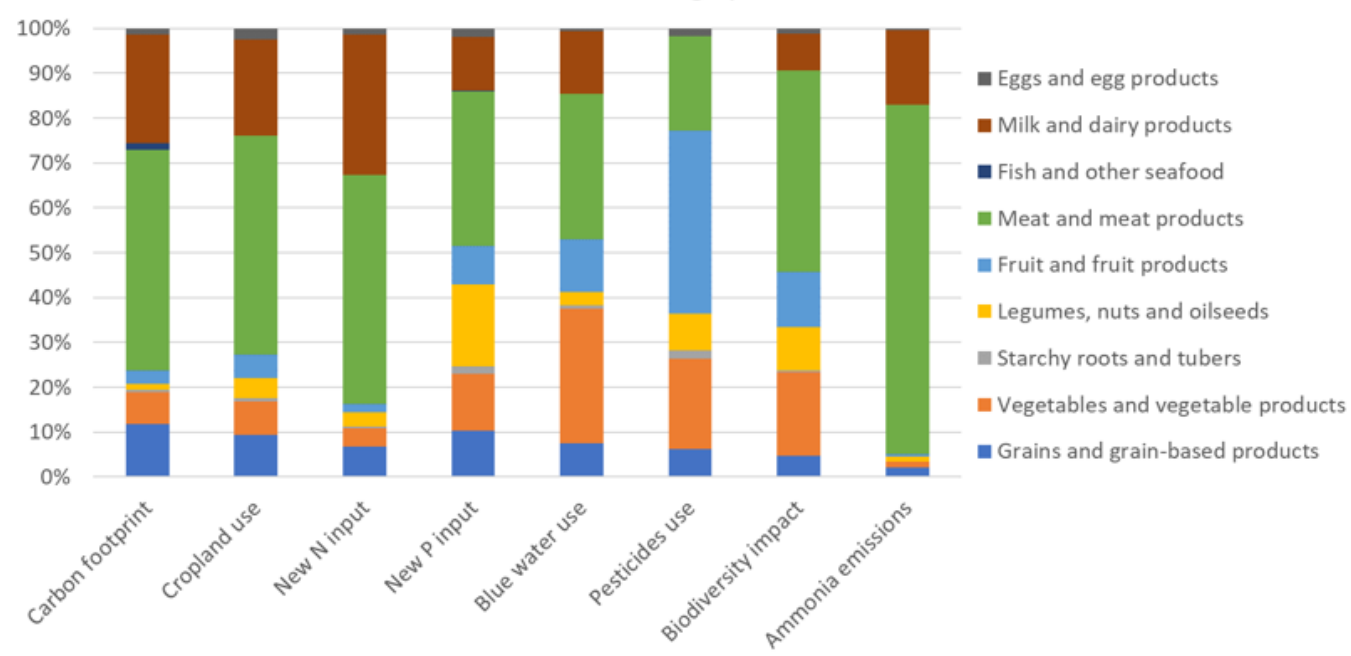


Figure 6: Relative contributions from different food groups of the baseline diet in the Hungarian Living Lab.

1.2.3 Greece

The focus of the Greek Living Lab is the elderly population (>60 years) with risk factors for NCDs; i.e., chronic diseases that are not passed from person to person, such as heart diseases, stroke, cancer and T2DM. Baseline dietary data were obtained from the 2014 European Food Safety Authority (EFSA) National Nutrition Survey for the general population aged 10 to 74 years in Greece.

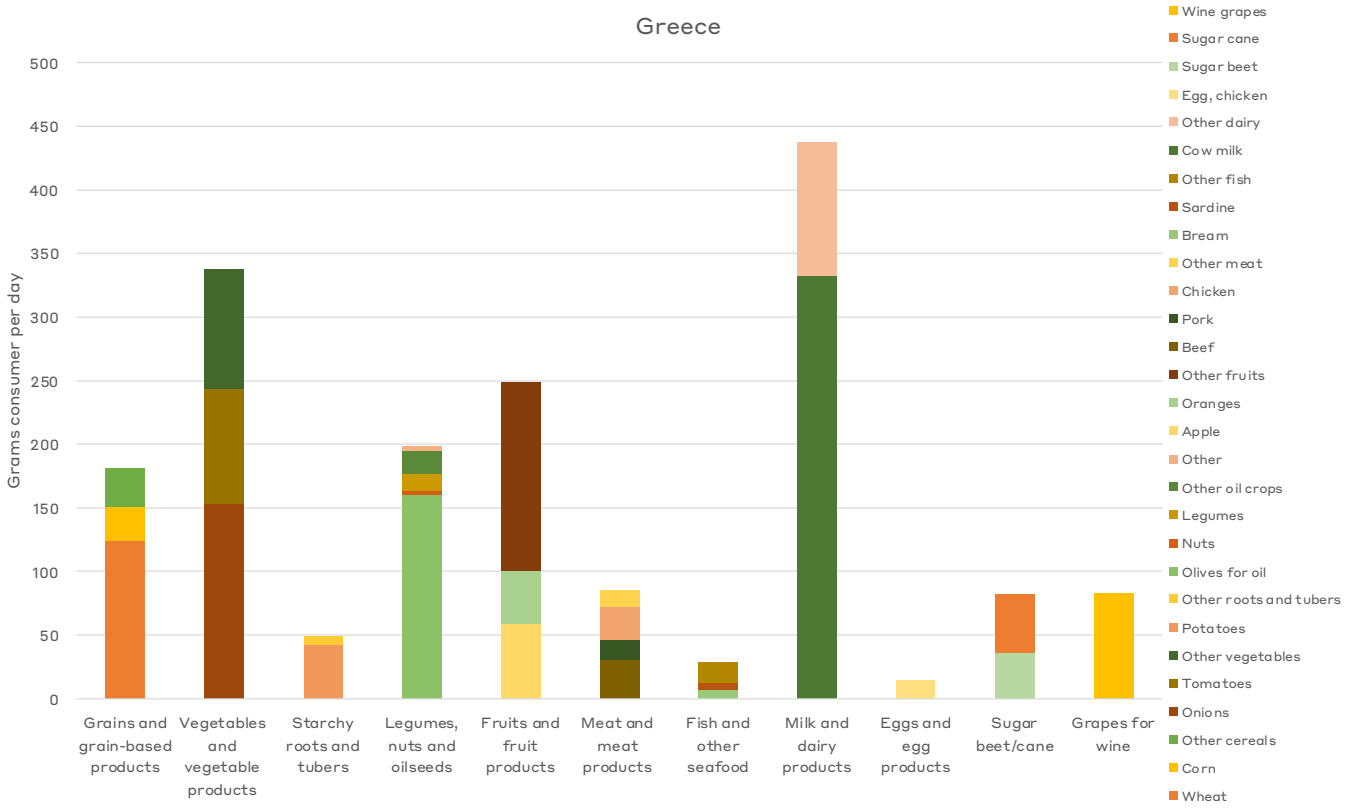


Figure 7: Food groups in the baseline diet for the Greek Living Lab.

Presented as raw commodities; e.g., "Milk and dairy products" also include, e.g., cheese and butter.

Environmental indicators	Amount
Carbon footprint	1.4 t CO_2e year^{-1}
Cropland use	0.20 ha year^{-1}
New N input	34 kg N year^{-1}
New P input	2.7 kg P year^{-1}
Blue water use	106 m^3 year^{-1}
Biodiversity impact	2.2 x 10^{-7} E/ MSY year^{-1}
Pesticide use	199 kg a.s. year^{-1}
Ammonia emissions	5.1 kg NH_3 year^{-1}

Figure 8: Environmental performance of the baseline diet in the Greek Living Lab.
Benchmarked against the EAT-Lancet boundaries.

