MISTRA FOOD FUTURES

Food as Industry, Food Tech or Culture, or even Food Forgotten?

A report on scenario skeletons of Swedish Food Futures

Line Gordon, Klara Eitrem Holmgren, Jan Bengtsson, Martin Persson, Garry Peterson, Elin Röös, Amanda Wood, Rakel Alvstad, Shyam Basnet, Anne Charlotte Bunge, Malin Jonell, Ingo Fetzer

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Food as industry, food tech or culture, or even food forgotten? A report on scenario skeletons of swedish food futures

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The overarching vision of the programme Mistra Food Futures is to create a science-based platform to enable transformation of the Swedish food system into one that is sustainable (in all three dimensions: environmental, economic and social), resilient and delivers healthy diets. By taking a holistic perspective and addressing issues related to agriculture and food production, as well as processing, consumption and retail, Mistra Food Futures aims to play a key role in initiating an evidence based sustainability (including environmental, economic and social dimensions) and resilience transformation of the Swedish food system.

Mistra Food Futures is a transdisciplinary consortium where key scientific perspectives are combined and integrated, and where the scientific process is developed in close collaboration with non-academic partners from all parts of the food system. Core consortium partners are Swedish University of Agricultural Sciences (SLU), Stockholm Resilience Centre at Stockholm University and RISE Research Institutes of Sweden.

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1. Introduction

As we look into the future of the Swedish food system, we are confronted with substantial uncertainty and complexity. How will conditions for food production in Sweden change due to climate change, technological advancements and demographic developments? What type of food will today's children eat when they are adults, and what will the children of 2045 eat? Where will our food come from; to what extent will it be grown on land, in oceans or manufactured in factories located in Sweden, or elsewhere?

By providing a structured way of thinking about the future, scenarios can be used to evaluate how current action and inaction can create alternative pathways and futures (IPBES, 2016). Scenario development uses diverse methods to explore how structural change in the food system can emerge from the interactions of conflicting actors, in a rapidly changing, and sometimes turbulent, dynamic world (Benton, 2019). Here, we define a scenario as a plausible, simplified description of how the future could develop, based on a coherent and internally consistent set of assumptions about driving forces and key relationships (MA, 2005), and a pathway is the course of action within each scenario.

The reason we use scenarios in this project is threefold. First, we know that business as usual is not an option. At the global scale, the current food system is far from a system that ensures healthy people and a healthy planet (Willett et al., 2019). This is also true for Sweden, where diets are the third leading risk factor for poor health (IHME, 2021), over fifty percent of the adult population is obese or overweight (Public Health Agency of Sweden, 2021), and dietary risk factors account for about 15% of deaths and 8% of disability-adjusted life years (DALYS) (IHME, 2020). The environmental impacts caused by the average current Swedish diet (scaled to per capita levels) exceed the national share of globally identified boundaries for greenhouse gas emissions, land use change and application of nutrients through fertilisation by two- to more than four-fold, and transgressed boundary for biodiversity loss by six-fold (Moberg et al., 2020).

It can be hard for people to even imagine what a sustainable food future would look like, and also how to get there, because achieving sustainable goals will require substantial changes in current diets, production systems and supply chains. Imagining pathways to such a transformation requires integrating diverse data, models, and perspectives, as well as thinking rigorously and creatively, about how change takes place. These are tasks well suited to scenario planning.

Second, many food system actors have starkly contradictory perspectives on the problems that the food system faces, the type of changes that will lead to sustainable future food systems, and who the actors are that have the responsibility and agency to change (Röös et al. forthcoming). Pluralistic scenarios can enable us to examine contradictory perspectives and how they play out over time, and such scenarios can also be useful for actors to develop plans to cope with a wide range of possible futures.

Third, the future in the Anthropocene is surprising, turbulent, and uncertain (Folke et al., 2021). Human societies are rapidly changing the Earth system, by increasing the speed, scale and interconnectivity of activities across the globe. This means that humanity is altering the fundamental properties of the food system and Earth's life support systems. The Covid pandemic and resulting restrictions on movement and trade is one such example of a surprise with substantial impact on food systems globally and in Sweden, as are the emerging global impacts of the Russian invasion of Ukraine on global trade, food and energy.

As the human and natural world continually change and evolve, it can be difficult to disentangle how intentional change in one place, reshapes opportunities in another. The Swedish future of food thus needs to be understood in a global context as it is strongly shaped by global policies and developments related to, e.g., trade, nature, and energy. Furthermore, changes in the Swedish food system impact other places by altering demand or production practices for products. Swedish actions can catalyse or impair the management of global commons, and the achievement of global goals such as the Paris Agreement and the Sustainable Development Goals. By linking our Swedish scenarios with existing global scenarios, in the next step, we can discuss Sweden's global connections.

In this report, we present the skeletons of four scenarios of future Swedish food systems in 2045 for the MISTRA Food Futures programme. A scenario skeleton represents a scenario's main structure and the core features of its narrative. Skeletons allow for a comparison between the different scenarios' narratives, to ensure that they are both internally consistent in their descriptions of the Swedish food system as well as sufficiently divergent to create an interesting range of futures to compare and contrast against each other. The skeletons will be further developed with more qualitative details and quantitative modelling in the second phase of this project.

To prepare the scenario skeletons we examined features, trends and drivers of change that have been identified in the current Swedish food system. We also explored what alternate futures of the Swedish as well as Nordic and global food systems have been developed as well as research on food system transformation. We compiled an overview of both short-term and long-term trends in the Swedish food system (2.1) and compiled and analysed previous food scenario studies (2.2). A more detailed report on this work will be published (Eitrem Holmgren et al., in prep.).

2. Current Trends, Drivers of Change, and Alternate Food Futures

2.1 Current trends in the Swedish food system

In order to build plausible scenarios that represent a logical development from the current state of the food system, we compiled recent (over the past few years) and long-term (over the past decades) trends in the Swedish food system. The compilation covers the main sectors of the Swedish food system, drawing a picture of how we currently produce, process, sell and consume food and in what ways this has changed over time. We focus on trends that either represent key developments in the Swedish food system in the last decades or align closely with issues that are discussed in the scenarios' storylines, covering mainly agricultural, social and economic trends. A report on this trends synthesis with additional in-depth analysis is published separately (Eitrem-Holmgren et al., in prep). Trends related specifically to the three targets for the scenario skeletons (relating to climate change, biological diversity and nutrition and health) are also found in Table 3b.

A compilation of trends is found in Figure 1. The figure represents the general direction of trends during 2010-2020, divided into the different sectors of the food system. Trends in yellow have experienced increases in the last decade, blue represent decreases, and grey represent trends or statistics that have kept a relatively constant development. Note that the colour of each trend only shows the direction of its development and does not represent whether it has improved or reduced sustainability of the food system. As an example, there is an increasing trend of the size of agricultural holdings (+16%) and a decrease in the number of people working with agriculture (-7%) between 2010-2020. The percentage change for the period is calculated as the difference between the first and the last year. The whole time period was however examined to ensure that these two years were not outliers in relation to the general development of the trend.

As seen in Figure 1, the agricultural sector has seen structural changes to fewer, larger and more specialised farms over time with a decreased workforce in size (OECD, 2018). With a seventeen percent decrease in the last decade, there were 58791 agricultural holdings in 2020, with an increased average size from 37 to 42 hectares over the same time period (Swedish Board of Agriculture [SBA], 2011b; 2020b, 2022i). The workforce has become older over time, both within agricultural production and inland and coastal fisheries (SBA, 2020a, p.17; 2022g; SBA & Swedish Agency for Marine and Water Management [SwAM], 2021). More farms are today involved in other economic activities outside of agricultural production, such as processing and selling of products on the farms or tourism (+25% in the last decade). There is a loss of arable land to forestry, a trend that has been more or less continuous since at least the 1950s (SBA, 2011a). The small increase in the area of pastures and meadows in the last decade (+3%) is partially a result of change in the area definition in the material that the statistics is based on (SBA, 2021d). The exploitation of arable land, for mainly buildings but also for example industry and infrastructure, comprises a smaller share of this loss of arable land. The exploitation rate has experienced a marginal increase in 2016 to 2020 compared to the previous five-year period, but continues at a quite stable rate of an average 600 hectares per year (SBA, 2013a; 2017; 2021a).

There are overall fewer farms working in the livestock sector, with more animals per farm but a reduction of the total number of animals, with the exception of for instance a large increase in the number of broilers (+67% between 2010 and 2020). While most livestock sectors have experienced an overall decrease in production since

1995 (OECD, 2018), Swedish meat production has increased in the last decade (+4% between 2010 and 2019 and +7% between 2010 and 2020). This is particularly because of the great increase in poultry production (+42% between 2010 and 2020) (SBA, 2019a). In 2010 to 2020, the volume and landing value of catchments from sea fisheries have decreased whilst inland fishery catchments increased in volume and value. The volume of aquaculture production decreased in recent years to increase slightly in 2020 again (SBA, 2021h).

The food processing sector is concentrated, shifting, and growing. The number of processing companies has increased as well as their value added, but with a declining number of people employed in the food industry (representing an 18 percent decrease between 2000 and 2019, and 4 percent decrease between 2010 and 2019). The number of people employed in the beverage and tobacco industry however increased by 14 percent in 2010 to 2019. Grocery retail shows a decline in the number of grocery stores, particularly thinning in rural areas, with an increase instead in the number of supermarkets (Amcoff, 2017). The slight increase in market consolidation has resulted in the three largest retail actors now covering almost ninety percent of the market (DLF et al., 2021). New trends in the retail market in the last decade include an increase in meal kit companies and a substantial growth in grocery e-commerce during the COVID-19 pandemic to represent 5.8 percent of total grocery retail in 2021 (Sweden Food Retailers' Federation, 2021b).

Swedish food consumption has greatly changed, resulting in diets with higher energy intake and changed eating habits. Many of the developments of the last decade represented in Figure 1 represent longer trends. For example, Swedish consumers bought substantially more processed foods (such as store-bought bread instead of flour), pasta, fresh vegetables and fruit and less potatoes and milk in 2020 than in 1990. Total meat consumption increased in the last decades but has decreased by ten percent between 2017 and 2020. The sales of plant-based proteins have at the same time increased by 33 percent between 2017-2019 from initial relatively low levels to reach a yearly sale of 862 million SEK in Swedish retail (Macklean, 2020). For more detail on consumption trends of particular food products, see Table 3b. While Swedish consumers spend relatively less on food in comparison to the 1990s (SBA, 2015b), the shares of Swedish household expenses spent on both food purchases and eating out have increased in the last decade (Ekonomifakta, 2022).

Sweden has a negative net trade of both agro-food trade as a whole as well as for particularly processed agricultural and food products, but with a smaller trade deficit concerning only processed products (OECD, 2018, p.38). Both import and export values of agricultural and food products have increased yearly in the last twenty years (SBA, 2022p). A change in this development occurred in 2020 as the trade deficit decreased for both total trade as well as specifically processed goods, which may be linked to the COVID-19 pandemic (SBA, 2021e). The market share of several types of Swedish meat experienced an increase from 2013 (+19% between 2013-2020), after a long decline following Sweden's accession to the EU in 1995 (SBA, 2021b). In the last decade, six categories of processed food products have dominated Swedish export: beverages; various food products (including for example products such as soups, sauces, margarine and other cooking fat); processed fish- and seafood products; processed cereals; coffee etc.; and dairy- and egg products (SBA, 2014; 2021e).

2.2 Analysis of food scenario studies

To ensure that our scenarios both build on and contribute to the field of food system scenarios, we compiled and analysed a selection of food scenario studies. We conducted an in-depth analysis of a selection of twenty-six foresight studies of food systems (see Appendix 2). The studies varied by type and included scenarios, megatrends analysis, and qualitative storylines and/or quantitative scenario modelling. We analysed studies that either include scenarios that are 1) influential in the scenario literature or 2) address aspects of particular relevance for the ambition of the MISTRA programme's scenarios, such as a focus on the Swedish food system. In addition to this set of studies, additional food scenario research has been used to improve the scenarios, but this research was not included in the in-depth analysis. The literature analysis was complemented by a meta-review of other literature reviews of food system scenario studies to compare and contrast the findings of our literature analysis. The meta-

Agricultural production	Size of average agricultural holding +16%	Farms with other economic activities (% of farms) +25%	Share of agricultural holders, 65+ years +33%	People working in agriculture -7%	Types of farms Mixed agriculture: -23% Farm animals: -23% Crop production: -19% Small farms: -10%	Agricultural holdings (n) -17%	
Cropping and livestock	Extent of pasture and meadow (ha) +3%	Exploitation of agricultural land Ca 3000 ha/ 5 years	Total crop production; yield per ha: Spring barley: +20%; +29% Winter wheat: +60%;+32%	Animals (n) Broilers: +67% Laying hens: +47%	Farms with livestock (n) Dairy cows: -45% Pigs: -32% Cattle: -29% Laying hens: -15%	Animals (n) Dairy cows: -13% Pigs: -10% Cattle: -6% Laying hens: -5%	Extent of areable land (ha) -3%
Blue food production	Catches in inland waters Value: +35% Metric tons: +15%	Aquaculture production of fish for consumption +7%	People employed in aquaculture +36%	Share of commercial fisherman in inland waters, 65+ years 2018: 30%	Fishing licenses (n) 2011-2018 Inland waters: stable Sea fisheries: decrease	Vessels in Swedish fleet (sea fisheries) (n) -23%	Catches by Swedish sea fisheries Value: -12% Metric tons: -19%
Processing	Farms that process and sell farm products (n) +80%	Food companies Net sales: +23% Value added: +20%	Food companies (n) +26%	Beverage and tobacco companies (n) +392%	People employed in food industry -8%	People employed in beverage and tobacco industry +19%	
Retail	E-commerce (% of grocery retail) 2019-2021: +195%	Market share of three largest retail actors 2+11-2020: +5%	Total value added of food retail companies 2011-2018: +32%	Organic food and drink products (value of sales) 2014-2020:+29%	Grocery retail companies (n) 2011-2020: -4%	Grocery retail stores (n) 2017-2019: -11%	Meal kit companies (n) 2007:1-2 2020: 20+
Consumption	Food costs (share of expenses) 2010-2019: +2% 2019-2020:+6%	Direct consumption Pasta: +3% Fresh vegetables: +7% Cheese: +7%	Plant-based protein (sales) 2017-2019: +33%	Total meat consumption 2000-2016: +16% 2016-2020:-10%	Direct consumption Milk: -28% Flour: -24%	Eating out and hotels (share of expenses) 2010-2019: +16% 2019-2020: -22%	
Import and export	Swedish market share 2011-2019 Onions +15% Eggs +7%	Trade deficit Processed goods 2011-2019: +63% 2019-2020: -7%	Trade deficit 2010-2019: +61% 2019-2020: -8%	Swedish market share 2011-2019 Dairy: -10% Cheese: -28%	Swedish market share of beef, poultry and pork 2010-2013: -11% 2013-2020: +19%		

Increase
Decrease
Stable

Figure 1. Overview of developments in the Swedish food system in the last decade. The time period of the trends is 2010-2020 if no other years are noted. Trends marked with an asterisk represent the time period 2010-2019. The time period of the trends are chosen to give a comparable material and may not reflect the total extent of the trend. Yellow boxes represent increases, blue boxes represent decreases and grey boxes represent constant trends or statistics without a direction of trend. The 2020 values of direct and total food consumption are preliminary. The majority of the trends are based on data and statistics compiled by Statistics Sweden and the Swedish Board of Agriculture. A full overview of the references can be found in Appendix 3.

literature review covered nine literature reviews over studies on food and agricultural scenarios, focusing on issues such as gender, poverty and nutrition (Lentz, 2021), food system change (Zurek et al., 2021) or food and/or nutrition security (van Dijk & Meijerink, 2014; Bourgeois, 2016; Maggio et al., 2019). More detailed information of the scenario analysis can be found in Appendix 1 and a corresponding reference list in Appendix 2.

A number of variables that impact future food systems were commonly included in these scenarios, in the form of drivers of change and other characteristic variables. Drivers of change are internal or external driving forces that cause changes in the examined food system. These can include both so-called direct drivers that unequivocally impact a system, such as greenhouse gas emissions, and indirect drivers that influence other direct and indirect drivers, such as socioeconomic and technological developments (Alcamo & Henrichs, 2008). Other variables include factors that describe the outcome of other processes. Variables that are regarded as drivers of change in one study may be considered an outcome in another, depending on the system that the study explores. In the examined studies, commonly included variables include aspects of agriculture and livestock production, consumption, diets and health, climate change and environmental issues, demography, technology, economic development, governance and market conditions. The identified variables reflect in large the findings of the meta-review of scenario reviews as well. For example, Zurek et al. (2021, p.19) lists climate change, environmental issues, technological change, societal changes, market dynamics and governance dynamics as key common drivers of the food system included in foresight studies. Maggio et al. (2019, p.63) also find natural resource availability, economic growth, climate change, dietary changes and demography as key drivers for food and nutrition security. In general, and across the scenarios, large-scale developments rather than weak signal and/or small-scaled, niched, initiatives are reflected. Similarly, the literature analysis found that shocks that may alter the trajectory of trends are not commonly emphasised, such as pandemics, large political shifts or economic crises (van Dijk and Meijerink, 2014; Lentz, 2021; Zurek et al., 2021).

In most scenarios, less emphasis is put on social-ecological as well as social-economic aspects. For instance, several of the twelve dimensions of the social foundation in the doughnut economy by Raworth (2017) are not discussed extensively in the scenario studies in the literature analysis or in the meta-literature reviews. These dimensions reflect the Sustainable Development Goals and social and economic dimensions of sustainability, including for example gender equality, equity and political voice (see Table 9 in Appendix 1). Cultural, religious, and spiritual values as well as indigenous or alternative knowledge are other elements that have so far not been widely included in food systems scenarios. Nevertheless, these aspects are all increasingly discussed in other types of scenario work. For example, these are included in the Nature Futures Framework developed by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Task Force on Models and Scenarios (Pereira et al., 2020).

Another finding from the scenario literature analysis was that few scenarios take a holistic view of the food system. Food production and consumption are thoroughly discussed by the majority of studies, followed by processes of trade and distribution, including trade regulations and levels of import and export. Processing and retail on the other hand, the so-called 'missing middle' of the value chain, is infrequently addressed in food scenarios (Zurek et al., 2021).

In the process of developing the MISTRA Food Futures scenarios, we aim to address some of the elements of food systems that have not been widely addressed in other scenario studies. Some of the features that we explicitly have included in the development of our scenarios are to capture more of the 'missing middle of the value chain', social-ecological perspectives, and an inclusion of cultural, religious, and spiritual values. As the skeletons are relatively short, we have not been able to include many aspects in each scenario. For the full scenarios we will articulate more of the social foundations of the Sustainable Development Goals. Elements that were infrequently discussed in the examined food scenario studies, identified either in our scenario literature analysis or by the meta-literature reviews, can be found in Appendix 1 (see Table 9).

3. Method

In this section we explain how we created the scenario skeletons. First, we explain the different types of scenarios that we are to create, namely target-seeking and exploratory scenarios. Then we explain how we defined the targets across our set of scenarios, and finally how we developed our set of four scenarios in a consistent way.

3.1. Target-seeking and exploratory scenarios

There exists a wide range of scenario development methods, useful in different types of situations. To organise and clarify the policy relevant differences among various approaches to scenarios, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)'s methodological assessment report on scenarios and models of biodiversity and ecosystem services (IPBES, 2016) organised scenario approaches into four types of scenarios; Exploratory, Target-seeking, Policy-screening (ex-ante), and Retrospective policy evaluation scenarios. According to the IPBES framework, policy-screening and retrospective policy evaluation scenarios are primarily used for policy implementation and review, while target-seeking and exploratory scenarios are used for agenda setting and policy design (Figure 2).

MISTRA Food Futures focuses on the creation of sustainable and resilient Swedish food systems by 2045 that also achieves a net-zero target for greenhouse gas emissions from the agricultural system. The purpose of developing scenario skeletons at this stage in the MISTRA Food Futures programme is to contribute to the broader agenda setting and policy design phases of food system transformation, rather than explicit policy evaluations. Based upon this goal, we have therefore developed a set of target-seeking scenarios.