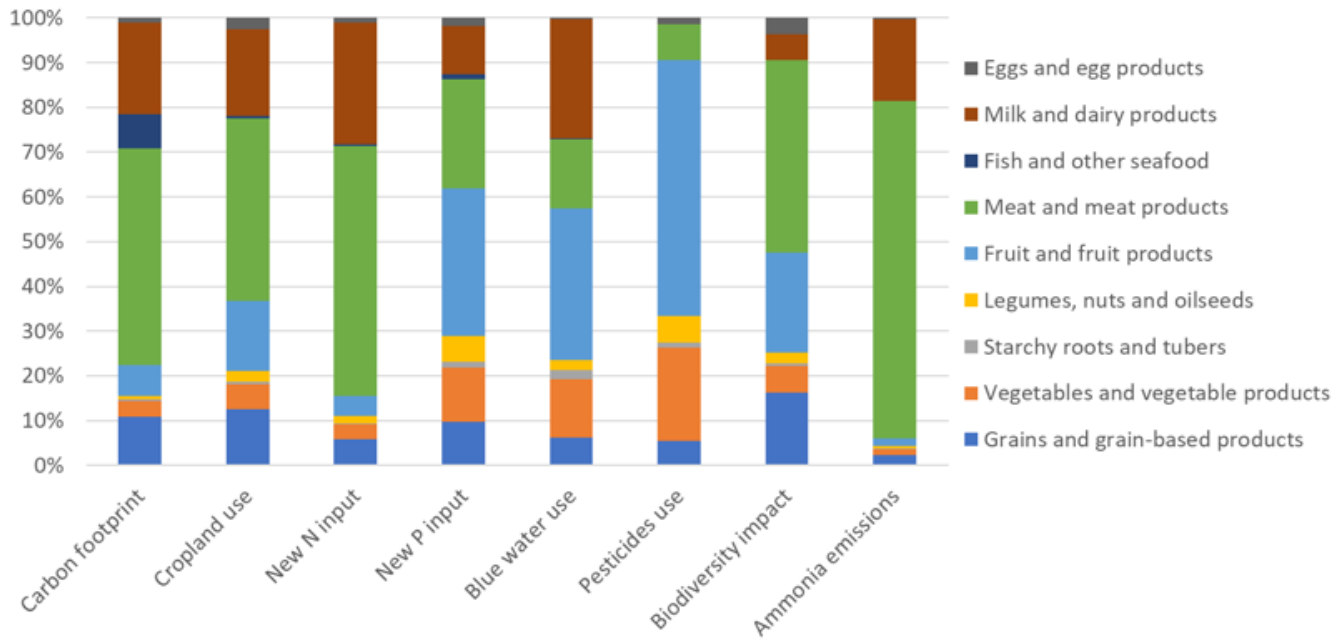


Figure 9: Relative contributions from different food groups of the baseline diet in the Greek Living Lab.

1.2.4 Conclusion

The diets examined here show similar patterns of environmental performance. Meat and dairy products contribute significantly to many environmental indicators. In terms of carbon footprint, the contribution of meat and dairy products is 50% or more in all countries. Meat and dairy products also dominate the contribution to cropland use and new N inputs, as feed production requires land and N fertilizers. For ammonia emissions, livestock production accounts for more than 95%, dominated by emissions from manure storage and handling.

Fruits and vegetables contribute substantially to blue water use, pesticide use and biodiversity loss.

Fish and other seafood contribute relatively little to the dietary impacts captured by the indicators used here. Wild seafood contributes only to greenhouse gas emissions from fishing vessels and has no impact on the other indicators used here as no land, fertilizers or pesticides are used, no feed is produced, and no manure is managed. For farmed seafood, emissions from feed production are substantial. The carbon footprint per kg of seafood is of the same order of magnitude as for meat, but consumption is generally lower.

In terms of biodiversity impacts, diets exceed the EAT-Lancet boundary by a factor of 100, but this limit and its assessment are highly uncertain. Land use is potentially the most straightforward indicator because it is based only on crop yields and available cropland, for which relatively good data are available. For cropland, the EAT-Lancet boundary is exceeded by 18–65% for the diets evaluated here. The carbon footprint of diets is typically twice the sustainable limit.

In all countries, diets exceed all planetary boundaries except for blue water use. The blue water use associated with the diets is low (compared to the other indicators) because agriculture in the Living Lab countries (where most of the food in the diets is grown) is predominantly rainfed. However, we only considered blue water consumption in terms of quantity consumed, not water scarcity. This means that even if the diets are within the limits for total blue water consumption, there may still be water scarcity issues at the local level. In addition, with climate change, the demand for irrigation is expected to increase substantially.[18] Therefore, water use by diets should also be monitored, although currently—and based on the data used here—it is still within sustainable limits. Products with high water use per kg include nuts, ruminant meat produced in warm countries and some tropical fruits.

1.3 Recommended action for consumers and food professionals

In the context of the environmental impacts, shifting dietary patterns to more environmentally sustainable ones is becoming ever more important. Here are some recommendations on how consumers and food professionals can change diets for the better.

Decreasing overall intake of meat and dairy, especially individuals that have a high intake of these foods.

Meat and dairy make considerable contributions to many environmental impacts. Replacing meat and dairy products with whole grains, legumes, roots and vegetables is the mitigation option with the greatest potential for improving the environmental performance of the diets.

Reducing food waste, especially the waste of food with high environmental impacts (e.g., meat, dairy, fish, products from tropical regions, etc.).

Wasting food means that impacts from food production are caused without the benefit of providing nutrition to diets. Food waste accounts for about 16% of

total GHG emissions from the EU food system[14]; therefore, reducing food waste is also an important strategy to improve the environmental performance of diets. Packing leftovers into lunch boxes, using them in new creative recipes, or keeping them for future consumption is good for the planet and one's budget.

Avoiding overconsumption in general and consumption of foods that contribute to little nutritional value; e.g. alcohol, sweets, sugar-sweetened beverages, (discretionary) foods high in added sugars, fats, or salt, and/or ingredients not found at home.

Another type of food waste resulting from overconsumption is "metabolic food waste." Consumption of food more than the recommended caloric intake poses a health risk and unnecessary environmental impacts.[109] The EU is responsible for the largest amount of metabolic food waste of any region in the world. Much of the excess calories come from foods that contribute little to nutrition or are even detrimental to health, such as ultra-processed foods (UPFs), discretionary and non-core foods, alcohol, etc. Therefore, reducing the intake of such foods and the portion sizes of meals in general could be an effective way to reduce total daily energy intake[113] and contribute to reducing the overall environmental impact of the food, mainly in terms of GHG emissions.[115]

Buying seafood from sustainably managed stocks and primarily choosing farmed seaweed and bivalves.

Wild seafood comes with a range of sustainability challenges including overfishing of wild stocks, destruction of seafloors, disruption of food webs, and destruction of coastal ecosystems.[12; 3] Sourcing seafood from sustainably managed stocks may have fewer negative impacts (several labels exist to indicate this, e.g., MSC, followfood and organic labels such as the Swedish KRAV).

Another option for more sustainable seafood consumption is to choose seafood such as farmed seaweed and bivalves like mussels. These species do not require feeding as seaweeds use photosynthesis and nutrients present in the sea to grow and bivalves feed from plankton filtered from the water. Hence, farming of these species helps clean the oceans of excess nutrients, counteracting eutrophication.[13]

Choosing organic foods to reduce the pesticide use associated with diets.

The use of pesticides associated with diet is not commonly reported in diet assessments.[15] However, chemical pollution is a major concern with many toxic substances being used in agriculture.[16] An effective strategy to reduce the pesticide use associated with a diet is to choose more organic products, as very few synthetic pesticides are allowed according to organic regulations.

Reducing consumption of products grown in tropical regions (e.g., coffee, tea, cocoa, tropical fruit) to reduce water use and impacts on biodiversity.

Fruit and vegetable production contributes substantially to blue water use (i.e., the water in our surface and groundwater reservoirs), pesticide use and biodiversity impacts. Many fruits and vegetables require irrigation, especially in warm countries. Many pesticides are also used on these crops. Fruit and vegetables from tropical regions can have a high impact on biodiversity as the number of species affected by using a certain area of land is considerably higher than those impacted by using the same amount of land in most regions in Europe.[11]

Choosing meat from low-intensity grazing systems where grazing helps preserve biodiversity-rich grasslands.

Choosing not only less meat but also meat and dairy from more sustainable production systems can have considerable benefits. For example, in some places, the grazing of animals in semi-natural pastures rich in threatened and unique plant and insect species can help maintain biodiversity. Such

ecosystems have developed through low-intensity farming over hundreds or thousands of years and rely on continued grazing values.[10]

2 Social and Socio-economic Impacts

2.1 Social and socio-economic impacts from European food systems

Among the myriad factors that shape social sustainability, food is of immense importance, touching upon economic, cultural and ethical dimensions. Food production has profound impacts on, for instance, decent livelihoods, labour rights and equity. In addition, food affordability, the food environment and animal welfare are important social sustainability challenges, although the cause-and-effect chain is long and complex.

Farmworkers' livelihoods

A decent standard of living—one that meets basic needs and provides a life of dignity—is a human right. Yet farmworkers too often live in financial insecurity, even though agriculture drives economically important supply chains. Agricultural commodity prices have recently shown substantial volatility, creating high levels of uncertainty for farmers and threatening their long-term viability.[20; 21] In perspective, this leads farmers to invest fewer resources in long-term investments that could increase their productivity, sustainability and profitability.[22]

A major challenge for rural areas across Europe is farm succession. While employment rates are generally declining, the ageing of farmers and the agricultural labour force is increasingly evident. Farmers under the age of 40 manage only 11% of all farms in the European Union.[23] Access to land and capital are two major barriers for young people wishing to enter the agricultural sector. This difficulty is particularly amplified for young females, further accentuating the barriers they face.

Market concentration and competition

Downstream segments of agri-food chains (such as processing, wholesale and retail) tend to be more concentrated than agricultural production, raising concerns about market power and competition in the agri-food sector.[30] However, the relationship between concentration and the exercise of market power is complex and evidence of market power abuse is not necessarily obvious and may be context-specific.[31] In addition, international trade plays a critical role in improving the diversity and accessibility of different foods and products across Europe, providing access that might not otherwise be readily available. Nevertheless, farmers are in a structurally weaker position than other actors and small and medium-sized farms in particular face increasing competitive intensity as the number of large farms increases, land prices rise and production price indices fluctuate.[32]

Forced labour and exploitation

Abused labour rights such as forced labour, also called "modern slavery," is globally pervasive and exist in European countries. While forced labour is most prevalent in low-income countries, its existence is inextricably linked to demand in higher-income countries. It is estimated that G20 countries imported 426 billion euros worth of goods at risk of modern slavery in 2021.[25]

While it is essential to note that not all food or food products are associated with modern slavery, there are instances of exploitation and forced labour in certain parts of the food supply chain. This might include the production of fruits and vegetables, seafood processing and even some cases in the restaurant and hospitality industry.[26; 27] Cases of forced labour have been documented in agriculture and, in some unfortunate situations, farmers may unintentionally employ seasonal workers

who are subjected to conditions akin to modern slavery without their knowledge. Some farmers rely on outside recruitment agencies or labour brokers to obtain seasonal workers, but not all these brokers operate as legitimate and fair businesses. Exploiters pose as legitimate labour brokers while forcing workers into jobs for which they are paid little or nothing.[28; 29]

Gender inequality in agriculture

Inequities are spread systematically throughout the food system and the agricultural sector is not exempt from gender issues and various forms of discrimination. While in Lithuania and Latvia, almost half of all farms are managed by women, in many other countries, such as Malta, Germany, Denmark and the Netherlands, the proportion of female farm managers remains below 10%, indicating a lower level of gender diversity in agricultural management in these regions.[33] Additionally, women working in the agricultural sector worldwide face a significant gender wage gap, earning nearly 20% less than their male counterparts.

Socio-economic well-being

Improving socio-economic well-being goes beyond physical health to include mental well-being, cognitive abilities and future opportunities.[34; 35; 36] It is important to recognize that nutrition and healthy food choices play an essential role in maintaining optimal cognitive function, energy levels and improved concentration.[37] However, adequate nutrition and healthy dietary choices can have economic implications, particularly for those with limited incomes. Affordability and access to nutritious foods play a critical role in facilitating healthy choices. Healthy diets may be more expensive than less healthy diets[38; 39] because energy-dense foods are cheaper than nutrient-dense foods when expressed per unit of energy.[40] The relatively high cost of fruits and vegetables affects people's economic access to recommended healthy and sustainable diets, especially in Eastern and Southern European countries (Table 1).

Food environment

Consumers face a food environment that makes it difficult to purchase and eat more sustainably.[114] These include exposure to products and dishes with unfavourable nutritional profiles high in added fats, sugar and/or salt (e.g., fast food, sugary beverages) and high environmental impacts, or portion sizes that are too large. Offerings (e.g., price, convenience, portion sizes) influence how much, when and where consumers can consume which foods. In addition, consumers are confronted with advertisements and social media content that make unhealthy foods appealing, whereas more sustainable food choices often lack reductive and easy-to-understand information. The challenge is to create a food environment, including access, price and marketing, that supports more conscious food choices by consumers—i.e., environmentally friendly, nutrient-rich, less processed and fair food.

Animal welfare

The welfare of animals in the food industry is an important aspect of social sustainability. Animal welfare can be defined as the physical and mental state of an animal concerning the conditions in which it lives and dies.[110] Often, high stocking densities in intensive production systems not only compromise the animals' freedom of movement, but also leave too little space for them to engage in motivated behaviours, such as rooting or retreating, thus increasing the risk of aggressive interactions and the spread of infections.

Antibiotic use

Management systems and regulations on animal husbandry are not only relevant for animal welfare but also for human health. Antibiotics are an important part of both human and veterinary medicine to cure and prevent

infections. A large proportion of all antibiotics sold worldwide are used to produce food of animal origin.[43] Food from animals treated with antibiotics does not cause immediate health problems for consumers, but it can potentially increase microbial resistance to antibiotics, threatening human and animal health and welfare.[44] In general, the more antibiotics we use, the greater the potential increase in antibiotic resistance and related risks.

Note: A recent modelling study showed that the cost of a healthy and sustainable diet in high- and middle-income countries could decrease by 22–34% when external costs are considered.[42] External costs occur when producing or consuming a good imposes a cost upon society through a negative effect. If there are external costs in consuming a good (negative externalities), the societal costs are higher than the private costs of one's own diet. However, according to Springmann et al., a healthy and sustainable diet would be the most cost-effective dietary option in most countries in the future.[42]

	Affordability of healthy diet**	Cost of vegetables	Cost of fruits	Cost of legumes, nuts and seeds	Cost of starchy staples	Costs of oils and fats	Cost of animal sourced foods
Hungary	**0.49**	**0.75**	**0.83**	**0.42**	**0.41**	**0.09**	**0.81**
Ireland	**0.49**	**0.58**	**0.62**	**0.29**	**0.33**	**0.06**	**0.52**
Sweden	**0.42**	**0.77**	**0.77**	**0.35**	**0.47**	**0.09**	**0.64**
Netherlands	**0.39**	**0.89**	**0.61**	**0.26**	**0.32**	**0.05**	**0.61**
Germany	**0.38**	**0.82**	**0.71**	**0.30**	**0.24**	**0.05**	**0.67**
Poland	**0.38**	**0.89**	**0.65**	**0.38**	**0.32**	**0.09**	**0.58**
France	**0.37**	**0.85**	**0.86**	**0.28**	**0.25**	**0.07**	**0.64**
Spain	**0.37**	**0.74**	**0.80**	**0.21**	**0.28**	**0.05**	**0.62**
Belgium	**0.35**	**0.68**	**0.79**	**0.37**	**0.22**	**0.06**	**0.75**
Greece	**0.35**	**0.74**	**0.58**	**0.41**	**0.41**	**0.10**	**0.80**
Italy	**0.33**	**0.75**	**0.81**	**0.27**	**0.22**	**0.06**	**0.78**

Table 1: Cost of food items in 2017 PPP dollar/capita/day.

Overview of the cost of food items in 2017 PPP dollars/capita/day[41] for PLAN'EAT partner countries. The first column shows the cost of the lowest-cost basket of foods that would meet requirements for food-based dietary guidelines in comparison to the total food budget. As the ratio approaches 1, the more unaffordable the healthy diet; as the ratio approaches 0, the more affordable the healthy diet. Further, the data clearly shows the high costs of fruit and vegetables, particularly when compared to starchy staples. Despite the common market, price differences can be quite substantial between EU countries.