Target-seeking scenarios are a valuable tool for examining the viability and effectiveness of alternative pathways to the desired outcome. Target-seeking scenarios begin with the definition of an objective or as an objective function to be optimised (e.g., minimising biodiversity loss) and then create alternative pathways that achieve these objective(s), as well as identifying what internal enabling conditions and what external system drivers would allow each pathway to be realised. Target-seeking scenarios are not forecasts, but rather coherent possible pathways that feasibly could achieve the desired objective(s).

Our target-seeking scenarios each outline a different pathway that achieves a set of targets. The selection and definition of these targets is explained in section 3.2. The scenarios skeletons are developed to describe different core food system strategies for how to achieve a set of targets. All scenarios achieve the targets, and therefore the scenarios also include different sets of enabling conditions and drivers that allow the targets to be achieved. Consequently, while the targets are achieved in all our scenarios, the Swedish food system will change in different ways in each of the scenarios. Furthermore, the conditions in the larger world that allow the Swedish food system to achieve these targets will vary across the scenarios. These target-seeking scenarios will be complemented by other scenarios later in the MISTRA Food Futures project where we also will combine them in various ways. A brief terminology of the concepts used in our target-seeking scenarios can be seen in Box 1, and the targets that the scenarios are to reach are presented in the following section (3.2).

We intend to complement the target-seeking scenarios in a later stage of the project with a set of 'shadow scenarios' that will test the robustness of the food system strategies adopted in the target seeking scenarios. We expect that without supportive enabling conditions, many of the food system strategies implemented in the target-seeking scenarios will be unable to achieve the targets in the set of exploratory scenarios. Examining these differences can be used to identify relative strengths and weaknesses of each food strategy, as well as suggest alternative or hybrid strategies. We intend to base the drivers and internal dynamics of these scenarios on the existing and widely used Shared Socioeconomic Pathways (SSPs) (O'Neill et al., 2014) that have been developed for climate change research. These pathways have already been adapted to explore European food and agriculture (Mitter et al., 2020).

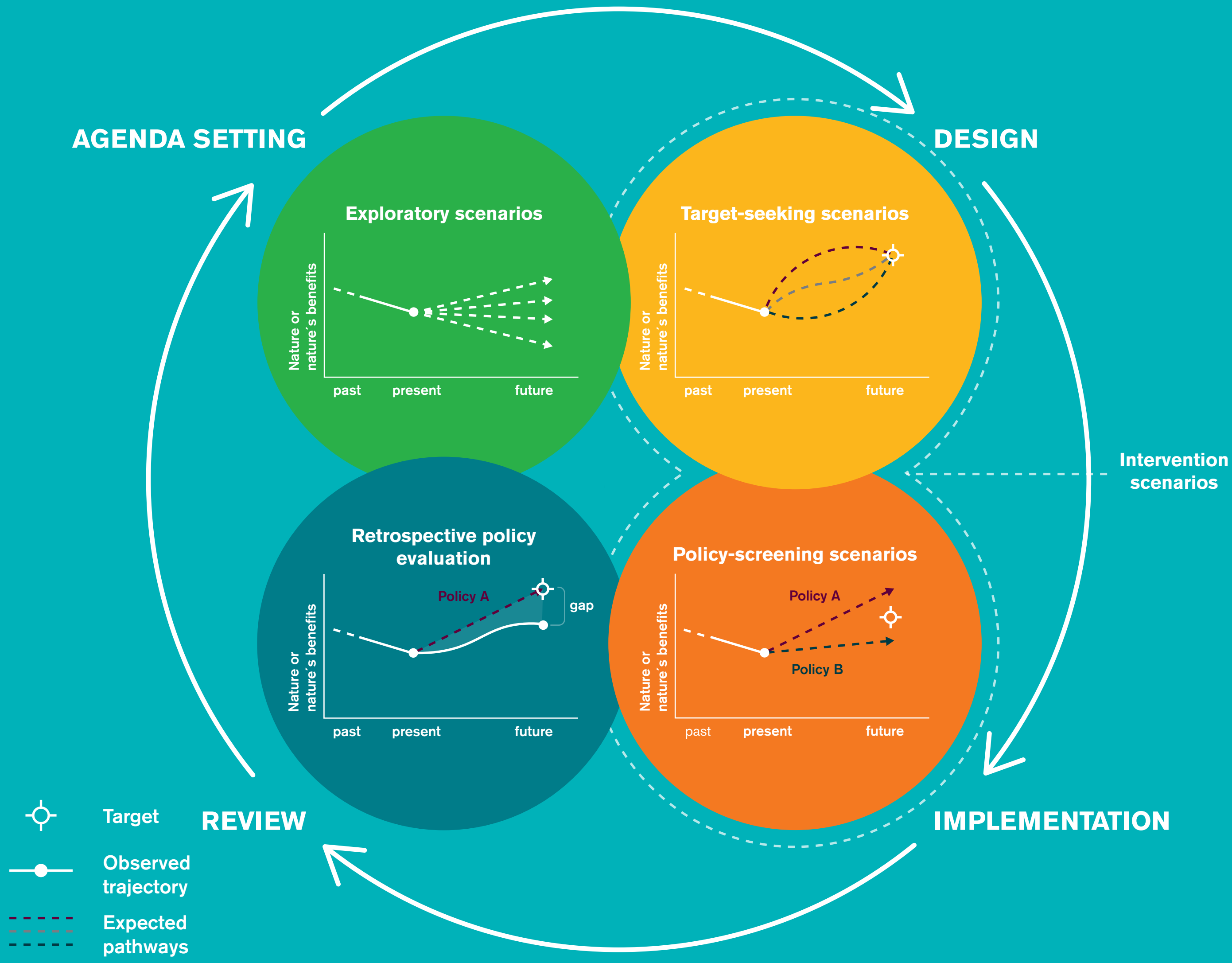


Figure 2. Figure of the four alternative scenario types (exploratory, target-seeking, policy-screening and retrospective policy evaluation) reproduced from the IPBES methodological assessment report on scenarios and models of biodiversity and ecosystem services. (IPBES 2016, p.xvii). Outside the circle with the four scenario types, four major phases of the policy cycle are represented (agenda setting, design, implementation and review).

These exploratory scenarios will likely not reach all the targets, and the differences between the target-seeking scenario and exploratory scenario for each food strategy reveal the robustness of each strategy. Comparisons across strategies can identify policy opportunities for synergistic policies that combine aspects of multiple strategies to achieve Sweden's food system targets, as well as to strategies to anticipate and navigate unexpected events or unsupportive global conditions (Figure 3).

3.2. Setting the targets

The target-seeking scenarios developed here all aim to achieve a set of climate, nutrition and health, and biodiversity targets. The work to set targets for Swedish food systems was led by MISTRA Food Futures Work Package 2 (WP2) in close collaboration with researchers in WP3. These targets represent some of the key goals to achieve a sustainable and resilient Swedish food system. The targets are derived from scientific literature, policy and commitments on a national, regional, EU or international level that greatly impact the future Swedish food system. The targets cover both territorial and consumption aspects, i.e. including impacts of Swedish consumption both in Sweden and abroad. The targets are also represented by two ambition levels to enable all of the scenarios to achieve the targets in a way that is aligned with their individual narratives. The targets and the process of setting the targets is presented in greater detail in an upcoming MISTRA Food Futures WP2 report (Jonell et al., in prep).

Box 1. Terminology of the MISTRA Food Futures scenarios

- **Target –** The targets represent a specific set of objectives that all the target-seeking scenarios are to achieve. These targets relate to climate change, biodiversity as well as nutrition and health. Each of the targets is represented by two levels of ambition, enabling scenarios to achieve the targets in a way that is aligned with their individual narratives.

- **Goal –** Goals are all types of objectives of importance for a sustainable food system. Examples are the Sustainable Development Goals, Swedish international commitments or national policy goals such as the Swedish environmental objectives. A scenario is unlikely to achieve all possible goals, and the extent to which goals are achieved will vary among scenarios. Indicators that relate to important goals will be tracked across all scenarios.

- **Indicator –** Indicators will be used to track how each scenario moves towards the three targets (nutrition and health, climate change, and biological diversity) and other goals. We will use the work of MISTRA Food Futures WP4 to refine a set of indicators for use in the next phase of scenario development.

- **Key Variable –** Key variables are core aspects of the Swedish food system or factors that drive change in the Swedish food system. Variables include both drivers of change, which are factors that directly or indirectly drive change in the Swedish food system such as population changes or policy, and characteristic variables that can be outcomes of other processes, such as crop diversity, and which are of importance to understand the scenarios. Variables may be a driver of change in one scenario and a characteristic variable in another, depending upon how food system strategies and enabling conditions change. The key variables used in this report have been identified by the expert group, drawing on insights from the background work on previous scenario studies (Table 1). The dynamics of all listed key variables are described in each scenario.

- **Enabling conditions –** Enabling conditions are the underlying conditions and context necessary in a scenario for its food system transformation strategy to be able to achieve the targets. The enabling conditions vary for each unique scenario, and include aspects concerning for example society, governance, technology, climate and environmental context (see section 6.3 for an overview)

- **Food system transformation strategy –** A food system transformation strategy is the dominant set of activities that are moving the Swedish food system towards sustainability. The actors, activities, and key types of structural change vary with each strategy. Each strategy has a supporting narrative that describes how a sustainable transformation of the food system is perceived. The narratives are aligned with different stakeholders' strategies and planned activities related to the Swedish food system and their view on food system transformation (Table 2). The strategies differ in how the Swedish food system best is to be transformed and their implementation will interact with other changes inside and outside Sweden. Each strategy will hence produce a unique future pathway along which various aspects of Swedish food systems will develop.

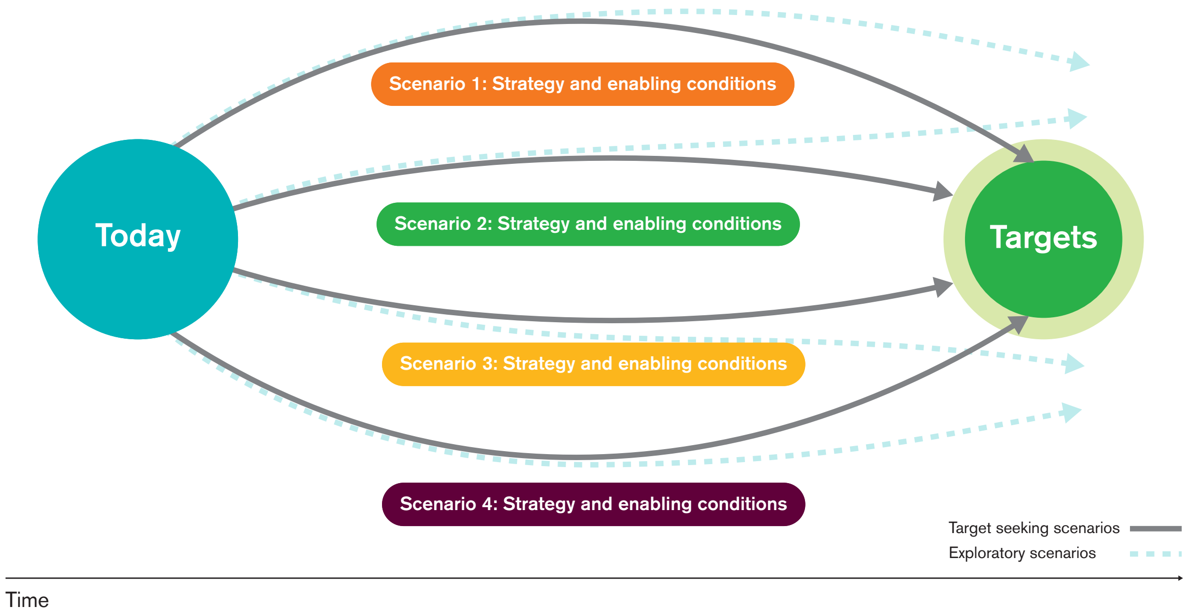


Figure 3. Target-seeking and exploratory scenarios. We will develop four target-seeking scenarios, where enabling conditions ensure the strategies achieve targets by 2045. We will then test these pathways in exploratory scenarios where the food system strategies exist in worlds described by adapted versions of the SSPs. We expect that without supportive enabling conditions many of the food system strategies implemented in the target-seeking scenarios will be unable to achieve the targets in the set of exploratory scenarios. Examining these differences can be used to identify relative strengths and weaknesses of each food strategy, as well as suggest alternative or hybrid strategies.

We choose three targets in order to balance the complexity of creating scenarios (which increases exponentially as the number of targets goes up), against the need to capture a diversity of goals of the Swedish food system. WP2 does however also suggest targets for other environmental goals, such as eutrophication, freshwater, chemicals and pesticides, use of antibiotics, as well as social goals, such as food waste and food loss. While the scenarios are not designed to achieve other targets, the outcomes on other goals can be tracked, and the extent to which each scenario achieves these goals can be analysed. Our scenario terminology of targets, goals, indicators, key variables, enabling conditions, and food system transformation strategy is defined in **Box 1.**

3.3. Developing consistent scenarios

The target-seeking scenario skeletons presented in this report represent the first step in an iterative scenario development process. Scenario skeletons represent the scenarios' main structure and the core features of their narratives. The details of these skeletons will be fleshed out in later work. These scenario skeletons capture the fundamental dynamics of each scenario, to ensure that the scenarios are both internally consistent as well as sufficiently divergent as a set to span to provide a useful comparison of alternative strategies and futures. Below, we explain the process by which this set of scenario skeletons were developed, and outline subsequent steps in the scenario development process.

3.3.1 Development of the scenario skeletons

The scenario skeletons were created through an iterative scenario development process that took place from spring 2020 to winter 2021 that involved a series of meetings and discussions among the MISTRA Food Futures WP3 working team (Figure 4). The working team consists of researchers from Stockholm Resilience Centre (SRC) at Stockholm University, the Swedish University of Agricultural Sciences (SLU) and Chalmers University of Technology. These researchers have a broad mix of research backgrounds that includes agriculture, food systems, ecosystem ecology, engineering, social-ecological systems, resilience and transformation, and scenario development processes in sustainability science. This diverse

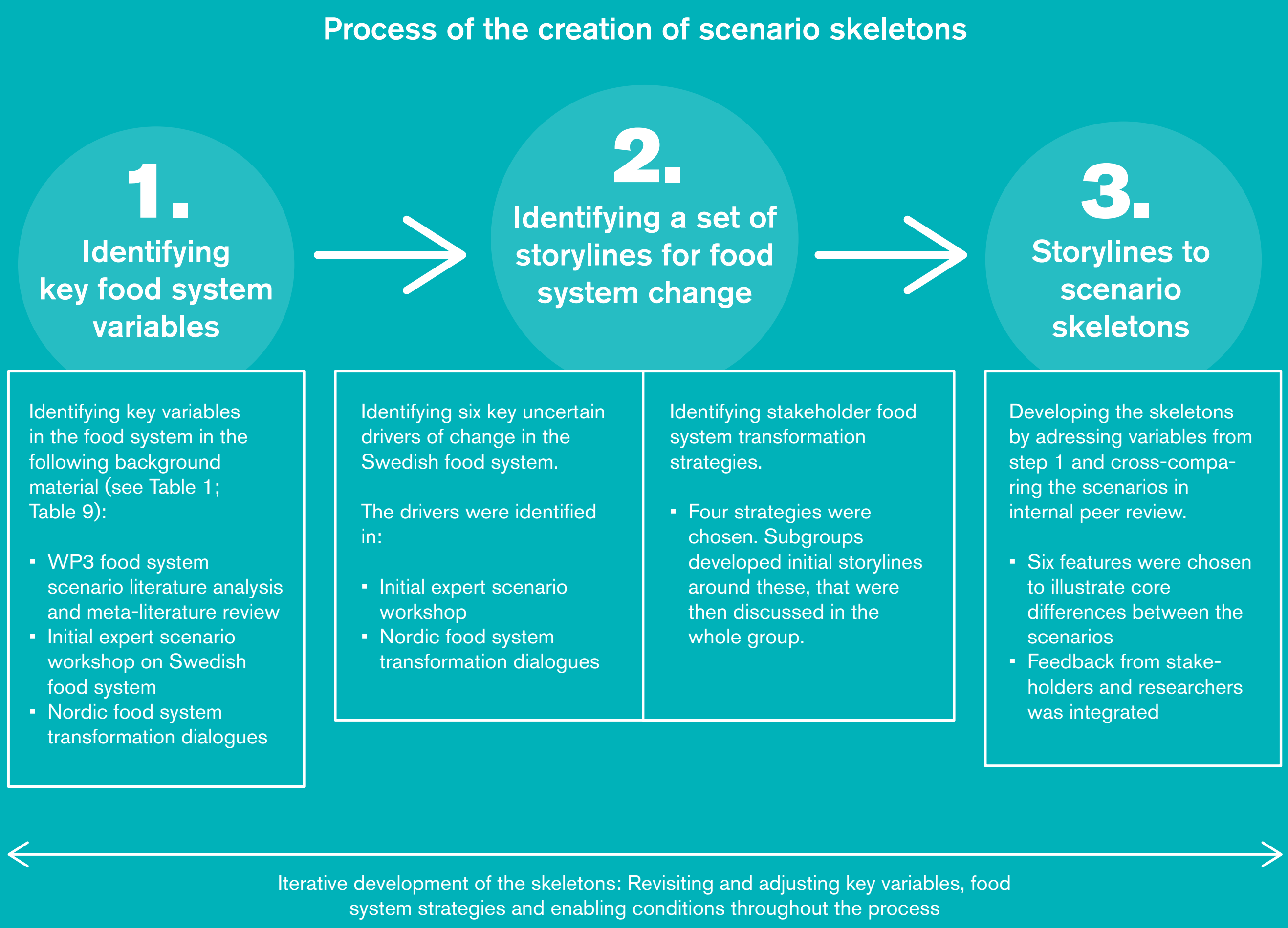


Figure 4. The process of creating the scenario skeletons was iterative, but can be represented as consisting of three steps. Step 1 identified the key food system variables; Step 2 identified a set of storylines by combining analysis of critical uncertainties and divergent food system strategies; Step 3 created a set of scenarios that combined strategies, drivers, and enabling conditions to identify pathways towards targets. This included clarifying targets. All steps involved interaction and dialogue with other MISTRA Food Systems WP groups, and the draft scenarios were all formally presented to MISTRA Food Futures stakeholders.

3.3.1.1 Step 1: Identifying key variables

We identified a set of key variables that should be discussed in each scenario in order to ensure consistency among the scenarios. The overall set of variables were chosen to align with MISTRA Food Futures' objective of enabling the creation of a sustainable and resilient Swedish food system that achieves multiple environmental, economic, and social goals.

We initially identified a set of variables through the background review (section 2.2), where we created an extensive list of key food system-related variables that describe key features of how the Swedish food system develops, their drivers, and food system outcomes. We systematically noted all drivers of change and key variables in the scenario literature analysis and meta-review of food scenario studies. This material allowed us to get insight into both existing approaches to Swedish food system scenarios, and identify aspects of Swedish food systems that were missing from previous scenarios.

We also considered important variables that emerged from our initial expert workshop on food system scenarios that was held in 2020 (see step 2 for more details), and other variables identified in other ongoing Nordic food projects such as the Nordic transformation dialogues that discussed food system transformation with Nordic policy makers and food system actors (Wood et al., 2020a,b,c; 2021).

A condensed list of key variables, which has been iteratively adapted during the course of the development of the scenario skeletons to ensure its relevance for the narrative, is found in Table 1. More details on the methodological process behind the identification of the variables can be found in Appendix 1.

3.3.1.2 Step 2: Identifying a set of storylines for food system change

In identifying a set of storylines for the scenarios, we combined the identification of critical uncertainties and the identification of policy relevant narratives. Using experts to identify a set of policy relevant uncertainties is common across many approaches to the development of scenarios (Wollenberg et al., 2000; Peterson et al., 2003). We adopted a version of such an approach that utilised the experience from two previous scenario exercises, as well as food system transformation strategies advocated by different actors in Swedish food systems.

We utilised the experience of two different recent scenario processes: an expert workshop and the Nordic Food System Transformation project. The expert workshop was held in 2020, with researchers from SRC, SLU, KTH and Chalmers, many of whom were involved in the development of these scenarios (Appendix 1 gives more details on the set-up and findings of this workshop). At this workshop, experts identified and ranked food system changes by uncertainty and importance. In this exercise, four uncertain and important drivers were identified:

- Responses of food systems to social and ecological impacts of climate change,
- Swedish and EU food policy (especially the Swedish food strategy and EU green new deal/CAP)
- Social-cultural change including: social movements, and social and cultural change
- Technological change (both within and outside agriculture)

The second source of scenario insight was the Nordic Food System Transformations project led by Dr. Amanda Wood (see Wood et al., 2020a,b,c; 2021). In this project, dietary change and globalization vs. localization were identified as two important and uncertain types of change in food systems. The combination of these two uncertainties could be used to identify a 2X2 set of scenarios along two axes (Wood et al., 2020c):

- The reductions in red meat consumption and corresponding increased consumption of nuts and legumes (versus status quo), and
- Moving towards more local food systems, versus the embracing global food systems

These insights from scenario work were complemented by our efforts to identify different strategies that food system actors promote as strategies to achieve sustainability goals. While there are many alternative strategies, we aimed to identify a small set of contrasting strategies that resonated, but did not simply align with the identified key uncertainties, and which addressed key issues of concern to stakeholders.

Key strategies were identified by reading policy documents, reports, and drawing on insights from the expert team's engagements with food sector stakeholders over many years. Stakeholders that represent private sector (ranging from small-scale entrepreneurs to investors and large-scale industry), public sector (at municipal, national and European levels), civil society, and academia (across multiple disciplines) often highlight quite different aspects as being of main importance.
Three core strategies emerged:

1. The Swedish Food Strategy (Prop. 2016/17:104), aligns with a dominant discussion around agriculture in Sweden that focuses on increasing agricultural productivity, views food as a key industry in Sweden, looks for job creation opportunities, increasing Swedish exports, and increasing Swedish food self-sufficiency. This discussion often emphasises that Sweden

Table 1. Key variables for the scenario skeletons. The key variables represent key drivers of change and/or outcome variables that all scenarios should address to some extent in their storyline

Overarching topic	Key variables	Examples	Representation in this report
Primary production	Cropping	- Agricultural land use - Main crops - Yield levels/ productivity rates - Energy use and production in agriculture - Fertiliser types - Technology abatement	Table 6.
	Livestock	- Livestock systems - Productivity levels - Technology abatement	
	Blue food	- Main blue food species - Main production types (e.g. fisheries, aquaculture)	
Supply chain	Processing and retail	Landscape of Swedish food industry, processing and retail	Table 5.
Consumption	What people eat	- Trends of food consumption - Food culture	Table 5.
	Food environment[a]	Availability and accessibility of different types of food	Table 5.; Figure 5a, 5b.
	Social values and norms	-Food production and consumption as cultural phenomenon - Level of food literacy	Table 5.; Figure 5a, 5b
Trade	Trade	Swedish imports (including sourcing regions), exports and share of Swedish production	Table 5.; Figure 5a, 5b
Governance and institutions	Policy and governance	Swedish and EU policy (agricultural, fisheries, climate, environmental, health and food)	Figure 5a, 5b.
	People and demographics	Level of urbanisation and rural development	Table 5.; Figure 5a, 5b.
	Key actors that drive change	Key actors involved in the Swedish food system (market; government; national/international actors; civil society; niche actors)	Figure 5a, 5b.
	Where key actors are situated	Description of how change occurs in the food system - driven from actors and events currently involved of the food system (primary production, the supply chain; food governance) or currently outside of the food system (other market sectors; other policy with main objectives not directly part of the food supply chain, such as energy or other health policy)	Figure 5a, 5b.
Climate and Environment	Climate/environment	- Climate change - Change in biogeochemical cycles (e.g. N/P) - Biodiversity loss - Extreme events	Table 4 (as outcome), N/A as drivers[b]

a) The food environment can be understood as "the physical, economic, political and socio-cultural context in which consumers engage with the food system to make decisions on acquiring, preparing and consuming food" (HLPE, 2017) and may include aspects of availability, affordability, convenience, and desirability (Herforth & Ahmed, 2015)

b) How climate/environment may drive change will be explored in the next step of the scenario analysis has comparatively high sustainability standards in food production, including animal welfare. There are large industry actors that support and promote this way of thinking about change. These perspectives have also been highlighted in discussions with stakeholders from public policy and industry conducted as part of the project North Western Paths sustainable food system modelling project, and much of the data in the storyline builds on the dialogues with stakeholders in that project. This discussion and perspective on change is represented in reports from e.g. LRF, Arla and others (HKScan et al., 2021), Lantmännen (2019) and Sweden Food Arena (2020).

2. Sustainability and public health challenges can be addressed by new forms of food tech (including things such as cellular meat, digitalisation of production systems, blockchain technologies and e-groceries), is an emerging narrative. This narrative is promoted by investors, entrepreneurs and technologists. It has attracted substantial venture capital for new start-ups, and existing companies from outside of the food system, from fields such as biotechnology, pharmaceuticals, and digital platforms, are investing into this area. Some promoters of this narrative hope that Sweden can become a new Silicon Valley for food. This narrative can be found in reports such as Food is Solvable (Gullspång Re:food, 2021), think tanks such as Rethink X (Tubb & Seba, 2019), and networks such as Sweden Food Tech (2021; n.d.).

3. A narrative that emphasises the importance of socio-cultural aspects of eating and producing food has been a persistent alternative narrative within Sweden. This narrative focuses on local landscapes and cultures and how they can reinforce one another to create a better food system. This narrative highlights the role of small-to-medium size farming, multifunctional landscapes that are circular and regenerative, alternative food networks, and niche markets. This narrative is present in works such as Rundgren (2016) and Vivero-Pol et al. (2018) that conceptualises food as a common good, as well as initiatives such as Makten över matkassen (Ingvarsson & Meyer von Bremen, 2015), Diet for A Green Planet (2021), Kålrotsakademin (2022) och Eldrimner (n.d.).

These narratives present alternative pathways along which Swedish food systems could develop and they offer alternative concepts of what the main solutions should be for improved sustainability, resilience and health. These strategies all consider change from the perspective of Swedish food system actors. However, there are many other actors and strategies that influence the Swedish food system, but are not focused upon it. Therefore, we also considered a fourth strategy, in which food systems are not a focus of policy or action. This narrative asks: What would happen to the food system if food is forgotten as a strategic pathway to sustainability and health, but rather the food system is shaped by Swedish and European actions on climate change mitigation and adaptation?

4. A 'food forgotten' narrative can be detected in recent trends. For instance, while food policy is an important area of debate in Sweden, many other issues have a much higher profile. As the economy of Sweden has become increasingly dominated by services, the number of people employed in agriculture and the share of agriculture in the economy has more than halved over the past fifty years. There are debates over use of agricultural land for food and energy production concerning solar power (see e.g. Melin, 2022) and a projected increased future demand for biomass (Fossil Free Sweden, 2021). There is similarly a great emphasis on climate mitigation in strategies and targets on a Swedish, EU and global level. This type of narrative is present in the Swedish government goal to make Sweden carbon neutral by 2045, and in the planned European Green Deal, that plans to change the EU's climate, energy, transport and taxation policies to reduce net greenhouse gas emissions by at least 55% by 2030 and to zero by 2050.

These strategies were sharpened by considering the key uncertainties identified in scenario studies to develop four storylines. This development was done in a half-day workshop with the expert team. An initial set of storylines was developed after the workshop by sub-groups of 1-2 researchers, who then presented back to the expert group in another workshop. The sub-groups related the four strategies to key variables and drivers. These workshops were complemented by online peer review, in which the team commented on and suggested changes to the scenarios. From this

Table 2. Comparison of the four scenarios versus key uncertainties identified in step 1.

	Food as Industry	Food as Food Tech	Food as Culture	Food Forgotten
Swedish/EU policy	Swedish food policy drives investments in increased production, productivity and exports	Policy allows and regulates new types of food, as well as driving investment into e.g. novel foods	Swedish rural policy, support for local governance and investment in artisan food key enabling factors	EU climate and development policy rather than food policy drives change
Socio-cultural change	Continuation of current food trends: globalised food, reduced consumption of meat and dairy.	Food less culturally important, more focus on individual health	Food, especially Swedish food, more locally diverse and culturally important	Continuation of current food trends: globalised food, reduced consumption of meat and dairy
Technological change	Large advances in sustainable agriculture and low carbon logistics	Disruptive developments in food processing, and value chains. Advances in personalised health & diet advice	Focus on developing locally adapted technology for multifunctional agriculture	Climate mitigation and adaptation technology, such as green infrastructure, low carbon building and logistics shape food systems
Local/Global Food systems	Continued globalisation	Increased globalisation	More localisation	Increased European integration

process a set of four scenarios were identified with clear names and key strategies;

- Scenario 1: Food as Industry,
- Scenario 2: Food as Food Tech,
- Scenario 3: Food as Culture, and
- Scenario 4: Food Forgotten

These four scenarios build on the main strategies identified and use the key uncertainties identified in the scenarios to drive these in contrasting directions, to ensure a relevant and diverse set of scenarios. Four out of the six key uncertainties identified in the first stage of step 2 were particularly relevant. The four scenarios address the four uncertainties:

- Swedish and EU food policy
- Social-cultural change
- Technological change, and
- Local/Global food systems

The other two key uncertainties are not addressed in this set of scenarios. The key uncertainty "Responses of food system to social and ecological impacts of climate change" was not included to define the scenarios, as this uncertainty will be addressed by the development shadow scenarios in the next phase of the project. The key uncertainty "reductions in red meat/increase in legumes" is assumed to happen, to some extent, in all the scenarios to meet the climate and nutrition targets and therefore does not strongly vary among the scenarios.

3.3.1.3 Step 3: Storylines to scenario skeletons

The initial storylines developed during step 2 were iteratively developed into skeleton scenarios. The goals of this process were to set up skeletons that could plausibly achieve the targets and were sufficiently detailed and internally consistent, while also addressing the four food system strategies identified in step 2. This was done by describing the scenarios in a consistent way, cross-comparing scenarios, quantifying change, and ensuring consistent language. Each of these steps for ensuring scenario quality is described below.

Based on steps 1 and 2, each scenario had a number of quality attributes that we worked to meet. In order to ensure that the changes in the scenarios could plausibly meet the targets, it required identifying and explaining enabling conditions required for the strategies enacted in the scenario to meet the target. The enabling conditions are discussed in section 6.3 of the analysis. Each scenario also needed to explain dynamics of all key variables in each scenario, although the importance and role of variables varies among the scenarios. We also aimed to describe change in a way that considers both growth of existing non-dominant initiatives, entrance of new actors, and role of policy, demographics, and economic change, as well as impacts of climate change.

After drafts of the skeletons were written up, they were cross-compared. This was done through internal peer review, in which experts ensured that scenarios were clear and plausible based upon their knowledge and expertise. Combined with this process we undertook a structured process that checked various aspects of the scenarios. We examined whether key variables in each scenario were consistent with past trends, current dynamics, and plausible rates of change. We checked that food system strategies were adequately described, and identified both agents of change and changes in the food system. Within each scenario we checked for consistency, by ensuring that changes in multiple key variables or drivers were consistent with one another. Across the scenarios, we ensured that the scenarios diverged from one another by verifying that the way change occurred in each skeleton's food system contrasted and complemented variation in critical uncertainties among the skeletons.

To reveal and check contrasts as well as ensure consistency and language and description among the scenarios, we quantitatively compared a set of key features. We identified six complementary features linked to the key variables that illustrate some of the greatest differences among Swedish food systems in 2045. These features were: size of Swedish food market share; government/EU or market-dominated development; relative emphasis on primary production policy versus other policy; key actors that drive change in the food system; size of corporations in the food system; and cultural value ascribed to food in society. Each scenario's features were scored to indicate how much change has occurred from 2020 to 2045. These rankings were developed through intense discussions in the WP3 research group, where each sub-research group proposed values for their scenario that were then discussed and modified with the full research group. The task of identifying and adjusting this relative scale of quantitative measures helped develop our shared understanding of the scenarios and ensured sufficient contrast between the scenarios.

We also checked our scenarios for policy relevance, by presenting the work in progress to MISTRA Food Futures partners and stakeholders during a stakeholder meeting in August 2021 and during the MISTRA Food Futures conference in November 2021. They were also presented to other Swedish food research groups in meetings between June and November 2021. While feedback was generally positive with the overall structure of the four scenarios, based on these discussions we clarified and emphasised some of the key variables in the text.

Finally, to ensure that scenarios are described in consistent and comparable fashion, the two lead authors revised all scenarios to ensure language, structure and length were similar for all four storylines. These revisions were then checked by the entire scenario team.

4. Results: Targets and trends on whether we reach them

The initial three core targets (for biological diversity, climate change and nutrition and health) that all scenarios are to reach by 2045 are presented in Table 3a. As stated in the methods, the development of targets was led by WP2 in close collaboration with WP3 researchers (see Jonell et. al in prep.). Each target is represented by two target levels with a slight variation in ambition level (more ambitious and ambitious). All scenario skeletons are developed to reach the ambitious or the more ambitious level for both territorial and consumption-based targets.

In the development of targets the overarching considerations relate to general global goals. This means that for climate, Sweden should take responsibility for meeting the Paris Agreement. The territorial target levels build on the nationally determined Swedish target of climate neutrality by 2045, which allows for 85% decrease of greenhouse gas emissions and 15% supplementary measures. The suggested territorial target in Table 3a is thus based on the allocation of greenhouse gas emissions between agriculture and other sectors in the EU Effort Sharing Regulation (ESR) in Sweden. The EU ESR includes the sectors that are not covered by the EU Emissions Trading System (EU ETS), namely transports, buildings, waste and small industry. See below for a discussion on the consumption climate target.

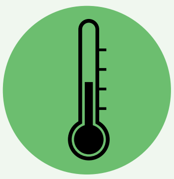
The literature on biodiversity targets is much more scattered and at the time of writing this report (2020-2022) the global biodiversity Aichi targets were to be replaced by new global targets still in discussion. We therefore searched for targets that should reflect the role that biological diversity plays for function, culture and composition of ecosystems. This resulted in the suggestion of four complementary territorial targets for biodiversity.

The suggested consumption targets for biological diversity and climate in Table 3a are based on allocation principles of global impacts from the food system. These include the egalitarian principle, the sovereignty principle, ideas of grandfathering, and historical accountability including perspectives of responsibility and capability (see e.g. Häyhä et al., 2016). The most ambitious target level for all three sub-targets (cropland use, species extinction rate, and greenhouse gas emissions) reflects an egalitarian principle with equal per capita shares of the global boundaries given by the EAT-Lancet Commission (see also Moberg et al., 2020).

The ambitious target level for all three sub-targets reflects a slightly greater impact space of Swedish food consumption than the equal per capita share. This can be justified according to the sovereignty allocation principle of emissions grandfathering (Knight, 2013; Häyhä et al., 2016) and the idea that historical Swedish food consumption trends are deeply ingrained in Swedish food culture, primary production and food industry. This allocation principle hinges on countries with other consumption trends to more easily shift to diets with lower impacts, giving the Swedish population's food consumption a slightly greater share of the impact space. For more details on the allocation principles underlying the targets, see Jonell et al. (in prep).

For nutrition and health the overarching goal can be to align with the SDG 3 on health, formulated as "Ensure healthy lives and promote wellbeing for all at all ages". For food, this can be translated into dietary targets, and we focus on established methods that look at how food groups contribute to reducing risk factors for health, including a balanced energy intake. The targets thus build on the EAT-Lancet healthy reference diet, guidance from the Nordic Nutrition Recommendations (NNR), and data from the Global Burden of Disease database. For the nutrition and health target, the first sub-target is suggested to be based on the food groups suggested by the Global Burden of Disease (GBD) 2017 (GBD 2017 Diet Collaborators, 2019) and the EAT-Lancet planetary health diet (Willett et al., 2019). Both these approaches are developed with human health in centre and include similar food groups with similar optimal ranges. The second sub-target on energy intake

Table 3a. Overview of suggestions of targets for 2045. Each target is represented by two target levels with a slight variation in ambition level, marked by a) high ambition and b) ambition in sustainability. See Jonell et al. (in prep) for an extended presentation of the targets.

Target area	Territorial targets	Consumption-based targets
Biological diversity 	1a) An increase of abundance and diversity of **pollinators or birds** in accordance with levels detected in a specific year (e.g. 1950).	1a) **Cropland use** is in line with an equal share per capita of the global land use boundary given by the EAT-Lancet Commission.
	1b) No further decrease in abundance or diversity of **pollinators or birds**.	1b) **Cropland use** is slightly higher than the equal share per capita of the global land use boundary given by the EAT-Lancet Commission.
	2a) Restoration of previous **semi-natural grasslands** at a substantial scale.	2a) **Extinction rates** are in line with an equal share per capita of the global extinction rate boundary given by the EAT-Lancet Commission.
	2b) No further reduction of **semi-natural grasslands**.	2b) **Extinction rates** are at maximum twice the equal share per capita of the global extinction rate boundary given by the EAT-Lancet Commission.
	3a) Substantially reduced use of **pesticides** and an increase of farm land with no application of pesticides or herbicides.	
	3b) Reduced use of **pesticides**.	
	4a) Sustainably utilised **fish and shellfish stocks** in the coast, sea and freshwater environments (under FMSY and above B TRIGGER), a shift to **less harmful gear** and an ambitious level of **marine conservation**.	
	4b) Sustainably utilised **fish and shellfish stocks** in the coast, sea and freshwater environments (under F_{MSY} and above $B_{TRIGGER}$) and a shift to **less harmful gear**.	
Climate 	1a) The food production sector reaches **net zero emissions** by 2045, i.e. the land currently used needs to accomplish the negative emissions needed to compensate for unavoidable emissions.	1a) **Greenhouse gas emissions** from food consumption are maximum at an equal share per capita of the global greenhouse gas emission boundary for food production given by the EAT-Lancet Commission.
	1b) The food production sector is given a **larger emission space** than other sectors in the EU Effort Sharing Regulation (ESR). Agriculture could then continue to emit along its current trajectory or even increase emissions as a result of an increased production. Negative emissions could be accomplished in other sectors, e.g. forestry or energy (BECCS or DAC-techniques).	1b) **Greenhouse gas emissions** from food consumption are slightly higher than the equal share per capita of the global greenhouse gas emission boundary for food production given by the EAT-Lancet Commission (5 Gt CO2e per year).

Nutrition and health		1a) The per capita **food intake** is in accordance with the optimal level intake of key food groups, including red meat, as suggested by the Global Burden of Diseases (GBD), and/or the EAT-Lancet planetary health diet ranges. 1b) The per capita **food intake** is inspired by the GBD optimal level intake of key food groups, including red meat, and/or the EAT-Lancet planetary health diet ranges, but allows for a higher intake of food groups currently consumed in high quantities in Sweden (i.e. red meat and starchy vegetables). 2a) The average **energy intake** amounts to 2400 Kcal per person and day, in line with the Nordic Nutrition Recommendation (NNR) reference values 2b) The average **energy intake** amounts to 2500 Kcal per person and day, in line with the EAT-Lancet planetary health target

has target levels based on the EAT-Lancet planetary health diet as well as the intake suggested by the NNR reference values (Nordic Council of Ministers, 2014).

Table 3b covers current trends related to the indicators of the targets, to give insight into how the Swedish food system has developed in relation to some key aspects of biological diversity, climate change and nutrition and health.

Agricultural use of land, the Swedish food industry and diets have changed over the past two decades, resulting in changes in biodiversity and greenhouse gas emissions. Swedish primary production both impacts and is impacted by changes in biodiversity. Swedish agricultural landscapes have changed dramatically over the past century, resulting in large areas of abandoned semi-natural grasslands, hay meadows and fields that are now overgrown or converted to other land uses. Other areas have experienced an intensification of agriculture resulting in more uniform landscapes. In total, many of the agricultural landscape's species and habitat types have decreased in size and distribution (SBA, 2019b). The increased number of plant protection hectare-doses sold in the last decade, as seen in Table 3b, is partly explained by the increased cultivation of winter crops during this period, which increases the demand for treatments (Statistics Sweden, 2021a).