2.2 Case Study: Performance of the Living Lab diets in terms of animal welfare

The objective was to assess how the Living Lab diets contribute to negative animal welfare impacts, using an animal welfare index for animals used for the production of animal-sourced primary products. The animal welfare index value considers: the number of animals involved in the production of one kg of food for different species; the animals' ability to perceive the negative effects of being used by humans (based on a questionnaire answered by 15 animal scientists and veterinarians); and a judgement of the welfare level in the production system (based on national data from scientific literature and "grey literature" from various organisations' and authorities' web pages and reports). The welfare level in the production system is based on frequencies of mortality (at the farm) and disease or injury, available space to body size and duration of the slaughter process. The different components are included in the animal welfare index with different weights. These weights have been identified by the researchers in PLAN'EAT based on scientific literature (e.g., Zira et al., 2020).[112]

2.2.1 Results and Discussion

Results for the different Living Lab diets are presented in Figure 10.

Although dairy consumption is high in terms of kg consumed in all diets, the overall contribution to animal welfare is low due to a low animal welfare index value per kg of milk. This is a result of one dairy cow producing large amounts of milk; i.e., the animal welfare impact is shared by a large mass of food products. The same is true for eggs, where each hen lays a large number of eggs. The animal welfare impacts of the diets reflect meat consumption to a high degree, with the Hungarian and Irish diets having the highest animal welfare impacts, mainly due to high total meat consumption levels in the diets assessed here. These diets also have the highest

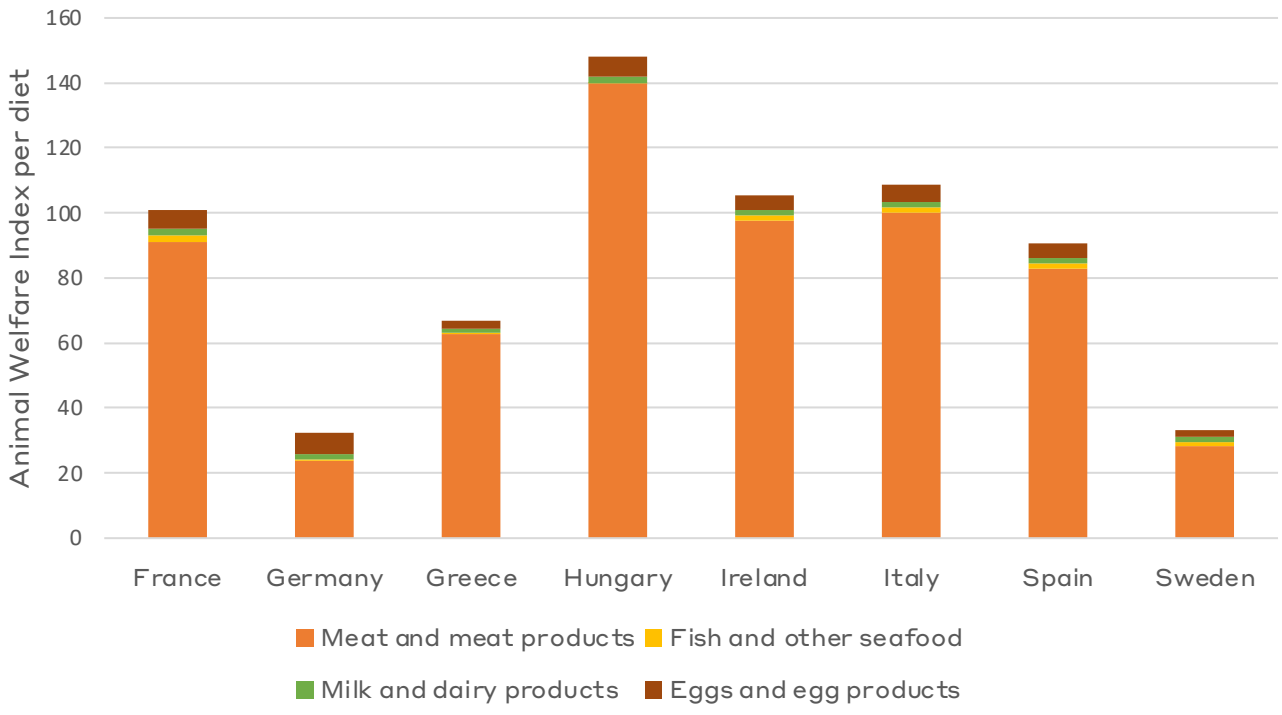


Figure 10: Animal welfare impact from the Living Lab diets.

consumption of chicken, which has a high animal welfare index value, partly due to the higher numbers of animal lives involved in 1 kg chicken meat (as compared to 1 kg beef). That small animals have a higher negative animal welfare impact on the sustainability of diets than large animals has also been shown in studies by Scherer et al.[46] and Paris et al.,[47] assessing diets including a variety of animals from cattle to shrimps and insects. The relatively lower animal welfare impact to total consumption from Swedish and German diets is partly explained by a lower share of chicken meat in diets and partly by higher animal welfare standards.

2.3 Recommended action for policymakers and food professionals

The food system is influenced by and impacts various social sustainability aspects. In this report, we have provided a summary of some of the most important aspects to consider. These aspects are related to dietary choices to varying degrees. While some are directly affected by dietary choices, others have a looser connection to the specific types of food consumed. In the case of the former category, dietary choices play a crucial role in mitigating challenges. However, for the latter category, alternative mitigation options and policies that target, e.g., food production is required. Since the focus of the PLAN'EAT project is on changing dietary patterns, we here focus on actions that food stakeholders can take to achieve such goals. That is, we do not give recommendations on measures to improve food production more directly, such as regulations in production (e.g., for pesticides) or the use of the Common Agricultural Policy to steer agriculture in a greener direction.

Embrace and support the consumption of plant-based foods and a reduction of foods high in added sugars, fats, salt and/or ingredients not found at home, as well as meat and dairy products.

Food can be a powerful driver for change. A fundamental stage in the process of dietary change is the distribution of country-specific guidelines to consumers or the adoption of country-specific guidelines by food professionals and public health organizations working for policy change and support for infrastructure to improve the food environment. It is important to empower food sector actors to integrate recommendations for healthy and sustainable diets based on the PLAN'EAT project.

Shaping sustainable and healthy food environments for consumers.

Consumers need to be supported through the design of appropriate food environments. Requiring actions from governments, food services and retailers, more health-promoting, socially acceptable and environmentally friendly choices need to be offered and promoted. Important measures would be, for example, easier access to information to identify more sustainable options; appropriate price incentives to increase affordability and access to more sustainable options; restrictions on social media advertizing (social influencing); and high-quality community catering and appropriate portion sizes, especially for all children in day-care and school catering. Integrating more sustainable and plant-based options into public food venues, such as restaurants and cafés, creates positive taste experiences among consumers and increases familiarity with such foods.

In the long term, creating a food environment that enables healthier and more sustainable food choices is fundamental to a society in which individuals can succeed physically, mentally and economically.

Create financial access to healthy and sustainable foods.

Affordability and access to nutritious food are crucial in promoting healthy choices. Therefore, it is important to implement fiscal policies such as taxing products that have a greater impact on

human health and the environment and targeting food subsidies and incentives towards fruits, vegetables, whole grains, pulses, nuts and seeds to make healthy and sustainable food more affordable.

2.4 Recommended action for consumers

Sourcing food from a wide variety of independent producers (e.g., at farmers' markets).

Sourcing food from small and local farmers, such as farmers' markets or nearby producers, supports local food systems and rural development and might prevent poor labour conditions. However, local food cannot simply be equated with sustainable food, since, in most cases, it can neither ensure food security nor necessarily have a lower carbon footprint.[45] Therefore, diversifying our sources by buying food from both large and small producers is crucial. This approach not only fosters healthy competition but also mitigates risks associated with over-reliance on a few large suppliers. In essence, it is about achieving a balanced approach that combines the strengths of various producers, regardless of their size, to ensure a robust and resilient food system.

Buying food from certified systems that include aspects of social sustainability, such as Naturland Fair and Fairtrade.

Adhering to certifications that include social aspects can support ethical and sustainable practices throughout the food supply chain, such as ensuring suppliers are paid fairly while promoting supplier transparency and accountability.