Greenhouse gas emissions of Swedish agriculture have decreased over the last three decades, to the current level of 6.93 million tons of carbon dioxide equivalent (CO2-eq) emissions in 2020. These agricultural emissions refer only to territorial emissions, excluding for instance emissions from the production of mineral fertilisers. The decrease of agricultural emissions relates mainly to fewer livestock, primarily cattle and pigs, as well to a lesser extent a decreased use of nitrogen in mineral fertilisers (SEPA, 2021e). Nevertheless, agricultural emissions are still assumed to comprise a substantial share of Sweden's future emissions according to the latest national scenarios that project Swedish agricultural emissions to reach approximately between 5.2 to 7.2 million tons in 2045, based on emissions levels in 2017 (SEPA & SBA, 2019, p.4-5). This can be compared to Sweden's territorial climate target of net-zero greenhouse gas (GHG) emissions by 2045, according to Sweden's Climate Act and Climate Policy Framework (Ministry of the Environment, 2020). The net-zero target

Table 3b. Trends in Sweden concerning the three targets related to biological diversity, climate change and nutrition and health. The darker blue rows include trends directly linked to the proposed indicators of the targets, whereas the light blue rows represent other trends related to the target area. Data points for only two different years were applied for each trend rather than an average of several years, which impacts the percentage of difference in the column of Direction of trend. Food consumption data is derived from FAO Food Balance Sheets (FAO, 2022). Standard conversion factors were applied to the data in order to account for retail and consumer waste as well as inedible parts of food products, in line with the methodology of Wood et al. (2019).

Biological diversity					
Trend	Time period	Start of period	End of period	Direction of trend	Source
Birds in agricultural landscapes	2010-2020	N/A	N/A	-2.3%	SEPA, n.d.-a
	2000-2020	N/A	N/A	-21.5%	SEPA, n.d.-a[5]
Grassland butterflies in agricultural landscapes	2010-2020	N/A	N/A	-34%	SEPA, n.d.-a[6]
Semi-natural grasslands (ha)[7]	2020-2020	154 373	148 856	-3.6%	Wallander, J., personal communication [8]
Sustainably exploited fish and shellfish stocks in the Swedish coast, sea and freshwater environments (share of stocks, %)	2015-2019	46%	40%	-13%	Swedish Environmental Protection Agency [SEPA], 2021b
Marine protected areas (%)	2020	14% of total marine area (incl. exclusive economic areas)		N/A	Statistics Sweden, 2021c
	2019-2020	11% of total marine area in Swedish territory	12% of total marine area in Swedish territory	+9%	
Plant protection in agriculture – Hectare-doses (units sold)	2010-2020	3.8 million	5.1 million	+34.2%	Statistics Sweden, 2020 & 2021a
Plant protection in agriculture – Average dose active substance (kg/ha)	2010-2020	0.38	0.31	-18.4%	
Total global land use for Swedish food consumption	Avg. 2011-2015	N/A	0.34 ha per capita	N/A	Moberg et al. 2020
Extinction rate of species of Swedish food consumption	Avg. 2011-2015	N/A	8.3×10^{-9} E/MSY[9]	N/A	Moberg et al. 2020
Red list index[10]	2000-2020	0.88	0.88	Constant	SEPA, n.d.-b
Temporary fallows (ha)	2010-2020	176 801 ha	137 650 ha	-22.1%	SBA, 2022j

5) The figures include an average of the indexes of point count routes and fixed routes. Index based on a baseline year of 1998.

6) Index based on a baseline year of 2010.

7) As there is no standardised definition of semi-natural pastures in Sweden, we base this trend on statistics of the land use category of pastures with certain values ('Betesmarker med särskilda värden') according to the SBA environmental compensation scheme. This category includes criteria that aligns closely with the definition of semi-natural pastures by the SBA as natural grassland that have been mowed or grazed for a long period of time without being ploughed, fertilised or affected by other production-increasing measures (SBA, 2022v).

8) The data on the land use category of pastures with certain values was shared in personal communication with Johan Wallander, Swedish Board of Agriculture, 20220506. The data shared is derived from the SBA BLIS database.

9) Extinction rate allocated over 100 years.

10) A red list index of 1 means that the loss of biological diversity has been halted.

Climate change

Trend	Time period	Start of period	End of period	Direction of trend	Source
Agricultural CO2-eq emissions per year (million tons)	1990- 2020	7.66 Mt	6.93 Mt	- 9.5%	SEPA, 2021e
Share of agricultural emissions: of total territorial CO2-eq emissions (%)	1990- 2020	10.7%	15%	+40.2%	SEPA, 2021e
Share of agricultural emissions: of total ESR CO2-eq emissions (%)	2005-2020	16.1%	23.3%	+44.7%	SEPA, 2021f
Food consumption CO2-eq emissions, tons per capita and year	2010- 2019	1.69 t	1.4 t	-17.2%	SEPA, 2021d [11]
Work machines in agriculture, CO2-eq emissions per year	1990- 2020	0.58 Mt	0.51 Mt	-13.5%	SEPA, 2021a
Food, beverages and tobacco industry (processing emissions), CO2-eq emissions per year	1990- 2020	0.96 Mt	0.28 Mt	-70.8%	SEPA, 2021c

Nutrition and health

Trend	Time period	Start of period	End of period	Direction of trend	Source
Energy intake from food (kJ)	1980-2019	12 300	13 100	+13%	SBA (2020b)
Whole grains (Wheat, corn, rice and other) (g/day)	2010-2019	203	221.2	+9%	FAO (2022)
Vegetables (g/day)	2010-2019	122.7	131	+6.8%	FAO (2022)
Fruit (g/day)	2010-2019	111.3	91.5	-17.8%	FAO (2022)
Seafood (g/day)	2010-2019	34.6	36.5	+ 5.5%	FAO (2022)
Nuts [12] (g/day)	2010-2019	8	5.8	-3.3 %	FAO (2022)
Tree nuts (g/day)	2010-2019	10.9	9.5	-12.8%	FAO (2022)
Legumes [13] (g/day).	2010-2019	8.6	9.3	+8.1%	FAO (2022)
Unsaturated fat (g/day)	2010-2019	15	14.9	-0.5%	FAO (2022)
Red meat (beef, lamb, pork) (g/day)	2010-2019	91.9	79.3	-13.7%	FAO (2022)
All sweeteners (g/day) (sugar, sweeteners, honey)	2010-2019	95.2	92.2	-3.2%	FAO (2022)
Starchy vegetables (including potatoes) (g/day)	2010-2019	107.4	115.2	+7.3%	FAO (2022)
Overweight and obesity (share of population, 16-84 yrs)	2010-2020	49%	52%	+6.1%	Public Health Agency of Sweden (2021)
Dietary risks contributing to DALYs	2009-2019	N/A	N/A	-5.8%	IHME (2021)

11) The data is based on Statistic Sweden's environmental accounts that cover Swedish consumption-based emissions. It is not fully clear what shifts that explain the strong decreases in the data in certain years. The data shows the general direction of the trend, however applying other methods could reach other absolute figures.

12) Tree nuts: nuts; sesame seed; rape and mustardseed. Does not include groundnut/peanuts.

13) Legumes: beans; peas; pulses, other and products; soybeans; groundnuts

entails a remaining total emission space in 2045 of about 10.7 million tons CO2-eq, that may be achieved by supplementary measures. Of this emission space, the current and projected agricultural emission space is thus substantial. While Sweden has no specific agricultural emission target, the sector is included in the milestone targets for the Effort Sharing Regulation (ESR) sectors, aiming for example to reach a 63 percent emission reduction in 2030 compared to 1990 emission levels. As seen in Table 3b, agriculture has increased both its share of total Swedish territorial emissions by forty percent between 1990 to 2020, and its share of ESR emissions by forty five percent between 2005 to 2020 as a result of decreased emissions in other sectors.

The large decrease in GHG emissions for the food industry in the last three decades (-71%) can primarily be explained by the decreased use of fossil fuels, especially oil products but also coal and coke (SEPA, 2021c). Individual food consumption emissions have decreased by 17% in 2010-2019 (SEPA, 2021d).

From a nutrition and health perspective, there has been an increase in energy intake over the last decade and the proportion of the population that are overweight or obese has increased to half the adult population. The latest national dietary survey in 2010/2011 by the Swedish National Food Agency [NFA] shows that Swedish diets are overall slightly healthier than in previous surveys in the end of the 1980s and 1990s, following an increased consumption of fresh vegetables, fruit, fish and seafood (NFA, 2012). Other important changes include more fibre and wholegrain and a decrease of sugar and fat (SBA, 2015b, p.15). Nevertheless, the average Swede still keeps an unhealthy diet with too little vegetables, fruit, fibre and wholegrain, and too much fat, sugary food, soda and sweetened drinks (NFA, 2012). Wood et al. (2019, p.31) show similar results of food groups that are lacking in the Swedish per capita food consumption in their comparison of the latest Swedish dietary survey with the EAT-Lancet planetary health diet. They also add that Swedes eat insufficient amounts of nuts and legumes, as well as unhealthy amounts of red meat and added sugars (Wood et al., 2019).

5. Results: Scenario skeletons

In this section we present the four scenario skeletons. These describe futures in which the Sweden food system achieves its climate, biodiversity and health targets in different ways. Each scenario starts with a short summary of the future in 2045 and its key features, then describes in greater detail the changes that have occurred and the driving forces behind these changes. Finally, there is a description on how each scenario managed to reach the targets on biological diversity, climate change and nutrition/health, specifying which target levels that were reached for each target area and the key developments that enabled the scenario pathway to reach the targets. Below we present each of these four scenarios: Food as Industry, Food as Food Tech, Food as Culture, and Food Forgotten.

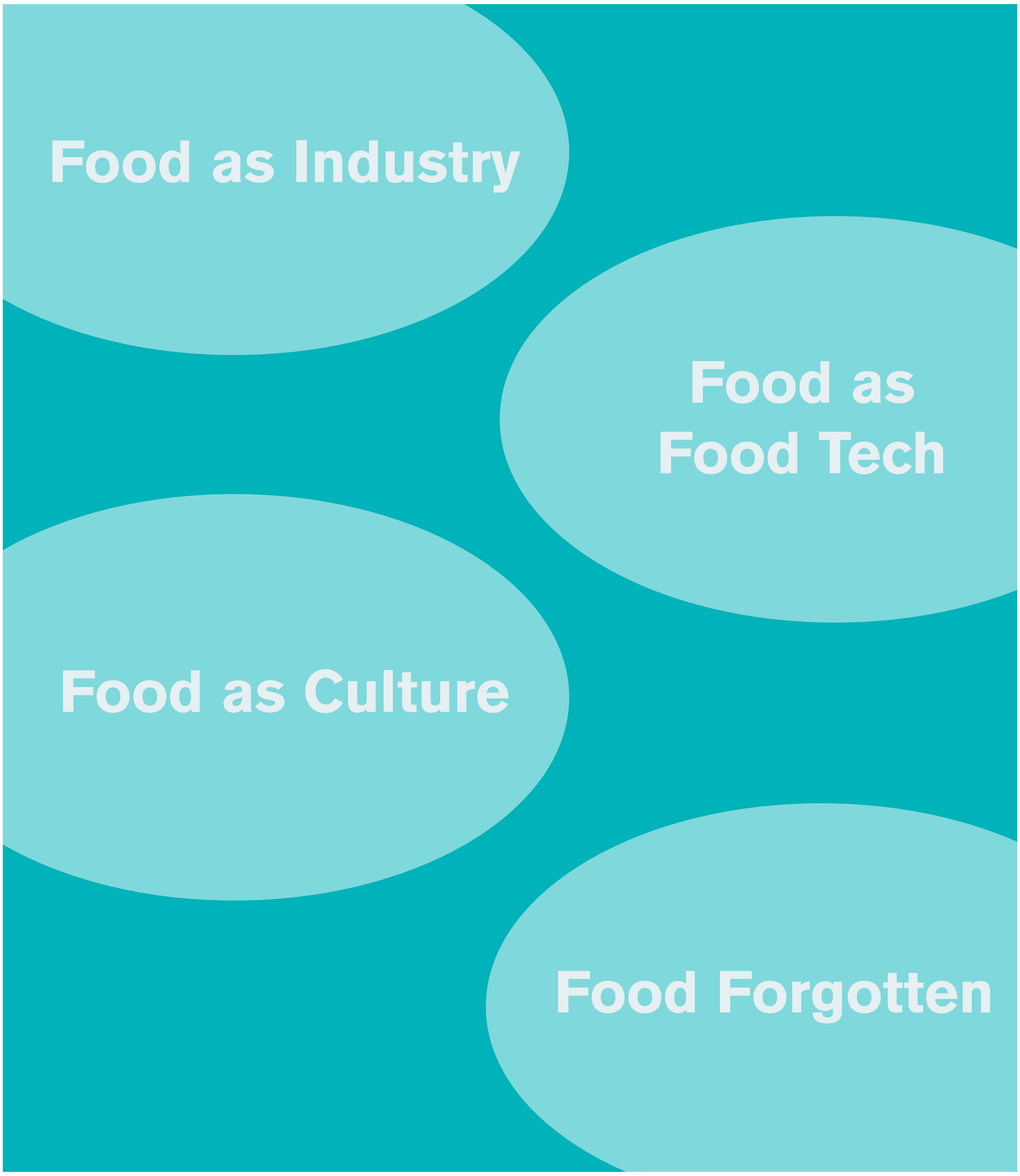


Photo: David Henrichs / Unsplashed

5.1. Food as Industry

In 2045, food is highlighted across Swedish society – as an important Swedish industry that creates jobs and a thriving rural landscape; as an engine for export of sustainable products worldwide; and as an important measure to reach healthier populations, driven by public policy. Food is considered an important commodity for investment and policy interventions, similar to those in e.g. fossil-free steel production in the HYBRIT project in the 2020s. The aim with investments into the agricultural and food sector has been to increase food production by creating a competitive Swedish food sector that grows the value of Swedish exports, hence replacing less climate efficient production in other countries, and increasing employment in the food sector across the whole country. Improvements in productivity, technological development and management in food production have been enabled by support from both government and the private sector (in line with pathways described by e.g. Lantmännen (2019) for wheat and HKScan et al. (2021) for milk and beef). Actors and structures in the food system remain similar to the food system in 2015, but value chains are further consolidated and food industries have grown in size. The increased accessibility of healthier and more sustainable products have made it easy for consumers to change their diets.

The changes to the Swedish food system outlined in this scenario were largely a result of concerted efforts from the government, industry, farmers and investors in meeting the goals of the 2017 National Food Strategy. By 2030, the plan was renewed to incorporate increased sustainability efforts. Food was seen as an industry that Sweden should invest in to benefit Swedish society as well as for increased export, in the same way that Sweden has invested in timber, cars and the music industry. Due to the growing public and private investment in the 'industry'-sector of food, Swedish food production has increased considerably since 2015 with increases in productivity and further intensification of land use, especially in the so called plain districts of Sweden (called slättbygd in Swedish).

By 2045 Swedish food exports have grown following major investments in export strategies and marketing of Swedish products abroad, also reaching out to new markets. While close to half of the Swedish food and agricultural export in the 2020s went to the neighbouring Nordic countries (SBA, 2021f), there has over the past decades been an increased consumer demand for European products in wealthy parts of Asia. The marketing initiatives started already in the early 2020s with exports of pork to the Philippines being one of the first successes (Karlstorp & Lindow, 2020). The marketing of niche export products as environmentally and socially sustainable because they are safe, healthy and climate-smart products with a high level of animal welfare are aligned with the goals of some stakeholders in early 2020s (e.g. Sweden

Food Arena, 2020). Innovative production and marketing enabled the creation of an international market of high quality, more expensive meat and dairy products which in turn resulted in an increased export value. Sweden's large certified organic production with strong environmental legislation is world-renowned and creates the field for other important export products.

Food products and commodities produced in Sweden in the early 2020s were prioritised in marketing investments, i.e. cereals and cereal products, meat and dairy products. Swedish unrefined cereals remain competitive on the global market due to high yields and low unit costs of production (Lantmännen, 2019). Exports of high value and luxury foods have also grown substantially. The export market also broadened to a range of new innovative, unique and mainly plant-based processed food products such as oat drinks, algae snacks and lupine/fava bean burgers, although these make up a much smaller share of the export value. Several of these products are especially aligned with more niche markets across the globe. As Swedish foods are exported based on their added value, this has created incentives to invest in sustainability improvements in agriculture and food processing. Swedish unrefined cereals remain competitive in the global market due to high yields and low unit costs (Lantmännen, 2019).

There has also been a focus on sustainable, and especially healthy, eating in Sweden. This has been driven by the increased health costs of poor diets, especially among groups with poor socio-economic status, and from an increase in environmental consciousness and demand among some consumer groups. The increased focus on healthy eating drove down health costs, stimulated by public policy (information, nudging, and other behavioural policies). Providing healthy and more sustainable foods has become a hygiene factor for the food industry and there has been a substantial increase in the production of fruits, vegetables and legumes to meet domestic demand from the transition to healthier diets. The increased attention on and investment in the added values of Swedish production has also put animal welfare higher on the agenda - people are buying less and better meat, especially with better meat meaning more sustainable meat. A substantial part of the meat consumption, especially for chicken products, burgers and minced meats, is replaced by cheap plant-based meat substitutes that can't be distinguished from original meat in taste and texture. The parallel development of increased livestock production in Sweden and decreased animal product consumption might seem as a contradiction, but is possible under the narrative of Sweden providing the world with its world-class sustainable animal products, while still acknowledging the need to decrease meat consumption in high-consuming countries (cf. Norway and its oil). With the rise in healthy eating, consumption of fruits and vegetables have gone up, and the Swedish market share of these have also increased.

The food environment and the general interest in food among Swedish consumers have developed in ways fairly similar to the trends seen in the early 21st century; people tend to eat out more often, and buy more ready-made meals. In general, people cook more seldom - for the joy of it or for special occasions. However, contrary to developments in the early 21st century, where these trends also drove unhealthy and unsustainable eating habits, food industries' tailoring of meals and products have helped in the transition to more healthy and sustainable eating. Food industries and food services have felt the pressure to develop more healthy and sustainable products to stay relevant and attractive. Such initiatives have made it easier for consumers to make a more sustainable choice (consciously or unconsciously). A somewhat higher interest in food among the wealthier is partly created by targeted governmentally funded campaigns, to stimulate an increase in interest for gastronomy and fine dining in order to promote Swedish products internationally. However, this only stays within rather small circles of devoted and more well-off Swedish consumers.

In general, there is a consolidation in the food sector and a few large retailers and food industries now own and control a large share of the food scene in Sweden. There is a similar consolidation also in the farming sector, where there has been a shift in owner structure, with almost half of the land now owned by limited companies compared to 91% being owned by individual farmers in 2011 (SBA, 2015a).

Many trends in how the agricultural landscapes have developed are a continuation and sometimes an acceleration of previous trends. For example, cereal crop yields have increased by almost 50% between 2015 and 2045. Productivity in livestock production has also increased; in 2045 average milk yields are 14 tons per year and cow, up by 42% since 2021 (HKScan et al., 2021), and livestock growth rates increased by approximately 10% during the same period. Primary production is further intensified, specialised and automated, especially on the plains where farms have tripled in size since 2020.

In cropping, technological advances in precision agriculture, digitalization and optimal management are widely adopted. Examples are autonomous farm vehicles by GPS, drones that link with satellites to analyse and assess the crops, and technological registration of the level of absorbed nitrogen by crops (Lantmännen, 2019, p. 18). Automatization, robots and sensor systems for precision livestock keeping are other examples that facilitate the daily care of cattle and enable a closer control and follow-up of animal health (HKScan et al., 2021, p.20, 29). Grass-clover leys and cereals are still the dominant crops. Agricultural land has decreased somewhat in the forest-agricultural areas.