Reducing the consumption of animal products in general and choosing organically produced meat or meat from extensive grazing systems.

Dietary choices have a direct impact on animal welfare and the use of antibiotics. Animal welfare outcomes can be significantly impacted by choosing not only less meat but also opting for better meat; i.e., products from countries with stricter animal welfare laws, and production systems with higher animal welfare standards, such as organic or private sector animal welfare labels. State animal husbandry labels and the EU-eco label can support sustainable food choices in this regard.

3 Health Impact

3.1 Food system-related health impacts

The association between food intake and chronic disease must be linked to dietary patterns as a whole, while also considering specific dimensions such as the ratio of animal to plant foods in the diet, the degree of food processing, and food diversity (including organic, local and seasonal aspects).[111] Besides diet-related health impacts, serious risks of communicable and non-communicable diseases and premature mortality are posed by the agri-food sector as a workplace and the environmental and pathogenic contamination associated with agricultural activities and livestock production.

Dietary patterns and chronic disease risk

Dietary patterns characterized by low intake of plant foods but high intake of red and processed meats, refined grains, high-fat milk, UPFs, alcohol and foods/beverages with added sugars have been associated with increased risk of chronic diseases such as coronary heart disease (CHD),[49] T2DM,[49, 50, 51] and cancer.[52, 53, 54] In contrast, a plant-based diet rich in fruits, vegetables, whole grains, legumes, low-fat dairy products, white meats and nuts is inversely associated with disease risk and mortality outcomes.[55, 56, 57]

Plant-based foods

To assess the relationship between diet

and human health, the simultaneous consideration of several potential dimensions of dietary patterns is required. These dimensions include the relationship between animal and plant foods in the diet. The inclusion of more plant-based foods (e.g., fruits, vegetables, whole grains, legumes, nuts/seeds) in the diet is consistently favourable for human metabolism (e.g., less inflammation,[58; 59] oxidative stress,[60] and cardiovascular disease risk factors[61; 62]) and for decreasing all-cause mortality (-10%),[56] T2DM (-23%)[63] and coronary heart disease (-23%)[57] risk. Great benefits can be achieved when replacing meat with minimally processed plant-based protein foods, such as legumes.[64]. It has been shown that substituting various animal proteins, especially red and/or processed meat protein with plant proteins may reduce the risk of all-cause and CVD mortality, T2DM, and CHD[65; 66] and may improve glycaemic control in individuals with T2DM.[67] This is particularly important considering that red meat consumption is associated with higher chronic disease risks, particularly stroke (+10%),[68] colorectal cancer[69] and prostate cancer (+4%).[70]

Food processing

With the increasing hyper-industrialization of food processing in recent decades, there has been an increase in the prevalence of chronic diseases. Related to this is the consumption of UPFs, which have often higher levels of added sugars, salt and/or saturated fatty acids and are associated with an increased risk of all-cause early mortality and various chronic diseases.[71; 72; 73; 74, 75; 76; 77; 78; 79] UPFs, such as soft drinks, sweet or savoury packaged snacks and pre-prepared frozen dishes, are formulations made mostly or entirely from ingredients derived from foods and additives that result from a series of industrial processes (hence "ultra-processed").[80] However, it should be noted that UPFs are a very broad category and, in some cases, include foods that are not always or equally harmful to health (e.g., dark/whole-grain bread, fruit-based products and yoghurt/dairy-based desserts).[81] Therefore, it is important to assess the impact of UPFs as part of a broader dietary pattern. In the context of a largely ultra-processed dietary pattern, the compositional differences between individual UPFs become less important and it is the ultra-processed dietary pattern (rather than individual foods) that contributes to the detrimental impacts on health.[82]

Dietary variety

Dietary variety scores are more strongly related to nutrient adequacy than health outcomes.[84] However, there is evidence suggesting that a higher food variety might protect, e.g., from degraded quality of life over time in human immunodeficiency virus (HIV) patients,[85] overweight/obesity,[86] T2DM,[87] metabolic syndrome[87] and certain cancers.[88, 89] Yet, further studies are warranted to substantiate these effects.

Organic foods

Concerning the consumption of organically certified foods, it has been found that some organic foods are more nutritionally dense than their conventional counterparts, including meat, dairy and some plant-based products.[90, 91] The first results point to the direction of increasing organic food intake as a means of reducing risks of overall cancers,[92] T2DM,[93] obesity[94] and metabolic syndrome.[95] Possible major explanations for these negative associations are the prohibition of synthetic chemical pesticides in organic farming and the difference in bioactive components between organic and conventional foods (e.g., n-3 fatty acids and antioxidants).[96]

Nutrient adequacy

A well-planned plant-based diet that ensures adequate nutrient intake may be further supported by the consumption of fortified foods and/or supplements for important nutrients. This is because those that follow a plant-based diet may be at increased risk for deficiencies of

certain essential nutrients such as vitamin B12, vitamin D, calcium, iron, zinc and iodine, which are primarily or preferentially available from animal foods. This applies to adults but especially to children and adolescents. Plant-based diets have been shown to support normal growth in children/adolescents, but care must be taken to ensure that they are nutritionally adequate.[97; 98]

Obesity

Obesity significantly increases the risk of chronic diseases such as cardiovascular disease, T2DM, hypertension, coronary heart disease and certain cancers.[99; 100] Obesity can also be associated with a range of mental health problems.[101] Weight problems and obesity are increasing rapidly in most EU member states. According to WHO, almost 60% of adults in the European Region are overweight or obese. Children are also affected: 8% of children under 5 and one in three school-age children are overweight or obese.[102]

Occupational and environmental health risks in food production

Occupational risks at sites of food production and processing make the agri-food sector one of the most dangerous workplaces. Exposure to chemicals, biological agents, physical hazards and injuries increase the risks of communicable (e.g., influenza viruses[103]) and non-communicable diseases (e.g., male infertility, eye and digestive complications, Alzheimer's disease, Parkinson's disease, specific types of cancer[104; 105] and hearing loss[106]). Moreover, our food systems contribute to a large extent to the rising burden of environmental (e.g., air and water pollution, global warming) and pathogenic (e.g., zoonotic diseases) risk factors, which pose serious threats to public health and increase the burden on health care systems.

	Sweden		France		Italy	
Food Group	**% energy intake**	**g/day**	**% energy intake**	**g/day**	**% energy intake**	**g/day**
Fruits	**4.5±4.3**	**121±110**	**3.6±3.8**	**131±128**	**4.7±3.8**	**217±161**
Vegetables	**3.7±3.6**	**137±98**	**4.4±3.9**	**185±129**	**2.3±1.5**	**209±107**
Grains	**20.9±9.1**	**210±119**	**20.6±9.8**	**185±115**	**31.5±8.6**	**219±93**
Legumes	**0.8±2.0**	**12±26**	**0.6±1.6**	**10±25**	**0.8±1.6**	**18±30**
Fish	**4.0±4.8**	**45±50**	**2.7±3.8**	**37±49**	**2.2±2.5**	**45±51**
Dairy	**6.9±5.5**	**241±201**	**5.9±5.6**	**178±185**	**3.7±3.5**	**128±115**
Nuts/seeds	**1.0±2.9**	**3±11**	**0.7±2.1**	**3±8**	**0.3±1.0**	**1±5**
Red meat	**6.8±5.8**	**75±64**	**4.9±5.2**	**53±56**	**4.1±3.5**	**59±50**
Processed meat	**3.9±4.4**	**32±36**	**4.1±5.3**	**36±48**	**3.8±3.6**	**27±27**
SSBs	**1.4±2.6**	**80±150**	**2.4±3.6**	**128±210**	**0.9±1.9**	**49±101**

Table 2: Composition of baseline diets in the test countries.

Values are presented as percentages of daily energy intake and average grams per day from selected food groups (mean standard deviation). The selected food groups represent only a proportion of daily energy intake. Grains refers to total grains (whole and refined). Vegetables refers to non-starchy vegetables. Dairy refers to milk and yoghurt. SSBs are sugar-sweetened beverages.