A continued focus on organic production in the last decades has resulted in increased sales of organic products and increased area under organic practices (after a period of stagnation in the early 2020s). The government target set in 2017, aiming for 30% of Swedish agricultural land under organic production, was reached in 2035 and the share has been stable since then. This corresponds to approximately a doubling of the production volumes in 2020 (Agrovektor AB, 2020). Productivity in organic farming has also increased considerably with higher crop yields and livestock productivity; the developments of the organic sector in Europe, including Sweden, has followed the 'conventionalisation' route (Röös et al., 2018).

Due to the focus on increasing food production, bioenergy production from crops on farmland is minor. However, crop residues and marginal lands are used for energy production following the plan by Fossil Free Sweden Strategy (2021, p.18). Most livestock farms have biogas production plants on their land by 2030. The biogas production, together with optimised handling of manure, has decreased farms' emissions by up to nine percent in 2050 (HKScan et al. 2021, p.32-33).

5.1.1 How the targets were achieved

The ambitious *territorial climate target* was achieved through the possibility to reach national climate targets without further reductions in emissions of agriculture (compared to baseline in the EU Effort Sharing Regulation (ESR)), as other sectors included in the ESR accomplish emission reductions that enable agriculture to take a large share of Sweden's total emissions. Emissions from agriculture remained relatively stable between 2015 and 2045, despite an increase in overall production. The stable overall emissions were a result of substantial reductions in emissions per kg of food produced due to efficiency gains, thus decreasing territorial greenhouse gas emissions per kg of product, but not overall territorial emissions. That agriculture didn't reduce overall emissions was considered acceptable by policy makers since there were climate benefits delivered in other countries by exports of Swedish produce that substituted products with higher emissions in those countries. The ambitious *consumption-based climate target* was met following both dietary change and more efficient production, and to some limited extent due to reduction in waste.

The ambitious *territorial biodiversity targets* were met through increases in dairy and beef production, with payment schemes that enabled maintained grazing of semi-natural pastures. Initially this did not mean expansion of these ecosystems, since cattle production was intensified and there was not a linear relation between the amount of cattle and semi-natural grasslands. However, as demand for beef and dairy with sustainability values increased, more grasslands were grazed. The ambitious *consumption-based biodiversity target* was primarily reached through substantial reductions of imports of foods grown in tropical areas.

The ambitious *nutrition and health target* was met by 2045. Driven by NGO and public agency advocacy in the form of information for improved health and other policies, with the exception of the post-pandemic years, the 2%/yr reduction in meat consumption that began in the 2020s continued through to 2035. This reduction stabilised at a meat consumption of around 55 kg per person (carcass weight) in 2035 (as was suggested by the National Food Agency in 2021 (NFA, 2021), and put into official goals in the mid 2020s). The trend in increased consumption of fruit, vegetables and legumes from the 2020s continued, and also levelled off in 2035 (at 330 kg per person per year; NFA, 2021). These trends come from the increased focus on healthy eating in Sweden, stimulated by public policy with information campaigns and nudging and the food industry's adaptation to meet public demand of Swedish produced, healthy, food products.

Photo: Shutterstock

5.2 Food as Food Tech

When you look at the role of food in Sweden in 2045, it is easy to notice large changes from 2015. Activity tracking watches and wristbands (such as Fitbits) of the early 2020s have evolved into a wide variety of wearable technologies that guide individuals towards a healthier lifestyle. The average Swedish consumer follows personalised dietary guidelines. They are tracked by new technologies, such as nutrient density trackers and microbiome mapping, that are coupled to smart kitchens and various apps that develop weekly sustainable and healthy menus. Healthy and sustainable diets are the norm, aided by the increased accessibility of novel food products that are considered convenient to prepare. These include artificial meat from cell cultures, bacterial and fungal produced proteins, and novel plant-based products replacing some of the original food groups, and being used combined with novel technologies such as 'printing' meat synthesising food products from various sources. Shopping for grocery and chef-prepared pre-cooked meals is convenient thanks to growth and integration of the e-grocery sector, and low-carbon delivery systems. While diets are more personalised, it does not mean consumer control, but rather that the food environment is enabled and shaped by transnational corporations producing, processing and selling food. Swedish food processing has increased substantially than in 2015, while the size of the primary production sector has declined.

The changes to the Swedish food system outlined in this scenario were largely a result of the success of new innovations, most of which were considered marginal in 2015 (e.g. cellular meat, fungi in tanks, protein production with light and electricity, as well as other technologies such as e-commerce). Investment companies and accelerator programs determined to disrupt the food sector, invested heavily in innovations that reduced climate emissions (such as alternative meat and dairy as well as new low carbon logistic systems and delivery vehicles), safe-guarded biodiversity (through e.g. reduced need for pesticides and overall land use) and developed health friendly food processing (e.g. through improving nutrient scores of products and reducing salt and sugar contents). These investments and innovations took place in a society that towards the end of the 2020s started to enforce substantial regulations focused on ensuring healthy and sustainable food processing, through both the Swedish government and the EU.

Many of the companies that did really well were new to the food sector. They built new business models based on expertise and experience from outside the food sector. Some of the major influences came from:

a) The medical sector, including the pharmaceutical industry that was strengthened during the pandemic in the early 2020s. Both capital and technology were mobilised and implemented in the food processing industry for development of meat replacement products, and to meet the emerging markets in preventative medicine (e.g. through food-as-medicine). Current examples of the nexus of biomedical research and the food industry include further development of cultivated meat (John Hopkins Biomedical Engineering, 2022; Eichhorst & Specht, 2018) and research on food as medicine (Hedlund, 2021).

b) The IT-sector, e.g. the development of personalised "fitness-type" apps that was merged with nutritional indicators to provide personalised nutritional recommendations, and development of new "Food as software" technologies.

c) The infrastructure sector where the electrification and development of smaller but more rapid vehicles, including bikes and robots, enabled through availability of clean energy, altered food delivery possibilities in both densely populated areas and for rural communities.

Consumer demand for both personalised diets and convenient novel foods, developed with stronger sustainability values, was also a driver of these changes. The personalised nutrition trends started in the 2010s, with a great increase in sales of gluten- and lactose-free products, and dietary supplements. Sales of sports nutrition related products went up and there was increased shelf space of protein bars and drinks These trends were driven largely by smart marketing skills of IT companies and integration of advertising with mobile phones and wearables. Digitalisation and AI further spurred this through companies merging personalised nutrition apps, fitness trackers and smart fridges, and data from food purchasing. The demand for more convenient food continued to grow in the 2020s with new food products on the market that reduced food preparation times.

By 2030, consumers had on average increased their plant-based portions of diets compared to 2015, as well as the proportion of novel food products[14].

New products had entered the market, marketed as nutritious and climate smart with long shelf-life and little food waste in both processing and consumption. These large changes in consumption were indirectly and directly supported by government policy and regulation. In the late 2020s these trends were further strengthened by increased governmental funding for preventative medicine. Major public funding complemented the private funding and together they supported development of infrastructure for new processing and food tech industries. Government policy allocated funds to research and development, which increased innovation and technological development, such as innovation incubators, across the supply chain.

However, throughout the 2020s, research on health consequences of the growing consumption of novel food products raised concerns about health risks. While many new plant-based processed products were biofortified with micronutrients, the overall effect on public health was still highly debated. In early 2030s the EU put very strict health regulation measures in place on novel food products. This caused a first rapid slowdown of the developments, but the markets were revived by 2040. Unhealthy products still exist but taxation has made them more expensive. Conditions that eventually enabled the development of more healthy novel foods were the rapid expansion of the usage of sustainable and healthy food/meal profiling for strict food policy purposes, the regulation of market access of processed products through food reformulation, optimisation, and taxation of products with bad performance, as well as public food procurement (public canteens supplied with good performing food). Partly forced through regulation, partly as an industry-wide collaboration, some of the major retail companies formed alliances to set stricter criteria on their portfolio of products, to exclude processed foods that did not meet new health standards.

In 2045, the food system is mainly controlled by transnational corporations. While the start-up scene exploded in the period leading up to 2030, many of the new innovations were purchased or copied by larger companies. Enabled by big data analysis technologies, and driven by new legislation, products and meals include data on the packaging (or through the synced apps) that include nutrition scores, carbon footprint and biodiversity index, and information about how and where the raw material is produced. While the

14) The European Commission defines novel food as "food that had not been consumed to a significant degree by humans in the EU before 15 May 1997, when the first Regulation on novel food came into force." (EC, n.d). This includes food that is newly developed, using for example new technologies and production processes, or food products that have previously been eaten outside of the EU (ibid).

data overwhelms consumers to some extent, most people delegate managing this data to their apps, and companies like it because it enables them to improve marketing and logistics.

As prices of cheap and healthy plant-based products fell, so did meat consumption. The livestock sector experienced enormous problems with collapses in several sub-sectors. This trend was further spurred by growing public concerns about animal welfare. In the 2030s, there were major policy developments across Europe that banned some of the worst ways of treating farmed animals. By 2045 the demand for meat had fallen by seventy percent from 2015, with chicken, pork and dairy production being the hardest hit. Grass-fed beef (and some grass-fed dairy) continue to be in demand, as this is considered to have substantial sustainability values that consumers are willing to pay for. With funding available also for production of ecosystem services, the overall land used for grazing on semi-natural pastures in Sweden is maintained over areas similar to those in 2015.

It has become hard to disentangle what a Swedish food product is. The raw materials are imported from wherever is cheapest, which varies by product and time, disconnecting food from where it is grown. However, food processing has increased substantially in Sweden. Sweden exports some of the processed foods being developed here, as well as some crops. Asia has a growing influence on alternative and novel foods and Sweden both exports to, and imports from, the Asian market.

Swedish agricultural production, both in terms of number of farms and farmers, land area under agriculture and total production of crops and livestock has continued to decline. The agricultural production in Sweden has had to respond to the cheap supply of sustainable produce on the global market. Many of the trends from the post-EU entrance in 1995 continue in much the same way. Swedish producers have had a hard time competing on the world market: many farms closed down and the ones that remain continue to grow in size. There are new types of farms being developed, such as fish farming on land. Overall imports of raw material for food have increased, partly due to that the use of raw materials is primarily based on optimisation, considering where it is cheapest, and Sweden is not always as competitive. Prices of fresh commodities have increased while prices of processed foods with long shelf-lives have declined as the food industry built up.

The cultural experience of eating, and the look of meals, are quite different in 2045 as compared to 2015. Convenient and functional food consumption are keywords shaping a substantial part of the market. A majority of the population follow more personalised nutrition advice. There has been substitution of end products (e.g. hamburger vs plant-based burger, milk vs vegan alternatives); ingredients in food products (e.g. sugarfree; plant-based, and biofortification, such as micronutrient additives), and forms of meals (e.g. increase in new convenient food products such as bars or smoothies instead of some meals). Food is less of a social phenomenon, and less time is spent both preparing food and eating, although families still eat together once or twice per week, but people seldom share the same meal, as most people have their own personalized diet.

5.2.1 How the targets were achieved

The most ambitious *climate targets* for both *consumption-based* and *territorial emissions* were met primarily through both a change in dietary demands for products with lower GHG emissions as well as a reduction of GHG emissions in the production of most products compared to 2015. As an example, the demand for animal products has fallen substantially, as a consequence of both lowered prices for plant-based products and concerns of animal welfare. Territorial emissions decreased by having substantially less livestock production within Sweden as compared to 2015. Carbon farming, forestry, and rewilding of Swedish landscapes increased through state supported 'climate fond' subsidies. The production and processing in industry buildings require more energy and other resources, such as minerals, vitamins as essential building blocks and carbohydrates such as starch and sugar, compared to what it did in 2015. However, the amount of energy and resources reduced from what was used for agricultural production in 2015, and most of that energy is low carbon due to the electrification of food supply changes and transport.

The most ambitious consumption-based biodiversity targets were met through a reduction of land area needed for production of food through the plant-based revolution, using novel food sources, and through new types of production that require no or substantially less land (e.g. such as Blue Foods, fungi, microbial fermentation, vegetable production in vertical greenhouses and farm buildings in urban areas). A global no-expansion commitment of agricultural land into tropical forests began in the late 2020s and the implementation of the commitment has been tracked through strong biodiversity reporting and monitoring standards for companies. The ambitious territorial-based Biodiversity targets were met through strong digitalisation of agriculture, enabling an agrarian revolution to optimised but regenerative agriculture that allows for more diversified agricultural fields and reduces need for herbicides and pesticides. Sweden's meat demand is met almost entirely through a low level of extensive grazing livestock on semi-natural grasslands. Seafood consumption in Sweden is sustained primarily through finfish production in recirculating systems on land and large scale musselfarms, with some consumption being replaced by novel plant-based fish-alternatives. Feed to aquaculture systems are supplied primarily from microbes produced from waste residues and by-products from food production and insect meal and from micro-algae (omega-3).

The most ambitious nutrition and health target was achieved by an average Swedish diet similar to the EAT Lancet Planetary Health diet. However, it is an interpretation of the Planetary Health diet adapted to include the same type of macro- and micro-nutrients, but with a substantial increased intake of novel foods. For example, artificial meat from cell cultures and bacterial and fungal produced proteins and starch are replacing some of the original food groups, and being used combined with novel technologies such as 'printing' meat synthesising food products from various sources. This means that the level of processed food has gone up, but that food processing has developed, through strict regulations, to enhance nutrition of food products, many which are biofortified with micronutrients. Relative to the Swedish diet in 2015, the development includes a large protein shift towards high levels of consumption of non-animal-based proteins, and a dietary shift away from dairy fats to unsaturated oils from novel sources. There is an increase in fermented products and functional food consumption.

Photo: Scandinav

5.3. Food as Culture

The Swedish food system has changed quite drastically since 2015, with an increased rural focus in policy and a closer relation between consumers and food production, to a large extent driven by social movements. A new cultural vision of rural-urban and human-nature relationships makes healthy and sustainable food, food production and food security of great importance on a national policy level and in the everyday life of most Swedes. Food trends that were small-scale in 2015, such as an appreciation of local food cultures, shopping in local food nodes, and interest in artisanal food processing, continued to grow and constitute a substantial part of the food system in 2045. People buy more locally produced and diverse food products that have become more easily accessible, spend more time preparing and sharing meals, and more people engage in small-scale food production. Enabled by digitalisation and an increased rural job market, living close to nature in rural and peri-urban areas is perceived as more attractive among many than in 2015. The increasingly specialised farms in the 2020s have transformed to create multifunctional and multicultural landscapes. Changes in both Swedish and EU policy reflect the societal recognition of a larger integration of policies around social equality, self-sufficiency, climate, and environmental justice at local, national and EU levels.

The changes to the Swedish food system outlined in this scenario are largely linked to a renewed and widespread cultural vision of rural-urban interdependence and stronger human-nature relationships. By 2045, food plays a much more central role in the everyday life of many Swedes, in terms of the time and effort that consumers spend in choosing, cooking and eating food, and in terms of rural and environmental focus in both policy and among the public. There is a larger recognition of the multifunctional values of Swedish farming landscapes and appreciation of the stewards (i.e. farmers as landscape managers) who manage this land. The scenario emerged during the 2020s from niches in socio-political and environmental discourses. Between 2022-2035 several major and disastrous events related to climate change, geopolitical tensions, financial crises, and urban-rural connections happened. These led to niche movements aligning with each other and the public in a common narrative that included climate mitigation and adaptation, environmental protection (including biodiversity), social equity, fairness and self-sufficiency as common underlying values.

What drove such a large transition towards higher appreciation of rural areas, local food cultures, less meat consumption, and cities becoming less attractive? Many trends in the early 2020s seemed to be developing in the opposite direction[15].

It started partly as a movement from large cities to medium-sized and small cities and towns and their surroundings, or to recreation hotspots such as Gotland and Åre. One starting point was the social changes during the COVID-19 pandemic, when a substantial part of the workforce began to work from home. This led to escalating housing prices and increased living costs in urban areas as people looked for larger housing to combine work and family. The inequality within large cities and between an urban elite and rural areas that had been rising before the pandemic, now rose even faster. Less favoured areas in cities were regarded as increasingly dangerous because of growing poverty, unemployment and crime rates, and people started to consider moving elsewhere. Rural areas around medium-to-small towns experienced population increases and started to be viewed as attractive. Rural and peri-urban areas were regarded as places of opportunity for farming and small-scale enterprises, resulting in a larger job-market in these sectors. Small-scale recycling technologies for urban and peri-urban areas were developed that depended on proximity between system components, thus lacking any advantages of scale.

Equally important for the transition were a number of growing social movements visible already in the early 2000s. At that time, they seemed to be a scattered and loosely organised collection of people against global and national inequality, questioning economic growth through a discussion of agrowth or degrowth, for better climate and environmental policies, animal rights and environmental justice, as well as agrifood movements placing food sovereignty on the agenda. When several major cities in Sweden and Europe were hit by a series of severe climate-related disasters (flooding and heatwaves) in the late 2020s, major political and social changes emerged. These societal changes resulted from an increased momentum for social movements, who came together creating a narrative of stronger linkages between environmental, climate and social issues and self-sufficiency, and through this became a major influence in the political and public spheres.

Electricity prices soared in Europe already in 2022. It became evident that the world could not produce enough electricity to substitute the global use of fossil fuels unless consumption patterns changed drastically, especially among the wealthy. There were similar developments for other scarce resources including mining for rare elements, resulting in local conflicts with food production or water quality.

These social conflicts and the questioning of the continued growth narrative drove grassroots movements supporting a toughened environmental governance. Eventually, Sweden, along with the EU, saw a substantial strengthening of environmental and rural policies. EU policies on climate, environment and food (in CAP 2028-34) contributed to new rural opportunities focusing on sustainable food production, regenerative agricultural methods, and subsidies targeting small farms providing labour and environmental benefits. Changes in the 2028 CAP were results from policy and public discussions on the EU Green Deal, Farm-to-Fork and Biodiversity strategies. Sweden translated these into policy leading to transitions to regenerative agriculture, agroecology, management for carbon capture and storage, biodiversity and increased animal welfare. This was made possible by combination with devolution of decisions to regional and local governance bodies, ensuring public participation. This development also led to increased interest in the regional food cultures that varied across Sweden and regional food strategies, complementing the National Food Strategy developed.

Agricultural landscapes started to change. By 2045, the farming systems have changed towards more complex crop rotations and a higher crop diversity. Subsidies helped new farmers to start smaller farms growing high value crops. Thus farm size began to decrease in many areas, although bulk production of cereals is still common in major agricultural regions. The livestock sector is smaller than in 2015, and with less environmental and climate impact. Livestock is now mainly fed on semi-natural grasslands, wood pastures, "lefto-

15) However, since this "food as culture" scenario shares many characteristics with the local self-sufficiency scenario in Svenfelt et al. (2019), it is not particularly novel and unthinkable, once the assumption of continued economic growth is abandoned. See also discussion in Svenfelt et al. (2019) and Hagbert et al. (2019).

vers" (e.g. food waste or by-products not suitable for human consumption from e.g. crop production and food processing), and on permanent grasslands and leys to capture carbon. Following EU and national subsidy reforms, farmers get paid for their production of multiple public goods like capturing and storing carbon and restoring biodiversity. Restored grazed grasslands and woodlands were highly positive for biodiversity. Red meat is expensive due to taxation on greenhouse gas emissions and higher production costs, but cutting middlemen in local supply chains and various subsidies has partly compensated. Small-scale pig, rabbit and poultry production has grown. Livestock production is regulated with strong animal welfare standards. International fishing is also highly regulated, banning uncertified fishing from the high seas. However, there are increases in blue foods from new rural industries, including freshwater fish and farming of fish lower in the food webs combined with local recycling. Mussel cultivation in coastal areas has expanded.

There is an increased need for labour in farming and forestry as the new production methods are more labour intensive. Large investments have targeted making farm work more attractive, prohibiting accidents and increasing social quality in rural areas. After years of policy discussion and negotiations, the limited company laws were changed to focus on fulfilment of all three sustainability goals rather than solely economic growth. Consequently, companies and entrepreneurs have started to define their activities in a social and equality context, rather than annual profits only.

Food trade has decreased in volume, but not as much in value, since high-value niche products are exported. The market share of international trade with food is substantially lower than in 2015. Transports are slower and more energy efficient by 2045 than in 2015. Chinese railways across Eurasia and Africa provide good alternatives for bulk transports and proportionally trade with Asian markets has increased.

Food has by 2045 become culturally important in society. More small-scale producers are present in or linked to retail. Alternative value chain networks have grown with digitalisation and ruralisation, making it easier for consumers to find local producers. People eat more Swedish produce, more fruits, tubers, vegetables and pulses, but less meat. More food is cooked at home than in 2015, since people spend more time in what they perceive as meaningful and family oriented activities such as making food and eating together.

5.3.1 How the targets were achieved

The ambitious *climate targets* were difficult to achieve. The extensification of agriculture with larger land use for food production, still a substantial number of ruminants, and higher self-sufficiency, means that Sweden's agricultural emissions could not be substantially reduced. However, continuation of trends of higher productivity led to yields that by 2045 were at the same level as in 2015. There were huge advances in carbon sequestration. Agroforestry, woodland grazing and various locally and regionally adapted methods for regenerative agriculture and agroecology (including innovative organics) contributed to carbon capture and less greenhouse gas emissions. Less food was also needed to be produced, since the fifty percent arable land used to grow animal feed in 2015 is now used for human food. Food waste has been cut by 75 percent and overall consumption levels were kept to 2400 kcal per person. The decrease of meat and dairy consumption helped to reach the ambitious consumption-based climate target.

The more ambitious territorial *biodiversity targets* were met by changes in farming systems that diversified landscapes, and improved ecosystem services like biological control, pollination and soil quality. Management of agricultural ecosystem services became more common as agricultural inputs got more expensive, and production systems promoting ecosystem services became subsidised. Increased grazing by ruminants on semi-natural pastures as well as grasslands in general, enhanced both common and red-listed biodiversity. The *consumption-based biodiversity targets* were met through a sharp decline in import of foods. The majority of food imports in 2045 were certified products that were not possible to produce in Sweden, like fruits and wild fish from sustainably managed fisheries.

The ambitious *nutrition and health targets* were met through an increase in healthy preparation of meals; in homes, in public meals and in restaurants. This shift in mindsets of consumers was driven by increased availability of healthy produce and a drive to eat better. A holistic approach to well-being placed food at the centre of a good life. The changes in food consumption were enabled by a shift in cultural values surrounding food consumption, where people reflected more on the ecological and social footprint of food production as well as its impact on human health, and demanded more locally produced, healthy and sustainable food products. This greater insight into and appreciation of the food system was a result of the Swedish population having a closer relationship to food production, either through participating in agricultural practices or through direct-to-consumer retail. A shift in the available sortiment of food products throughout the country, enabled greater access to more diverse and more local food, and food retailers demanded more diverse food and were willing to spend more on local production. A new greenhouse gas taxation increased the prices of for instance meat, decreasing the consumption of meat and dairy, while consumption of protein from legumes increased by four to eight times compared to 2015. Old and new varieties of peas, beans and other protein crops were developed and introduced on the market. There were similar developments in the cereal sector, as interest grew in using whole grains in food. The exploration of heritage crops also increased Swedish fruit and vegetable consumption (and production). Intake of proteins from fish increased, mainly because of an increase in fish farming along rivers and lakes in Sweden.

Photo: Shutterstock

5.4. Food Forgotten

According to most people, the Swedish food system has not changed much in 2045 compared to 2015. Things seem similar – people seem to eat similar food, and there are farms and red barns across the countryside. However, if you look below the surface, many things have changed. Food that looks the same as in 2015 has different ingredients, food is imported from new regions, and the rural landscape produces other products and services than before. While a change to healthier diets has been enabled by increased accessibility and convenience of healthy foods and new policies, especially at the EU level, food is overall given less importance in people's everyday lives than in 2015. Increasing action to both reduce climate emissions, adapt to the consequences of climate change, as well as address biological diversity concerns has shaped the food system including both food production and consumption in Sweden and Europe, in ways that saw new jobs, activities and actors. The Swedish food industry has become even more deeply integrated into the European food system. These changes have marginalised many former organisations' influence in the food sector, and led to the rise of new rural policies and jobs in Sweden. Due to the strong focus on climate mitigation, farmers have converted land previously used for food and feed to bioenergy production, climate mitigation and adaptation infrastructure and the interests of farmers have seen its political importance and influence decline.

The changes to the Swedish food system outlined in this scenario were primarily the result of two separate developments, both of which affected policy debates: On the one hand there was an increased emphasis of climate and biodiversity concerns in Sweden, on the other hand a loss of influence of food and agricultural actors.

The growing emphasis on climate and biodiversity policy was visible in the early 2020s as countries and the EU acted to reduce their national emissions following the Paris agreement. A sequence of following global agreements on forests, aviation, and food further funded climate action, spurring investment in low carbon products, infrastructure and policy across all of society, from land use, energy production, building, transport, and consumption.

The EU Green Deal accelerated the transformation of social and economic activity across the EU to reduce greenhouse gas emissions by 55% by 2030, along with promoting electrification, building renovation, and changes in land and energy use. These policies furthermore imposed carbon taxes and restrictions on imports to the EU, that required to pay a carbon tariff for the carbon embodied in imported goods.

Part of the EU Green Deal focussing on food, the EU's Farm to Fork policy aimed to make food systems fair, healthy and environmentally-friendly. This reduced support to farmers based on area farmed, and made more funding available for farming based on climate and biodiversity performance. In the EU, the 2020 Farm-to-fork strategy unfolded: under intense pressure from both internal and external actors (including global agribusiness powerhouses, led by the US), and a general weakening of support for EU agricultural policy, the EU weakened the most radical components of the plan, such as increased organic production, reduced pesticide use, and stricter food sustainability regulations for food imports apart from carbon taxes on imports. What remained was a slimmed-down version of the strategy, that emphasised the need to reach global climate and biodiversity targets, but left it much more open to farmers and markets to decide on how to achieve those targets. In parallel, the primary EU agricultural policy tool since the union's inception – the Common Agricultural Policy (CAP) – also increasingly supported agriculture that minimised emissions of greenhouse gases. The EU also further liberalised agricultural markets and trade, while adding taxes on the carbon embodied in agricultural and other imports. These policies combined encouraged food producers and consumers to reformulate existing foods and meals to reduce their carbon footprints to reduce cost, and avoided abrupt increases in food prices.

In Sweden this political development became evident through a number of different policy changes. Sweden's 2017 food strategy was pursued based on an increase of food production, and with the assumption that agriculture would not have to reduce its total emissions to the same extent as other sectors in society[16]. At this time, it was forecasted that by 2045, about half of all Swedish emission space would belong to agriculture[17]. As climate change intensified, and other industrial sectors radically transformed, stakeholders from industry, transport and households all began to feel it was fair to require more action from agriculture. Agricultural subsidies that tended to increase emissions, such as on diesel use, were abandoned and the climate target for consumption – adopted in the early 2020s, but initially only covering aviation and shipping (Miljömålsberedningen, 2022) – was soon extended to also include food consumption. This paved the way for the Swedish climate tax on food, which put a price on the greenhouse emissions from agricultural production, regardless of whether it was produced in Sweden or imported.

There was a consolidation of the European and Swedish food system regime, where dominant corporate actors within the food system were able to consolidate their power through increased economies of scale and specialisation in production where Swedish farmers could hold a competitive advantage, such as cereal production. Large businesses adopted and adapted innovations from both the agro-ecological and agri-tech movements and used these innovations to cope with increased costs of greenhouse gas emissions, shifting production to the most effective location to increase the value of food production and minimise greenhouse gas emissions. Farmers were squeezed in this increasingly competitive global market, as they were facing stricter environmental policies and diminishing demand for animal products. Requests from farmers for assistance and policy support were disorganised and mostly ignored as Swedish policy debates focussed on other issues.

Due to taxes and carbon linked subsidies, farmers and businesses worked to improve their profits by investing in better nutrient and soil management. These changes occurred through both changes in farming practices such as precision agriculture, feed management for reduced methane emissions, as well as the increased integration of other land-management practices for ecosystem services on farmland, climate mitigation, climate adaptation, and energy production. Additionally, food producers gradually modified foods sold to consumers to reduce their greenhouse gas footprints, altering ingredients by blending vegetable proteins into processed meat products to counteract the price impact of the climate tax on foods. They also shifted modified transport and packaging to reduce carbon footprints further.

The strengthening of climate policy, in both Sweden and the rest of the EU, as well as Sweden's

16) SBA (2012a, 2018); Ministry of the Environment (2020).

17) In order to reach net zero emissions, the Swedish climate policy framework aims to reach a level of territorial emissions of about 10.7 mton CO2-eq. in 2045 (representing a 85% emission decrease from 1990 figures). The latest national scenarios project agricultural emissions to be between circa 5.2-7.2 mton CO2-eq in 2045 (SEPA & SBA, 2019, p.4-5). This agricultural emission level thus represents between 49-67% of territorial emissions in 2045.

decision to price food products' greenhouse gas emissions lowered the total climate footprint of Swedish food consumption. This was achieved through a gradual process where people shifted what products they purchased, cut back on the consumption of animal products, in particular beef and dairy, and reduced food waste in response to overall higher food prices.

This scenario saw an even deeper integration of Swedish food companies with European ones than seen in 2020. Increasingly, European firms expand into Sweden, while a few Swedish companies expand into Europe, but even these Swedish companies are internationally owned and operated.

In Sweden there is more focus on the non-food producing green sector (e.g. forest management and wetland restoration to capture funding for climate and biodiversity adaptation rather than food production), while other European countries take larger market shares of food related commodities.

Swedish food producers increasingly integrate energy production in their land management. This includes wind and solar energy, as well as biomass for bioenergy. It also includes combining carbon sequestration with food and energy production, nutrient retention (to reduce greenhouse gases emissions and achieve other environmental goals) through low nutrient farming, recycling of farm nutrients, and reduction of runoff. This occurs in conjunction with the restoration and creation of novel ecosystems to reduce nutrient flow in the landscape as well within farming areas. Overall, the area of Swedish farmland has declined a little, but the way it is being farmed is substantially different as farmers and other land-owners combine food production with other activities.

5.4.1 How the targets were achieved

The more ambitious *climate targets* (both *territorial* and *consumption-based*) were achieved through strong implementation of policies enacted by the EU and Sweden to move all of society towards a net zero future. With CAP being drastically reduced and climate policies in place that pay for carbon sequestration, it was more profitable for Swedish farmers to invest in carbon storage through afforestation or bioenergy production than in food production. Sweden also adopted a climate tax of food products, based on products' carbon footprint. Increased food prices also led to reduction of food waste. Territorial emissions from Swedish agricultural production fell by over 85 percent from 1990 levels, from around seven to under one million tonnes of carbon dioxide equivalents (MtCO2-eq.) per year in the period 2015 to 2045. In other words, Swedish farmers reduced their emissions as much as other sectors in order to reach the overall Swedish climate target of net zero carbon emissions by 2045. Farming a substantial amount of agricultural land in ways that produce low or negative GHG activities, and reduction in climate intensive meat production, such as beef and lamb, made it possible for the Swedish agricultural sector to meet its stringent greenhouse gas emission target, making its part in achieving the target of Sweden becoming climate neutral by 2045.

The ambitious *biodiversity targets* and ambitious *nutrition and health targets* were met, largely driven by climate action. A focus on climate resilience development ensured investments in ecological restoration as well as green infrastructure to assist with climate mitigation and climate adaptation. The climate tax on food did not only bring down consumption of red meat to really low levels, but the income generated was also earmarked to incentivise farmers to enhance carbon sequestration by restoring drained peat wetlands, building flood rendition wetlands, and maintaining high biodiversity value grasslands (Gren et al., 2021). This resulted in preservation and restoration of landscapes, and the plants and animals that inhabit them for recreation, rather than food production. Due to European action on farming biodiversity, and the imposition of biodiversity taxes on European food imports, the biodiversity impacts of imported food were also reduced to meet the biodiversity consumption target. The health target was also met through new EU directives on healthy food processing and policies that forced both retail and meal providers such as the public sector to provide an accessible assortment in line with dietary guidelines.

Photo: Pixabay

6. Analysis and intercomparison of scenario skeletons

In this section, the four scenarios are analysed and compared to one another. We focus on comparing how they achieve the targets, and how the scenarios relate to the identified key variables. We also highlight the most contrasting features of the scenarios.

6.1 Comparison of the scenario skeletons

All the scenarios were designed to achieve the targets for climate, biodiversity and health. All of the targets are ambitious in that they require substantial change in relation to how the trends of the food system have developed over the past decades. Two scenarios are suggested to achieve the more ambitious targets for nutrition and health and for climate (Food as Food Tech and Food Forgotten), while only one scenario achieves the more ambitious level for biodiversity (Food as Culture). The achievements of the targets are preliminary estimates for the scenario skeletons. In the next phase of this project, these pathways will be articulated and refined using quantitative models and qualitative checks on consistency. In order to do this, the targets themselves also need to be set quantitatively (WP2).

Table 5 and 6 gives an overview of the key variables for the four different scenarios, with Table 6 covering the key variables related to the production system. The variables are described in terms of how they have developed until 2045. For some of the scenarios and variables they continue to develop in a similar manner as the trends have been developing over the past decade, while for many variables there are larger shifts. For several of the production variables this is also a first attempt at indicating a quantitative development. In this report of scenario skeletons, we primarily focused on the production side out of the different sectors of the value chain, due to time and capacity constraints. As the work develops with the scenarios, it will be important to develop and quantify more of the variables, and the current quantifications may have to be adjusted.

Table 4. The target levels of the three targets that the scenarios reach. See Table 3a for the corresponding target levels. How the targets are reached in each scenario is covered in the skeleton presentations.

Targets	Food as Industry	Food as Food Tech	Food as Culture	Food Forgotten
Nutrition and health	Ambitious	More Ambitious	Ambitious	Ambitious
Climate	Ambitious	More Ambitious	Ambitious	More Ambitious
Biodiversity	Ambitious	Ambitious	More Ambitious	Ambitious

Table 5. Overview and comparison of key variables in scenario skeletons (apart from primary production that is covered in Table 6). These variables describe the future state in the food system by 2045 or the key drivers of change leading up to this development. When marked 'Trends continue', the current trends of change seen are expected to continue.

Overarching topic	Variables	Food as Industry	Food as Food Tech	
Supply chain	Processing and retail	Trends continue in terms of - Consolidation in food sector - A few large retailers and food industries	Increased food processing in SE, producing healthier novel foods - Retail alliances restrict product portfolio for health reasons - New types of food deliveries, increased e-commerce; ghost kitchens	
Consumption	What do people eat	- Consumption of, and investment in, sustainable and healthy food increases, incl. less meat consumption - Trends continue of ready meals at home, box-meals (matkassar) and eating out	-I ncreased intake of novel processed foods - Large increases in consumption of non-animal-based proteins; unsaturated oils instead of dairy fats; products without added sugar - Personalised nutrition - Less time spent on cooking	
	Food environment	Trends continue as today	- Prices of fresh commodities increased, processed food prices dropped - Food environment dominated by transnational corporations	
	Social values and norms	- Food is viewed as a commodity to invest in, similarly to steel or forestry. - Increased attention Swedish added value	- Food viewed as necessary nutrition - Individualistic focus - Animal welfare important	
Trade	Trade	- Increasing value of Swedish food export, focused on Swedish climate and environmentally added values - Exporter of meat products - New markets reached, e.g. parts of Asia	- More raw material imported - Increased export of processed foods - Europe but also Asia as important markets, for imports and exports	
Governance and institutions	Policy and governance	- Development along the Swedish national food strategy adopted in 2017. - Investments in information, regulation and behavioural projects to increase awareness and interest of healthy and sustainable foods	- Some state supported climate and biodiversity subsidies enabled carbon farming practices and rewilding of Swedish landscapes - Large public investments in infrastructure; innovation, R&D and incubators; preventative medicine to lower health costs; regulation on unhealthy processed food; stronger animal welfare regulations; taxation on meat and other unhealthy foods; using public food procurement for healthier diets	
	People and demographics	- Employment created in the food sector across the whole country	Urbanisation trends continue, rural areas as amenity landscapes	

Food as Culture	Food Forgotten
Expansion of alternative food networks - Closer links between producers and consumers with increased direct-to-consumer retail - Increased production and processing of artisan food	Trends continue and may be amplified; - Consolidation in food sector - A few large retailers and food industries - Less focus on Swedish production as well as processing
- Local and artisanal foods increase - Less meat consumption - Food has a central role in Swedes' everyday life - Big shift in trends towards more time spent on cooking at home and eating together	- Diets in 2045 are similar to diets in 2015, but consist of other ingredients. - Gradual increase of imported and low carbon food. - Decreased consumption of animal products
Increased availability of local and Swedish artisanal food	- Prices of food increased, internalising their GHG emis-sions
- Food viewed as central to culture and as a human right - Rural areas relatively more attractive - Questioning economic growth. - Strong social and local civil society movements	- No great shift in values of food (e.g. changes in diets is a reaction to increased prices)
- Substantially lower trade than today.	- Increased trade
- Stronger environmental focus in policy than today. - EU subsidies for small farms, regenerative and agro-eco-logical production practices and for ecosystem services on agricultural lands, and subsidies for providing labour -Some policies intentionally slowing economic growth	- Strong climate policies in Sweden and EU, including taxes and regulations on GHG emissions; investments in renewable energy, carbon sequestration, and green infrastructure. Reduced EU's GHG emissions by 55% by 2030 among other changes - Incentives to preserve cultural landscapes for recreation - Former organisations lose in influence as the Swedish food system is more deeply integrated in the European food system - Interest of farmers have seen its political importance and influence decline
- Growing inequality in cities; cities less attractive. - Movement from large cities to medium-sized and small cities and towns	- Rise of new rural policies and jobs in Sweden - Urban gardening and urban green infrastructure trends

Table 6. Tentative comparison of scenario skeletons in terms of expected development of domestic primary production.

	Variable	Food as Industry	Food as Food Tech
Cropping	Change in agricultural land use	Slight increase (more profitable to use also more marginal land)	Decrease in agricultural land as animal production is heavily reduced. Freed land primarily afforested, potentially rewilded
	Main crops	Cereals and grass-clover leys	Cereals, grass-clover leys, increase in pulses and oil crops
	Cereal yield increases	Approx 50%[18] until 2050 following heavy investments in food as a commodity	Follows historic trends
	Energy use and production in agriculture	Fast introduction of renewable fuels and other energy as Swedish agricultural produce are marketed abroad as 'sustainable', some bioenergy, solar and wind energy production on farms.	Intermediate introduction of renewable fuels and other energy in agriculture following investments in bioraffinaries, some bioenergy, solar and wind energy production on farms.
	Fertiliser type and use	Fast introduction of fossil free mineral fertiliser, improved N efficiency, limited recycling of nutrients from society.	Intermediate introduction of renewable mineral fertiliser, improved N efficiency, limited recycling of nutrients from society.
	Other technological abatement	Fast introduction of precision ag tech, no nitrous oxide inhibitors allowed as food sold as 'healthy and clean'.	Intermediate to fast introduction of precision ag tech, nitrous oxide inhibitors allowed.
Livestock	Change in livestock systems	Strong increase in production of pork, beef and dairy (for exports).	Strong decrease. Maintaining just enough cattle for grazing semi-natural pastures.
	Productivity increases	Milk yields up 42% in 2050 and growth rates increase by 10%[19].	Milk and beef productivity is reduced as most production follows enhanced animal welfare demands and is mainly sustained by part time farmers and animals mainly fed by grazing.
	Other technological abatement	Fast introduction of tech for manure handling and feed additives to cattle (potentially reducing methane emission with 50% per animal on average in 2050).	Slow introduction of tech for manure handling and feed additives to cattle (potentially reducing methane emission with 10% per animal on average in 2050) as major investments are rather in food tech.
Blue food	- Main species - Production types	- Expanded aquaculture, primarily including recirculating (RAS) salmon farming in Sweden. - Continued forage fishery in the Baltic sea to feed e.g. salmon farming. High levels of persistent pollutants restrict eating some fatty fish from the Baltic Sea and many lakes - Small scale fishing is almost non-existent.	Expanded aquaculture, Fish farming on land (e.g. in RAS and aquaponics), innovative feeds made from e.g. microbes, insects, algae oil etc. - An increased production of plant-based and laboratory grown seafood. - Increased interest for algae production, substantially increased and used as raw material, as food and animal feed. - Clever use of fish by-products for human consumption and feed.