3.2 Case Study: Quantifying health impacts of shifting European dietary patterns towards dietary recommendations

The objective of this study was to use a health impact model to assess how the large-scale adoption of the Mediterranean diet (MD) and the Planetary Health Diet (PHD) (hereafter referred to as the target diets) would affect the annual burden of major chronic diseases (i.e., CVD, T2DM and cancer) in three European countries (Sweden, France and Italy) for which consumption data were freely accessible.

The health effects of changing dietary patterns were assessed using data from national food consumption surveys. Table 2 summarizes the composition of the baseline diets as calculated using data from adult individuals (≥18 years) in each dataset. The percentage of daily energy intake per food group was calculated for the target diets (see Table 4 for recommended intakes in an adult diet). As shown in Table 3, the MD gives more emphasis to increasing fruits and vegetables, moderately decreasing red and processed meat and largely decreasing added sugars, while the PHD prioritizes an increase of legumes and nuts and a reduction of red and processed meat.

The effects of 10 dietary factors on the risk of nine chronic diseases (CHD, ischemic stroke, subarachnoid and intracerebral haemorrhage, colorectal cancer, breast cancer, oesophagal cancer, tracheal/bronchial/lung cancer and T2DM) were calculated. These chronic diseases, which are partly attributable to diet-related risk factors,

	Mediterranean diet		Planetary health diet	
Food Group	**% energy intake**	**g/day***	**% energy intake**	**g/day***
Fruits	6.9	276	5.0	200
Vegetables	9.6	919	3.1	300
Starchy vegetables	1.8	59	1.6	50
Grains	33.7	241	32.4	232
Legumes	5.0	33	11.3	75
Red meat	2.2	26	1.2	14
Processed meat	1.2	14	0.0	0
Fish	1.6	28	1.6	28
Poultry	2.3	27	2.5	29
Dairy	7.5	306	6.1	250
Nuts/seeds	8.0	34	11.6	50
Added sugars	1.4	9	4.8	31
Saturated fat	NS	NS	3.8	12
Unsaturated fat	16.5	47	14.1	40

Table 3: Composition of the target diets

Values are presented as percentages of daily energy intake and grams per day from main food groups.
* Based on an average energy intake of 2500kcals per day. Values in the Planetary health diet correspond to the scientific targets as outlined in the summary report of the EAT–Lancet Commission.[109] Grains refers to total grains (whole and refined). Vegetables refers to non-starchy vegetables. Sugar-sweetened beverages (SSBs) are included in the Added sugars category in this study. NS stands for not specified.

are a major cause of disease burden and together account for more than 715 million Disability Adjusted Life Years (DALYs) worldwide.

3.2.1 Sweden

The baseline diet in Sweden was closer to the PHD recommendations for fruit intake and closer to the MD recommendation for SSB (i.e., added sugars) intake, but it deviated from both target diets in terms of other food groups. In general, the intake of grains, legumes and nuts was below the recommendations of both diets; red meat, processed meat and fish intake was above recommendations; and vegetable and dairy intakes were in between the recommended intakes of the target diets. The MD scenario was estimated to save a total of 15,369 DALYs/year, with main contributions from increased consumption of legumes, grains, nuts/seeds and vegetables and reduced consumption of red and processed meat (Figure 11). This corresponded to a 6.5% reduction in aggregate disease burden. In turn, the PHD scenario was estimated to save 18,942 DALYs/year (8% reduction in aggregate disease burden), with main contributions from increased consumption of legumes, grains and nuts/seeds and reduced consumption of red and processed meat.

3.2.2 France

The French diet was low in fruits, grains, legumes, dairy and nuts/seeds and high in red meat, processed meat and fish compared to the target diets, while the intake of vegetables and SSBs was in between the recommended intakes of the target diets. Shifting the French diet towards the principles of the MD was estimated to save 70,346 DALYs/year (6% reduction in aggregate disease burden) with main contributions from increased consumption of grains, legumes, nuts/seeds, fruits and vegetables and reduced consumption of red and processed meat (Figure 12). Shifting to the PHD was estimated to have a larger health impact with 80,901

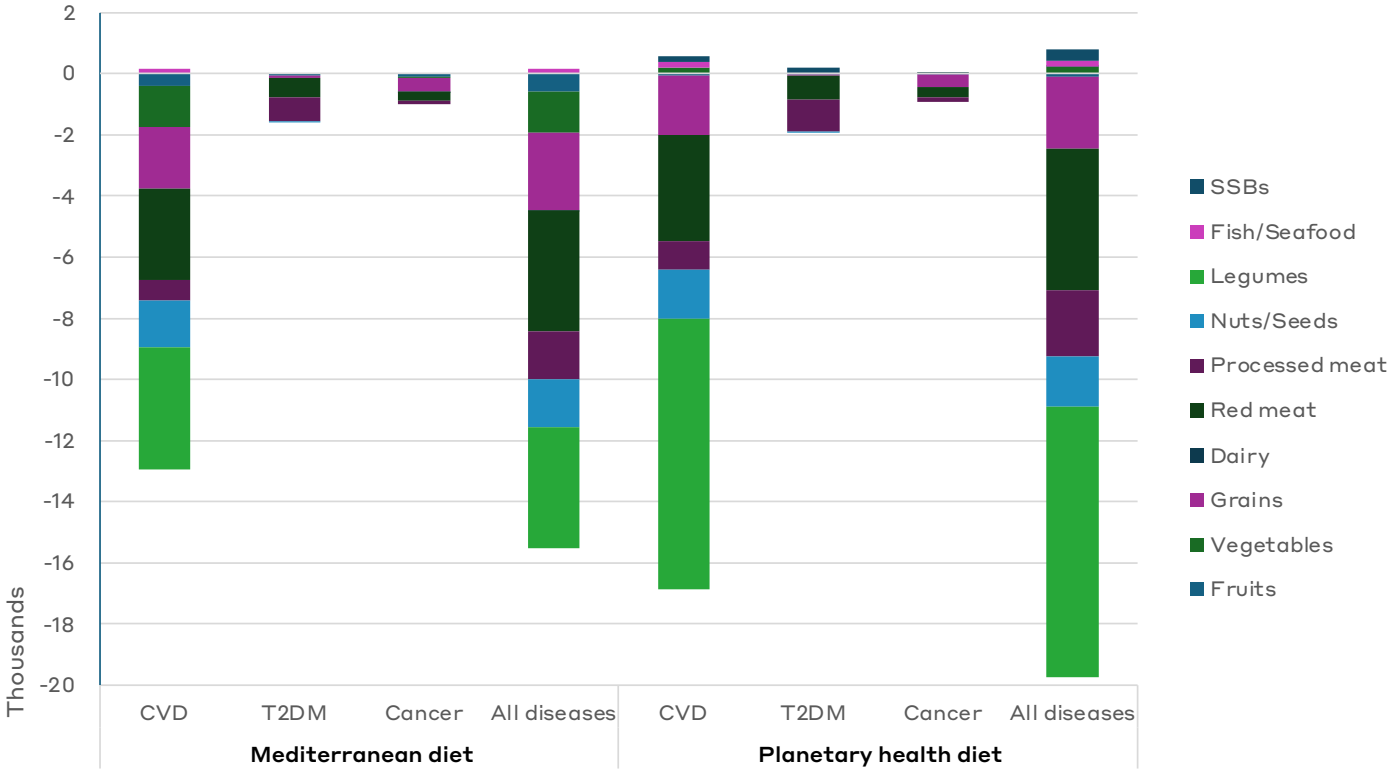


Figure 11: DALYs saved or lost per year following each dietary shift scenario in Sweden.

CVD: cardiovascular disease; SSBs: sugar-sweetened beverages; T2DM: type 2 diabetes mellitus.