Food as Culture	Food Forgotten
Substantial increase in semi-natural pastures while cropland use stays similar to today but managed more extensively	Decrease in overall agricultural land use, substantial part used for climate mitigation and bioenergy production
Substantial increase in diversity: more legumes, fruits, vegetables and roots but cropland use still dominated by cereals and grass-clover leys, more diversity in crop species	Cereals, grass-clover leys and bioenergy crops
Similar to today because of use of more traditional cultivars.	Follows historic trends
Intermediate introduction of renewable fuels and other energy in agriculture, limited amount of bioenergy, solar and wind energy production on farms.	Fast introduction of renewable fuels and other energy in agriculture, large amount of solar, wind and bioenergy production on farms, following strong governmental support for green energy production.
Slow introduction of renewable mineral fertiliser, improved N efficiency, substantial recycling of nutrients from society.	Fast introduction of renewable mineral fertilisers, improved N efficiency, limited recycling of nutrients from society.
Slow introduction of precision ag tech as smaller farms cannot afford this tech. No nitrous oxide inhibitors allowed.	Intermediate introduction of precision ag tech, nitrous oxide inhibitors introduced following heavy focus on climate mitigation.
Strong increase in grazing livestock, mainly on semi-natural and extensively managed grasslands (and leys), decrease in pigs and poultry.	Strong decrease.
Average milk yields decrease due to targeting breeding more on longevity, robustness and animal health, growth rates stay similar to current levels.	Milk yields up 42% in 2050 and growth rates increase by 10%.19
Slow introduction of tech for manure handling (smaller farms) and feed additives to cattle (reducing methane emission with 10% per animal on average in 2050, feed additives difficult to administer on pasture).	Intermediate introduction of tech for manure handling and feed additives to cattle (reducing methane emission with 20% per animal on average in 2050) following some but no major investment in agriculture.
- Increase in fish farming with mainly native European species feeding at lower trophic levels, e.g. carp-fishes, filter feeders and algae for human consumption. Farming of salmonids is less common. - Wild fisheries managed sustainably (also small scale), but high levels of persistent pollutants restrict eating some fatty fish from the Baltic Sea and many lakes. - Small scale aquaponics for recycling nutrients and local production.	- Blue food production in Sweden remains small and at current levels. Instead of investing in an expansion of aquaculture, Sweden imports around 70-80% of the seafood consumed (in line with current trends (see Hornborg et al., 2021)).

18) Lantmännen (2019)

19) HKScan et al. (2021)

6.2 Overall pathways of change; transformation, technological substitution, re-orientation and de/re-alignment

In all the four scenarios, substantial changes to the food system are needed to reach the targets. Across the scenarios there is a pressure on the food system from societal, economic and political levels, in both Sweden and elsewhere, following increased societal demands for improved environmental performance (primarily in climate mitigation and biodiversity conservation) and improved health outcomes. The scenarios deal with these pressures for change in different ways, and the pressures themselves are also slightly different in the different scenarios. This leads to some overall variations in the pathways that the scenarios take.

In Food as Industry, for example, extra pressures are related to political emphasis on increased domestic food production and food sovereignty. Food as Industry sees gradual adjustment of the existing system where incumbent actors reorient and reinvent themselves in response to the pressures, partly by accelerating ongoing innovations among the current main actors (e.g., using technological innovations such as precision agriculture), and partly by co-opting niche innovations (agro-ecological /carbon storing agricultural methods). This type of pressure-change transition is similar to what Frank Geels and Johan Schot (2007) call a transformation pathway, which is a pathway characterised by outside pressure, institutional power struggles, negotiations, and adjustment of rules. The main actors in such a pathway are incumbent actors, who adjust practices and rules (goals, guiding principles, search heuristics) in response to outsiders (e.g., social movements) that voice criticism.

As a contrast, the major pressures in Food Forgotten are the withdrawal of EU agricultural support through reorganisation of the CAP and increased liberalisation of agricultural trade. This reorients Swedish agriculture to climate mitigation rather than food production. In Geels and Schot's categorization (2007) this can be seen as a dealignment and realignment pathway, characterised by erosion and collapse of the preexisting food system, multiple novelties, prolonged uncertainty and changing interpretations, new winners and stabilisation. This type of pathway is often dominated by new niche actors, with interactions driven by changes in deep structures. Incumbents lose faith and legitimacy. New actors compete for resources, attention and legitimacy. Eventually one novelty wins, leading to destabilisation of the previous food system configuration.

In both Food as Food Tech and Food as Culture, the societal pressures for change of food systems are leveraged by niche actors in the current food system to transform it. In the Food as Culture scenario this leads to changes to the current systems that include a strong political focus on rural development, plus a cultural shift that emphasises reconnection with producers and production landscapes. Geels and Schot (2007) call this type of transformational change a reorganisation pathway, characterised by cumulative component changes because of economic and functional reasons. This is followed by new combinations, changing interpretations and new practices, and the main interactions are related to how niche actors and incumbent actors adopt innovations, with competition between old and new suppliers.

In the Food as Food Tech scenario there is also a cultural shift in what food means to people, but in the opposite direction, away from traditional production to the consumption of more processed, ready-made, and even synthesised foods. This shift is driven by private and public investments in R&D and liberalisation of trade in response to an increased demand for healthy and personalised food. It is similar to what Geels and Schot (2007) call a technological substitution pathway, characterised by market competition and power struggles between old and new firms. Newcomers develop novelties, which compete with current food system technologies.

6.2 Contrasting features between the scenarios

There are a number of key differences between the scenarios (Figure 5a and 5b). The variables that contrast the most are a) the share of the food consumed in Sweden that is also produced in Sweden, b) the extent to which national and international policy versus markets drive the development of the food system, c) how much the government and EU is investing in primary production in

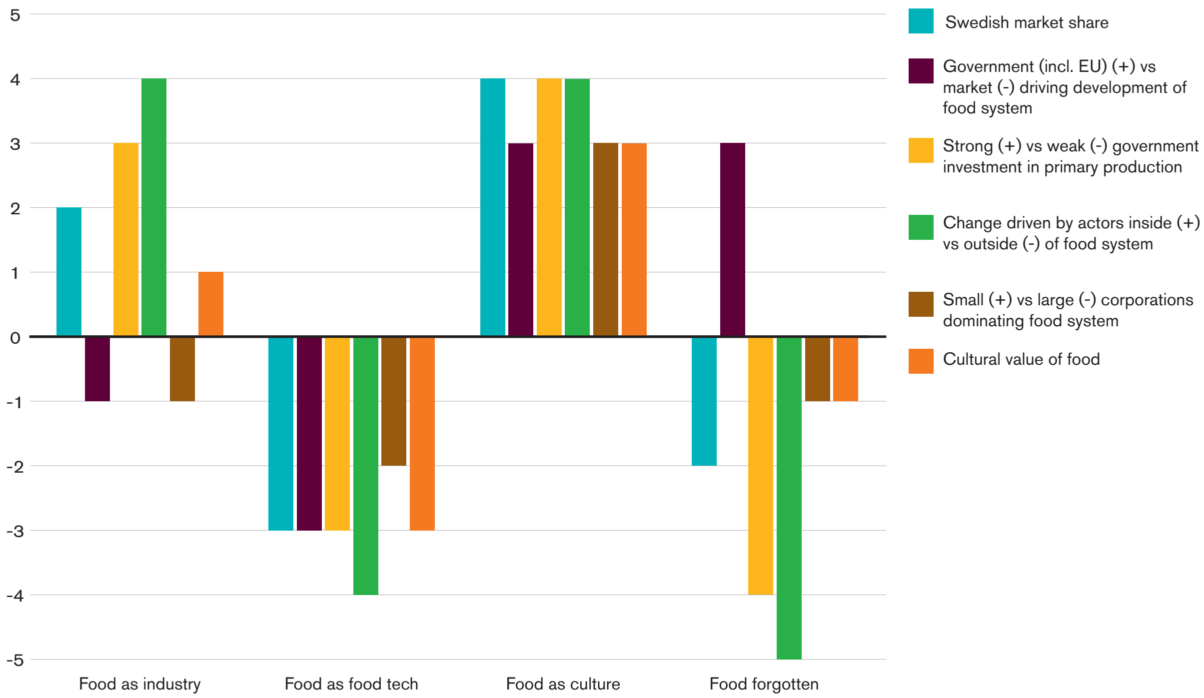


Figure 5a. Six features that vary substantially among the skeletons. These features were chosen as they were considered to be aspects that represent the contrasts between the scenarios, and were derived from the scenarios' set of key variables (see Table 1). The numbers represent the relative change between 2015 and 2045.

Sweden, d) to what extent change in the food system is driven by actors currently in the food system (e.g. farmers and retail), vs actors currently outside the food system (e.g. general climate policy and non-food related e-commerce sector), e) whether the food system is dominated by small or large companies, and finally f) how central food and primary production is to the everyday culture of Swedes.

Despite representing quite different narratives and pathways, Food as Food Tech and Food Forgotten show similar trends in the majority of the features in Figure 5a and b, apart from that changes in the food system occurring in Food Forgotten are mainly driven by policy and investments by the Swedish government and EU, while it is spearheaded by market actors and regulated by policy, in Food as Food Tech. The two scenarios clearly contrast with Food as Industry and Food as Culture. These two scenarios nevertheless display substantial differences between them as well, where the future Swedish food system in Food as Culture experiences a more government-supported transition led by local governance and civil society where also smaller corporations play a bigger role than in Food as Industry. Food has the biggest cultural and social role in society in Food as Culture with for example artisan food in focus, and then decreases successively in Food as Industry and Food Forgotten to ultimately have the least dominant role in Food as Food Tech, where food is considered more of an individual fuel than something to be socially enjoyed.

The development in the different scenarios is driven by different types of actors within and outside of the food system. While actors currently within the food system such as primary producers, retail actors and food industry drive change in two of the scenarios (Food as Industry; Food as Culture), a range of actors and events outside of the current food system impact the system in the other two scenarios, such as pharmaceuticals and climate policy (Food as Food Tech; Food Forgotten). The actors involved also vary in size. Niche actors disrupt the current system, supported by governmental policy and investments, in Food as Culture and Food Forgotten, whereas change is driven primarily by current dominant actors in Food as Industry and Food as Food Tech.

Key features	Food as Industry	Food as Food Tech	Food as Culture	Food Forgotten
Swedish market share [20]	Increase in Swedish market share, following increased Swedish production and strong export strategies	A likely decrease in Swedish market share, due to support to Swedish production. Increased processing in Sweden, but raw material is often imported.	Large increase in Swedish market share. Emphasis on self-sufficiency and increased Swedish production. Less volume of food exported.	Decrease in Swedish market share with decrease in Swedish food production and increase in import food commodities.
Government/EU vs market driving food system development	Market slightly more dominant than in 2015 but support also from government	Market much more dominant than in 2015	Local government, enabled by national government support, much more dominant than in 2015	Government dominant
Government investment in primary production	High investment in Swedish primary production	Low investment in primary production, but instead in other food system sectors such as novel production and processing	High investment in living landscapes	Minimal investment in food production, but instead in e.g. carbon farming and bioenergy production
Change driven by actors inside or outside the food system	Driven by dominant food system actors and policy initiatives and investments	Driven by actors new to the food system. Disruption by niche actors	Driven by actors in the current food system including niche actors	Driven by non-food system actors
Size of corporations dominating the food system	Current trend continues towards larger corporations	Large multinationals but with a thriving start-up scene	Smaller corporations thrive	Current trend continues towards larger corporations
Cultural value of food	The role of food similar to 2015, with slightly higher cultural value	Food more individualised and less important than in 2015	Food central in Swedish culture	Food considered less important in everyday lives of Swedes than in 2015

Figure 5b. Additional information for the features in Figure 5a.

20) The Swedish market share represents the share of the total Swedish food consumption that is produced in Sweden (production plus import minus export) (SBA, 2021a).

6.3 Enabling conditions of the skeletons

In order for the scenarios' food system transformation strategies to reach the three targets, they require certain conditions to be in place. Some of these conditions are similar across all the scenarios, while others differ. For all the scenarios we assume a full electrification of the Swedish food supply chain by 2045, including fossil free transport systems. We also assume that there is a general increased demand for healthier and more sustainable food for all consumers, and that food loss and waste is at least halved in accordance with the Sustainable Development Goal (SDG).

At this stage of the analysis, we have not dealt with specific shocks and disturbances to the scenarios. Whether the suggested scenarios are robust to shocks will be explored later. This means that we for now assume relative political stability in Sweden and the EU (e.g. we have not accounted for aspects such as possible impacts of a WWIII in the aftermath of Russian war on Ukraine 2022). We also assume climate change mitigation to be in line with meeting the Paris Agreement, i.e. climate pathways that takes us to a 1.5-2.0 degree development by 2050, but we have not specifically addressed consequences of climate shocks, or what happens if the Paris Agreement is not met. How the scenarios and their corresponding food system strategies withstand shocks to the food system will be more closely examined at a later stage of the project, alongside the creation of shadow scenarios that will explore a different set of enabling conditions for each scenario.

More specific assumptions on enabling conditions for the different scenarios are presented below. These assumptions are, for now, not backed up by an analysis of data or trends.

For *Food as Industry* we assume that there is a national *interest in* increased food production in Sweden and in national food sovereignty, which results in increased public and private investments in agriculture/seafood production. We assume an increased global demand for Swedish production, especially of cereals, meat and dairy production, some of which comes from new international markets. The increased interest is especially driven by increased global demand for products with high sustainability values and Swedish products are assumed to be competitive in terms of meeting that demand.

For *Food as Food Tech* we assume that there are national and European policies regulating processed foods so that it needs to meet a certain health standard. We also assume that the geographic sourcing of produce used for food processing is not of importance for food processors; they buy produce from where it is most sustainable and at the lowest price. We also assume substantially increased concern for animal welfare and an increased consumer willingness-to-buy novel food alternatives, and that they are willing to change how they buy food.

For *Food as Culture* we assume that there will be a new wave of urban to rural migration, with greater opportunities for farming and small-scale enterprises in rural and smaller towns. Increased living and housing prices together with urban inequality are considered as 'push' factors from cities. Work in primary production will be perceived as more attractive than today. There will be increased governmental investments in primary production. There will also be an increased growth of influential social movements.

For *Food Forgotten* we assume that multilateral governance is strong, e.g. through EU CAP and Green Deal. This leads to strong implementation of climate policies in EU and Sweden but less government/EU funding for food production, and more funding for climate mitigation. This includes investments in climate change mitigation and adaptation, biodiversity and energy production. The emphasis of climate and biodiversity concerns rather than food underlies shifts in landscape production and food consumption.

Further testing and elaborating these enabling conditions is central to the next phase of scenarios work in MISTRA Food Futures.

7. Conclusions

The scenarios demonstrate that there exists a variety of pathways that could achieve ambitious territorial and consumption based targets for Sweden's food system, as related to climate, biodiversity and nutrition. The food system development will differ substantially depending on the scenario, with substantial but different consequences for the people involved in production, processing, retail, trade, restaurants and the public sector. They also differ substantially in terms of who owns different parts of the food system, what is produced in Sweden and how much of the food that is imported, what the Swedish landscape looks like, how people consume food, and what people eat.

Future work by this group will do more thorough analysis of the internal consistencies of these skeleton scenarios, quantitative various aspects of them, and better assess what types of enabling conditions are needed for the scenarios to achieve the targets. We intend to develop shadow scenarios that will assess how well the food system strategies cope in a world without the enabling conditions that allow them to meet the targets, and test the robustness of these scenarios to different shocks. We will also analyse trade-offs and synergies across various indicators. Comparing what works better across scenarios and how different changes can reinforce or impair one another will be used to identify: what actions are needed to drive change, and what hybrid policies are practices could help Sweden achieve food system targets in a fair and effective fashion.

Our aim has always been that stakeholders would find the scenarios useful in their work. Hopefully we can now get feedback from stakeholders that could improve the scenarios. These scenarios can be useful for stakeholders to discuss what actions they can take to either help create and enable their desired scenario, or build robustness of their operations if an alternative pathway unfolds.

Our hope as authors is that the scenarios, by spelling alternative pathways that all reach shared goals, could enable respectful dialogues among stakeholders with different perspectives on how the food system can develop. In reality, the future will likely not be just Industry, Culture or Food Tech. Nor will food be completely Forgotten in policy and investment strategies. The future will most likely be a mix of all of these pathways. Now it is time for all of us who have the agency to act to shape future food system development to ensure that this mix will unfold in a way that builds a better society for all. Let's do this with respect, curiosity and determination that a more sustainable, healthy and fair world is possible.

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Appendix 1. Additional description of method

This appendix presents the iterative methodology behind the development of the scenario skeletons in greater detail, in addition to section 3.

Table 8 gives deeper insight into how the broad range of materials used informed the process of the creation of the skeletons. The four scenario skeletons have drawn insight from a range of sources including 1) an initial scenario expert workshop at the Stockholm Resilience Centre (SRC) in 2020; 2) the work package's scenario literature analysis, meta-literature review and trends overview; 3) findings from other current projects of the Swedish or Nordic food system (Wood, Halloran & Gordon, 2020; Wood et al. in prep); and 4) the expert group's insight of both the Swedish food system landscape, actors and trends as well as food system transition in general.

Food scenario workshop in 2020

One material that was used to inform the table of variables (Table 7) as well as the rationale and content of the scenarios was the results from an initial mapping of key drivers of change in the Swedish food system at a workshop in 2020 at the Stockholm Resilience Centre with food and scenario experts from SRC, SLU, KTH, and Chalmers (many of whom are part of this report author team). During the workshop, key drivers in the Swedish food system were identified and ranked according to both their importance in the Swedish food system and their uncertainty in a future food system in 2050. The most interesting combinations of these drivers, ranked as most uncertain and important, were combined during the workshop to create four clusters of drivers of change (Table 7). These clusters were used to inspire both the food system strategies of the MISTRA Food Futures scenario skeletons as well as the key variables that the skeletons address.

Creation of overview of food system variables

We created an overview of drivers of change and key variables in food system scenario literature to support the creation of our skeletons (Table 9). The analysis was done by undertaking a mapping of key drivers of change and food system-related variables in order to create a list of the most common drivers of change and outcome variables as well as important missing variables related to the food system in the literature, from which we could choose a set of variables suitable for our scenarios. The mapping was conducted on the background material prepared by WP3 (a scenario literature analysis and a meta-literature review); the material that emerged from the initial expert

Table 7. Clusters of key drivers of change for the future Swedish food system, developed during the expert scenario workshop in 2020.

Responses to climate change	Sweden + EU food policy
Climate policy, climate change impact, and adaptation and mitigation practices on climate change	Swedish food strategy and EU policy and regulation
Social-cultural change	Technological change
Social movements and social and cultural change (food consumption)	Tech change outside of agriculture, incl. eg. lab-grown meat and new plant-based products

Table 8. Overview of material that informed the scenario skeletons.