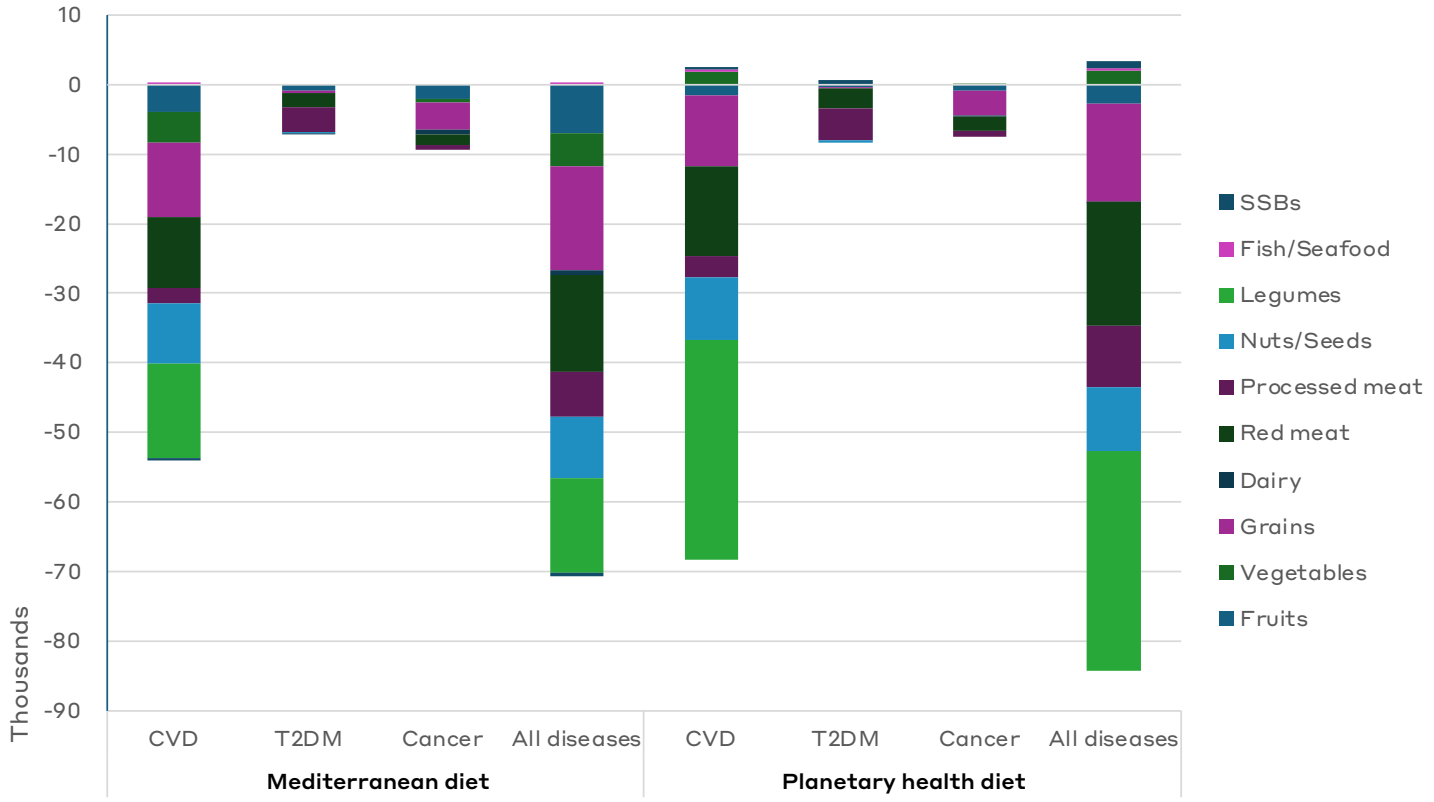


Figure 12: DALYs saved or lost per year following each dietary shift scenario in France.

CVD: cardiovascular disease; SSBs: sugar-sweetened beverages; T2DM: type 2 diabetes mellitus.

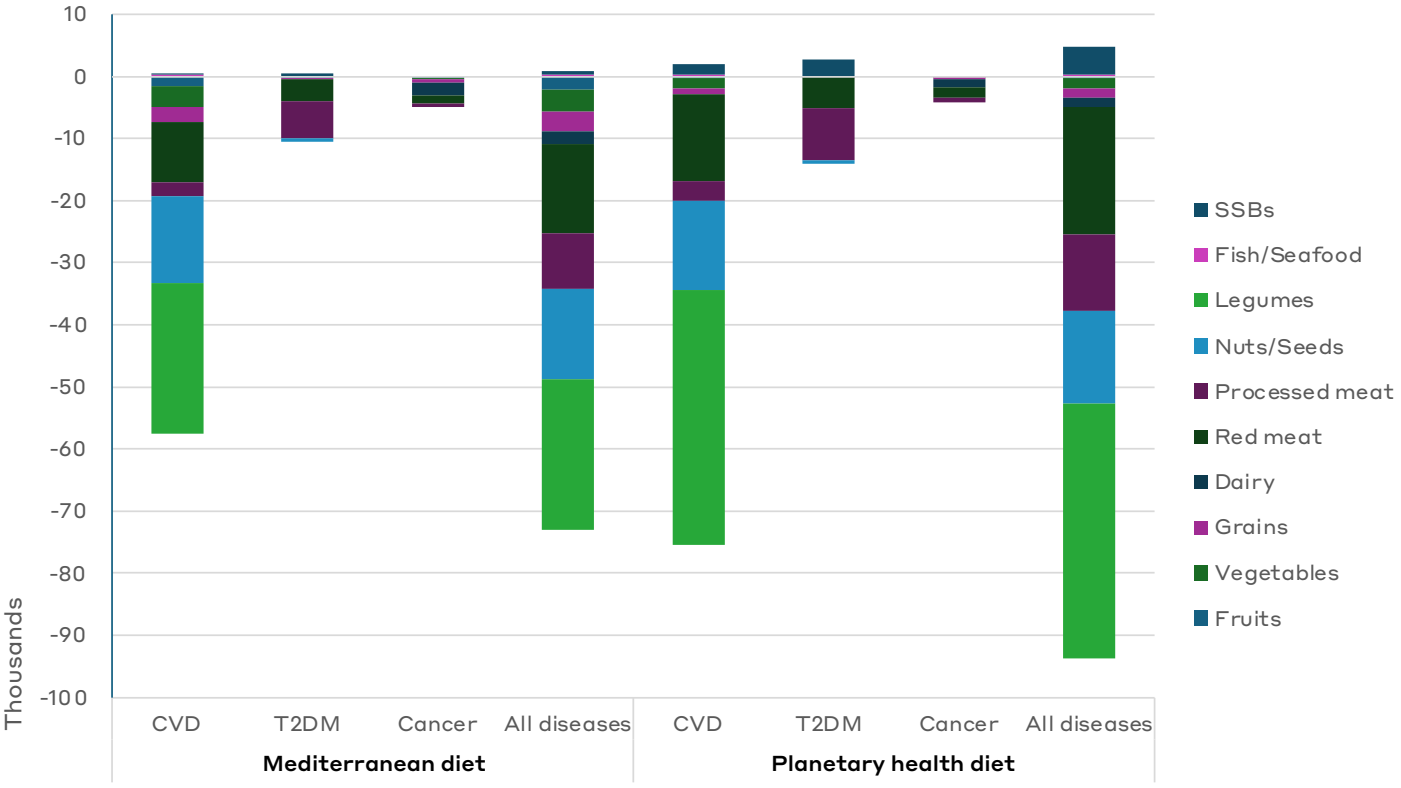


Figure 13: DALYs saved or lost per year following each dietary shift scenario in Italy.

CVD: cardiovascular disease; SSBs: sugar-sweetened beverages; T2DM: type 2 diabetes mellitus.

DALYs saved per year (6.9% reduction in aggregate disease burden) and main contributions were from increased consumption of legumes, grains and nuts/seeds and reduced consumption of red and processed meat.

3.2.3 Italy

The baseline diet in Italy was low in vegetables, legumes, nuts/seeds, and SSBs and high in red meat, processed meat and fish compared to recommended intakes in the target diets. Fruit intake was close to the PHD recommendation and grain intake was close to the recommendations of both target diets. A total of 72,017 saved DALYs/year (4.9% reduction in aggregate disease burden) was estimated for the MD scenario, while the PHD scenario was found to have a larger health impact with 88,964 DALYs saved per year (6% reduction in aggregate disease burden) (Figure 13). In both scenarios, main contributions were from increased consumption of legumes and nuts/seeds and reduced consumption of red and processed meat.

3.2.4 Conclusion

Although both dietary shift scenarios proved to be healthier alternatives compared to the baseline diets in the test countries, the PHD scenario was found to have a more pronounced positive health impact than the MD scenario across countries (6%–8% versus 5%–6.5% reductions in disease burden for PHD and MD, respectively) (Figure 14). This was largely due to the fact that the PHD prioritizes the consumption of legumes and nuts/seeds as protein sources, while also reducing red and processed meat consumption considerably. On the contrary, the MD prioritizes increased consumption of fruits and vegetables and is more moderate in legumes, while recommending smaller reductions in red and processed meat compared to the PHD. Given that, across countries, legume and nut/seed intake was considerably below recommended intakes of both target diets and red and processed meat intake was considerably above, these dietary factors were the most determinative of the overall health impact associated with each dietary shift.

Interestingly, baseline fish intake in all countries was higher than recommended intakes in both target diets. Both dietary shift scenarios therefore led to lost DALYs for this dietary risk factor. The same was the case for vegetable intake in Sweden and France. Conversely, baseline SSB intake was lower than the recommended intake of added sugars in the PHD, thereby also leading to DALYs lost in all countries in this scenario.

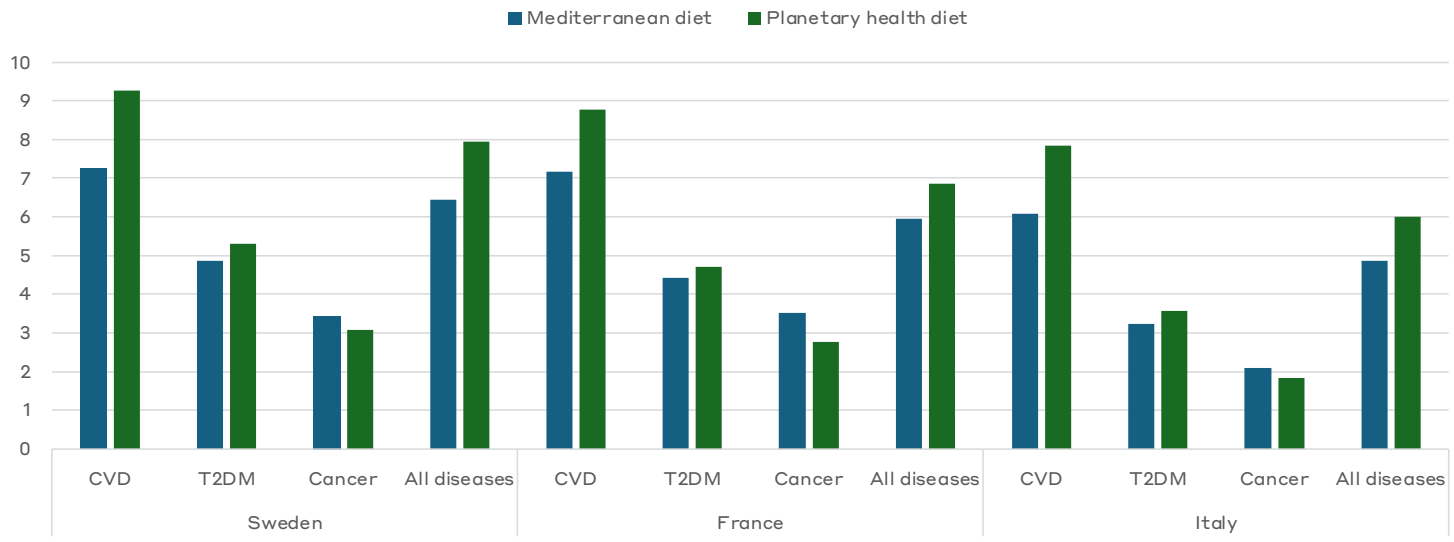


Figure 14: Percentage of reduction in disease burden associated with each dietary shift scenario in Sweden, France, and Italy.
CVD: cardiovascular disease; SSBs: sugar-sweetened beverages; T2DM: type 2 diabetes mellitus.

3.3 Recommended action for consumers and food professionals

The recommended diet is characterized by a high consumption of fruit, vegetables, whole grains, legumes and nuts/seeds; moderate consumption of low-fat dairy and white meat; and limited consumption of red and processed meats, foods with added sugars, fats, salt and/or ingredients not found at home, and alcohol.

A large-scale transition in consumers' dietary choices could help reduce health impacts associated with unhealthy food consumption and could perhaps work as a driver of change for the production and processing stages of the farm-to-fork chain. A large-scale adoption of a diet high in a variety of minimally processed and plant-based foods, with only moderate consumption of high-quality animal-based foods, would reduce the burden of key chronic diseases such as cardiovascular diseases, T2DM and various types of cancer by 5%–8%.[107]

Prioritize the replacement of red and processed meats, rather than that of other animal-sourced foods, such as dairy products, poultry and fish.

Fish as a source of omega-3 fatty acids can be consumed several times a week, alongside optional moderate consumption of poultry, which provides protein and micronutrients such as vitamin B12, tryptophan, choline, zinc, iron and copper.[16]

Embrace alternative sources of protein.

When decreasing meat and meat products, the individually required protein intake should be provided by protein-rich, plant-based foods, as well as low-fat dairy and eggs. However, many plants are both healthy and sustainable sources of dietary protein. The aim is to consume three servings of beans, lentils, peas and other legumes per week (one serving for an adult diet is 70 g of dried legumes or 125 g of cooked).

When following a primarily plant-based diet, make sure to frequently consume foods rich in calcium, iron and zinc.

Tofu, beans, lentils and nuts can be good sources of calcium, iron and zinc. Eating or drinking a source of vitamin C (e.g., citrus fruits, bell peppers) will improve iron absorption from plant foods, as will avoiding the consumption of tea and coffee for around one hour before or after meals.

When following a primarily plant-based diet, consider adding fortified foods to the diet and/or supplementing adequate intakes of nutrients.

Following a vegetarian or vegan diet with no or little consumption of animal products has implications for nutrient intake, as it is difficult to meet the needs for certain nutrients like vitamin B12, vitamin D and iodine when restricting all animal foods or consuming very little of them. In some circumstances, this can lead to nutrient deficiencies and increased risk of malnutrition. The consumption of fortified foods like breakfast cereals (preferably not ultra-processed), whole grain bread and plant-based milk/yogurt alternatives (preferably not ultra-processed) or supplements will ensure adequate intakes of these key nutrients.

Limit the consumption of UPFs and products with high levels of added sugars, fats, and/or salt.

The consumption of UPFs is associated with increased risks of early all-cause mortality and several chronic diseases. Limiting UPFs (particularly refined breads, sauces, spreads, condiments, artificially and sugar-sweetened beverages, processed animal-sourced foods, most industrial ready-to-eat dishes and desserts) in the diet may therefore prevent or reduce health impacts.

Favour whole grain products over refined grains.

Carbohydrates should primarily be sourced from whole grains, with a low intake of refined grains and less than 5% of daily energy from simple sugar (i.e., from fruit juices, honey and added table or industrial sugars).

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About the project

PLAN'EAT is a Horizon Europe project that seeks to facilitate the transition towards healthy and sustainable dietary behaviour through an in-depth understanding of the underlying factors and drivers and the development of innovative, effective recommendations, tools and interventions addressing different agri-food system actors.

PLAN'EAT aims to implement a systemic approach at the macro (food system), meso (food environment) and micro (individual) levels. Various socio-cultural and geographic contexts across Europe will be considered by implementing nine living labs in different European areas, five pan-European food value chain consultation and working groups, and national and pan-European policy labs.

As part of a consortium of 24 partners, TMG is leading work on True Cost Accounting (TCA) to analyze the environmental, socio-economic and health impacts of European diets and their associated costs. This component of the project includes:

- analyzing the availability of TCA data
- developing a database of the impacts and true costs of 2,000+ food products consumed in Europe
- assessing the true costs of three different European dietary patterns
- providing recommendations for using TCA for holistic food systems policy and the development of national dietary guidelines

Building on this work, TMG will also be involved in developing a roadmap for the establishment of a proposed European Food Policy Council, as well as setting up a methodology framework to design easy-to-understand healthy and sustainable food-system-based dietary guidelines at the national level, for various population groups.

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