Material	How the material fed into the skeleton creation
WP3 Literature analysis of food system scenario studies	- Mapping of key food system variables (both common and less featured) identified in the studies. These variables were included in the list of food system variables, Table 9, that acted as the basis for the key variables to be included in each of our scenarios (Table 1). - The studies' scenarios' storylines and narratives were used as inspiration for the skeletons.
WP3 Meta-literature review of food system scenario studies	-Mapping of common and less featured key variables of food system scenarios as identified by the literature reviews. These variables were fed into the extensive list of variables, Table 9, that was the basis for the key variables to be addressed in the scenario skeletons (Table 1).
WP3 Overview of trends in the Swedish food system	- Used as inspiration for the skeletons' storylines and information for how the scenarios reach the targets. - Will be used more extensively when the skeletons are developed into full scenarios.
North Western Paths (Wood et al. in prep)	- Mapping of key variables in Basnet et al. (2020) by the WP3 team, that were included in the list of food system variables, Table 9, that acted as the basis for the key variables to be included in the scenario skeletons (Table 1).
Data on the Swedish food system, primarily agricultural and environmental statistics, were included in the WP3 overview of trends.	- Will be used more extensively when full scenarios with modelling.
Scenario workshop on the Swedish food system with researchers in March 2020	- The workshop's mapping of key drivers of change of the Swedish food system (Table 8) played a key role in the formulation of the food system strategies that underline the four MISTRA scenarios. The identified key drivers were also included in the extensive list of variables (Table 9) from which we formed the list of key variables to be addressed by each scenario (Table 1) as well.
Nordic food system transformation dialogues (Wood et al. (2020a,b,c; 2021)	- Mapping of key variables in the material, identified by WP3, were fed into the list of variables (Table 9) that acted as the basis for the key variables to be included in the scenario skeletons (Table 1).
The expert team's insight in the Swedish food system and of previous scenario work	- Informed all parts of the creation of the scenarios, from the selection of variables in the final variable list (Table 1), the shaping of the skeletons' rationale, to the skeleton storylines.

scenario workshop held in 2020; and the findings of other current Nordic food projects (Wood et al., 2020a,b,c; 2021).

We systematically mapped all key variables of the twenty-six included food scenario studies of the scenario literature analysis. The key variables were mainly discussed in this literature as drivers of change, but also occasionally in other terms such as key uncertainties, assumptions or storyline elements. As the included studies in the literature analysis differed in their core focus of their scenarios, from for instance agricultural systems or diets to broader scopes of the food system, the drivers of change and key variables naturally differed between the studies as well. Variables that are seen to drive change in some studies may thus be considered as outcome variables from other processes of change in other studies. For studies that quantitatively model outcomes (e.g. Röös et al., 2016; Karlsson et al., 2021), the key variables that are modelled and thus shifts between the scenarios were considered. For studies that used the common scenario development technique of a 2x2 matrix approach, where the two most significant uncertainties of the future food system define two scenario axes (Curry & Schultz, 2009), we included the scenario axes. A few of the studies described megatrends or combined discussions of drivers of change and megatrends, in which case we mapped the megatrends as drivers of change but not their proposed outcomes.

We complemented this list of variables by identifying common drivers of change and key variables in our meta-review of nine food and agricultural scenario study reviews in a similar methodological manner as described above. This helped us to ensure that our findings from our scenario analysis were supported by other reviews and to explore if there were additional variables to add to the list.

In addition to commonly discussed variables, we also identified a number of less frequently addressed issues in food system scenarios in the literature analysis and the meta-literature review in a similar methodological manner. The less frequently discussed or 'missing' issues were either identified by us in our analysis of the material or by the authors of the examined studies. Section 2.2 discusses some of the findings.

Key variables and elements discussed in the Nordic food system transformation dialogues (Wood, et al., 2020a,b,c; 2021) were also identified in a similar manner and added to the list. These dialogues, part of the project 'Towards sustainable Nordic food systems', gathered Nordic policy makers and food system actors in discussions on food system transformation in the Nordics and possible social, environmental and economic impacts a transformation may result in. Drivers of change were not explicitly identified by this project. Instead, we analysed the leverage points identified by the study's authors to a number of key barriers for food system transformation identified by the participants (Wood et al., 2021) as well as uncertainties that the participants associated with different food futures concerning moving towards more localised food system or continued global food systems as well as consumption of less red meat or more legumes and nuts (Wood et al., 2020c); and opportunities of Nordic food system collaboration (Wood et al., 2020b). From this material, a number of key recurring elements and implicit driving forces were summarised.

From this extensive list, we created an overview summarising the main variables of the most common and least frequent drivers of change and outcome variables in our selection of food and agricultural transformation literature (Table 9). Based on Table 9 and the WP3 team's collective insight in the Swedish food system, the team then chose a selection of variables that all scenarios are to address, that was found suitable for both the Swedish food system and the scope and aim of the target-seeking scenarios (Table 1. in section 3.3.1.1).

The examined scenario and food system studies share a number of broad drivers of change, including demographic, social, economic, environmental, technological and political drivers (Table 9). The studies include a mix of indirect and direct drivers, and the emphasis of different types of drivers depend partially on the scope of the study. Overall, the findings in the table suggest that drivers such as population change and demographics, introduction of new technologies, policy and governance, market and trade conditions, changed consumer demand alongside changed values and lifestyle norms, as well as impacts of environmental and climate change-related processes are commonly used as variables in food system foresight studies. Furthermore, changes in both primary production (concerning for instance cropping and livestock systems, fisheries and aquaculture) and the food industry in large are touched upon by several studies.

Table 9. Summarised list of common drivers of change and variables in foresight literature on food systems divided in broad categories (e.g. Primary production). Under-recognized variables are identified at the end of each category.

Primary production	
Variables	Data source: Literature analysis, *Meta-literature review*, Other Material
Agricultural production, production systems and cropping systems Different production systems (e.g. agroecology, sustainable intensification, organic), resource-efficiency, cropping intensity, technology shifts, mitigation and adaptation practices of agriculture etc.	Basnet et al. (2020); FAO (2018); Hauck et al. (2017) & Priess et al. (2018); Karlsson et al. (2018); Karlsson et al. (2021); Lehtonen et al (2021); Le Mouël et al. (2018) & Mora et al. (2020); Lóránt & Allen (2019); Mitter et al. (2019, 2020); Poux & Aubert (2018) ; Röös et al. (2016); Röös et al. (2021); Searchinger et al. (2019); Sellberg et al. (2020); Springmann et al. (2018); WEF (2017) *Maggio et al. (2019); van Dijk & Meijerink (2014)* Expert food workshop
Nutrient management and agricultural inputs	Lehtonen et al. (2021); Mitter et al. (2019, 2020); Poux & Aubert (2018); Searchinger et al. (2019); Sellberg et al. (2020); Springmann et al. (2018); Öborn et al. (2011, 2013)
Changes in yields and/or irrigation	Basnet et al. (2020); FAO (2018); Lóránt & Allen (2019); M'barek et al. (2020); Poux & Aubert (2018); Hauck et al. (2017) & Priess et al. (2018); Röös et al. (2021); Searchinger et al. (2019); Springmann et al. (2018); Öborn et al. (2011, 2013) *Godfray et al. (2010); van Dijk & Meijerink (2014)*
Land use and land use management Availability of and changes in land use of primary production; demand for agricultural land; competition between land uses	Basnet et al. (2020); FAO (2018); Haines-Young et al. (2011); Karlsson et al. (2021); Lóránt & Allen (2019); M'barek et al. (2020); Poux & Aubert (2018); Röös et al. (2016); Sellberg et al. (2020); Öborn et al. (2011, 2013) *Godfray et al. (2010); Lentz (2021); Zurek et al. (2021)*
Biofuels, biomass and biomaterials Biomass/fuels production and level of consumption	Basnet et al. (2020); FAO (2018); Karlsson et al. (2018); M'barek et al. (2020); Hauck et al. (2017) & Priess et al. (2018); Poux & Aubert (2018); Searchinger et al. (2019) *van Dijk & Meijerink (2014)*
Livestock systems Levels of livestock production and productivity, livestock practices and feed	Basnet et al. (2020); FAO (2018); Karlsson et al. (2018); Karlsson et al. (2021); Le Mouël et al. (2018) & Mora et al. (2020); Lóránt & Allen (2019); Mitter et al. (2019, 2020); Poux & Aubert (2018); Röös et al. (2016); Röös et al. (2021); Searchinger et al. (2019); Springmann et al. (2018)
Marine and freshwater capture fisheries and aquaculture	FAO (2018); Searchinger et al. (2019); Spijkers et al. (2021); Öborn et al. (2011, 2013) *Godfray et al. (2010); Zurek et al. (2021)*

Less featured drivers of change or themes	
▪ Agricultural pests and diseases (Lentz, 2021) ▪ Aquaculture (van Dijk & Meijerink, 2014; WP3 literature analysis); Marine and freshwater capture fisheries (WP3 literature analysis) ▪ Farm structures, including production and production systems (Maggio et al., 2019; van Dijk & Meijerink, 2014) ▪ Gender aspects linked to primary production (e.g. accessibility) (Lentz et al., 2021) ▪ Lack of key fertiliser ingredients (Lentz, 2021) ▪ Oceans and coastal areas (Maggio et al., 2019) ▪ Post harvest losses and storage (van Dijk & Meijerink, 2014) ▪ Rewilding (WP3 literature analysis)	
Supply chain	
Variables	Data source: Literature analysis, *Meta-literature review*, <u>Other Material</u>
Agri-food chain structure and actors Level of collaboration, vested interests of food actors, change in ownership and power of corporations	Grivings et al. (2020); Lehtonen et al (2021); Le Mouël et al. (2018) & Mora et al. (2020); M'barek et al. (2020); Mitter et al. (2019, 2020); Mylona et al. (2016); Raudsepp-Hearne et al. (2020); Sellberg et al. (2020); WEF (2017) *Maggio et al. (2019)* <u>Wood et al. (2020a,b,c; 2021)</u>
Agricultural, marine and food sector workforce and work conditions Age, education, social status, size of workforce, livelihoods	M'barek et al. (2020); Mitter et al. (2019, 2020); Spijkers et al. (2021) <u>Wood et al. (2020a,b,c; 2021)</u>
Food loss and waste Food loss and waste in different parts of the food system, incl. production, retail and consumption	Basnet et al. (2020); FAO (2018); Grivins et al. (2020); Karlsson et al. (2018); Mitter et al. (2019, 2020); Röös et al. (2021); Searchinger et al. (2019); Springmann et al. (2018) *Zurek et al. (2021)*
Less featured drivers of change or themes	
▪ Agricultural and food sector workforce and work conditions (WP3 literature analysis) ▪ Missing 'middle' of the value chain, e.g. processing and retail (Zurek et al., 2021; WP3 literature analysis)	
Societal context	
Variables	Data source: Literature analysis, *Meta-literature review*, <u>Other Material</u>
Energy Often society-wide energy issues such as energy efficiency, energy prices, energy mix, access to energy	EC (2017); Haines-Young et al. (2011); Hauck et al. (2017) & Priess et al. (2018); Le Mouël et al. (2018) & Mora et al. (2020); M'barek et al. (2020); Searchinger et al. (2019); Spijkers et al. (2021); Öborn et al. (2011, 2013)

Technology, research and innovation --- Technology and innovation applied to the whole value chain, R&D, science, development, level of uptake, acceptance of users	EC (2017); FAO (2018); Grivins et al. (2020); Haines-Young et al. (2011); Lehtonen et al (2021); Le Mouël et al. (2018) & Mora et al. (2020); Merrie et al. (2018); Mitter et al. (2019, 2020); Mylona et al. (2016); Raudsepp-Hearne et al. (2020); Spijkers et al. (2021); WEF (2017); Öborn et al. (2011, 2013) *Bourgeois (2016); Bourgeois & Sette (2017); Lentz (2021); Maggio et al. (2019); Zurek et al. (2021)* Expert food workshop 2020
Societal values --- Shift in values, preferences, interest and behaviour concerning e.g. nature, food production, environmental and sustainability issues	Grivins et al. (2020); Haines-Young et al. (2011); Hauck et al. (2017) & Priess et al. (2018); Le Mouël et al. (2018) & Mora et al. (2020); Mitter et al. (2019, 2020); Raudsepp-Hearne et al. (2020); Sellberg et al. (2020) *Bourgeois (2016); Bourgeois & Sette (2017)* Wood et al. (2020a,b,c; 2021)
Social cohesion --- E.g. polarised and fragmented or connected social dimension	Grivins et al. (2020); Merrie et al. (2018); Mitter et al. (2019, 2020); Mylona et al. (2016); Spijkers et al. (2021)
Social movements --- Movements for environmental and/or societal causes related to the food system	Expert food workshop 2020; Wood et al. (2020a,b,c; 2021)
Less featured drivers of change or themes	

- Agricultural biotechnology (Lentz, 2021)
- Cultural and religious drivers (WP3 literature analysis); cultural diversity (Raudsepp-Hearne et al., 2020)
- Differential adoption of technology (Lentz, 2021; Zurek et al., 2021)
- Gender (Lentz, 2021; WP3 literature analysis)
- Global food supply technology (Lentz, 2021)
- Governance of technology (Zurek et al., 2021)
- Inequality and equity (incl. social dynamics of power) (Lentz, 2021; Zurek et al., 2021)
- Shocks as drivers of change, such as human disease and pandemics, economic crises and energy crises (Lentz (2021); Reilly & Willenbockel (2010); van Dijk & Meijerink (2014); Zurek et al. (2021); WP3 literature analysis) (Note: A few studies in the WP3 literature analysis includes shocks as drivers of change, e.g. Raudsepp-Hearne et al. (2020) with e.g. environmental, population and food quality crises and Milestad et al. (2014))
- Social-ecological dynamics and feedbacks (WP3 literature analysis; Merrie et al., 2018; Raudsepp-Hearne et al., 2020)
- Social values (incl. education, capacity building) (Maggio et al., 2019)
- System or spatial perspective on technological innovation, including e.g. regional differences (Zurek et al., 2021)

Economic and market	
Variables	Data source: Literature analysis, *Meta-literature review*, <u>Other Material</u>
Economic development/growth (e.g. GDP)	FAO (2018); Haines-Young et al. (2011); Le Mouël et al. (2018) & Mora et al. (2020); Mitter et al. (2019, 2020); Mylona et al. (2016); Hauck et al. 2017 & Priess et al. (2018); Öborn et al. (2011, 2013) *Bourgeois & Sette (2017); Maggio et al. (2019); Reilly & Willenbockel (2010); van Dijk & Meijerink (2014)*
Market dynamics E.g. market conditions and connectivity; level of liberalised/regulated market; trade barriers; trade policies and regulation; price volatility; international/global trade	Basnet et al. (2020); Haines-Young et al. (2011); Lehtonen et al. (2021); Le Mouël et al. (2018) & Mora et al. (2020); M'barek et al. (2020); Mitter et al. (2019, 2020); Mylona et al. (2016); Searchinger et al. (2019); Spijkers et al. (2021); WEF (2017) *Bourgeois (2016); Bourgeois & Sette (2017); Godfray et al. (2010); Lentz (2021); Maggio et al. (2019); Reilly & Willenbockel (2010); van Dijk & Meijerink (2014); Zurek et al. (2021)*
Localisation of the food system Levels of imports and exports; Particular emphasis on localised food systems with high national market shares and/or globalised food systems	Basnet et al. (2020); Haines-Young et al. (2011); Hauck et al. (2017) & Priess et al. (2018); Karlsson et al. (2018); Karlsson et al. (2021); Lehtonen et al. (2021); Lóránt & Allen (2019); Mitter et al. (2019, 2020); Röös et al. (2021); WEF (2017) <u>Wood et al. (2020a,b,c; 2021)</u>
Globalisation Globalisation emphasised as an impacting factor of demand and supply; trade; and social fabrics.	Grivins et al. (2020); Spijkers et al. (2021) *Godfray et al. (2010); Maggio et al. (2019)*
Less featured drivers of change or themes	
▪ Socio-economic footprint of imports; Environmental footprint of exports (WP3 literature analysis)	

Governance and institutions	
Variables	Data source: Literature analysis, *Meta-literature review*, <u>Other Material</u>
Demography Demographics, patterns of settlement, role of e.g. rural areas	Haines-Young et al. (2011); Le Mouël et al. (2018) & Mora et al. (2020); M'barek et al. (2020); Öborn et al. (2011, 2013) *Bourgeois (2016); Maggio et al. (2019)* <u>Wood et al. (2020a,b,c; 2021)</u>
Equitable and just food transformation	<u>Wood et al. (2020a,b,c; 2021)</u>
Population growth/change	Basnet et al. (2020); FAO (2018); Haines-Young et al. (2011); Hauck et al. (2017) & Priess et al. (2018); M'barek et al. (2020); Mitter et al. (2019, 2020); Mylona et al. (2016); Searchinger et al. (2019); Springmann et al. (2018); Spijkers et al. (2021); Öborn et al. (2011, 2013)

	Bourgeois (2016); Bourgeois & Sette (2017); Godfray et al. (2010); Lentz (2021); Reilly & Willenbockel (2010); van Dijk & Meijerink (2014)
Urbanisation	Hauck et al. (2017) & Priess et al. (2018); Le Mouël et al. (2018) & Mora et al. (2020); Mitter et al. (2019, 2020) *Godfray et al. (2010); Lentz (2021); Maggio et al. (2019); van Dijk & Meijerink (2014)*
Urban rural connections	Le Mouël et al. (2018) & Mora et al. (2020) Mitter et al. (2019, 2020) Wood et al. (2020a,b,c; 2021)
Migration	Haines-Young et al. (2011); Spijkers et al. (2021) *Bourgeois (2016); Lentz (2021); Maggio et al. (2019)* Expert food workshop 2020
Politics and governance Includes e.g. policies and institutions (e.g. cross-sectoral policy); budget issues; distribution of power and decision-making between e.g. local communities, municipalities, states, NGOs, IGOs, private sector, supra-national unions	Basnet et al. (2020); Grivins et al. (2020); Haines-Young et al. (2011); Hauck et al. (2017) & Priess et al. (2018); Le Mouël et al. (2018) & Mora et al. (2020); M'barek et al. (2020); Milestad et al. (2014); Mitter et al. (2019, 2020); Raudsepp-Hearne et al. (2020); Sellberg et al. (2020); Spijkers et al. (2021); Öborn et al. (2011, 2013) *Bourgeois (2016); Bourgeois & Sette (2017); Zurek et al. (2021)* Expert food workshop 2020; Wood et al. (2020a,b,c; 2021)
Subcategories to Politics and governance with specific policy conditions or sectors	
Agricultural policy	Lehtonen et al. (2021): Mitter et al. (2019, 2020); Öborn et al. (2011, 2013)
Climate policy (adaptation and mitigation) National adaptation and mitigation strategies; global climate agreement	Haines-Young et al. (2011); Milestad et al. (2014) *Zurek et al. (2021)* Expert food workshop 2020
Environmental policy Change in protected areas, environmental policies, standards and regulation	Basnet et al. (2020); Haines-Young et al. (2011); Hauck et al. (2017) & Priess et al. (2018); Mitter et al. (2019, 2020) *van Dijk & Meijerink (2014)*
European or international policy/governance Policy, agreements and division of power and responsibility related to the food system on an international scale; geopolitical context	Haines-Young et al. (2011); Hauck et al. (2017) & Priess et al. (2018); Le Mouël et al. (2018) & Mora et al. (2020); Milestad et al. (2014); Mitter et al. (2019, 2020); Spijkers et al. (2021) Expert food workshop 2020

Less featured drivers of change or themes

- Alternative governance and market dynamics, such as degrowth (Zurek et al., 2021; WP3 literature analysis)
- Barriers to policy implementation (Lentz, 2021)
- Causes of poverty (Maggio et al., 2019)
- Conflicts (Maggio et al., 2019)
- Decline in public research funding (Lentz, 2021)
- Education and health (WP3 literature analysis)
- Geopolitical dynamics (Lentz, 2021)
- Indigenous peoples - in policy (WP3 literature analysis)
- Lack of inclusion of local perspectives and processes in scenarios (Bourgeois, 2016; Raudsepp-Hearne et al., 2020). This is suggested to constrain the studies' analysis of power, rights and institutions (Bourgeois, 2016).
- Policy and governance in large, related to e.g. the increasing influence of new governing systems (Maggio et al., 2019)
- Political economy analysis (Raudsepp-Hearne, 2020)
- Poverty, inequity and inequality (Bourgeois, 2016; Lentz, 2021; Maggio et al., 2019; van Dijk & Meijerink, 2014; Zurek et al., 2021)
- Urban-rural linkages in global scenarios (Mora et al., 2020)
- Water and sanitation (Lentz, 2021; Maggio et al., 2019)

Consumption

Variables	Data source: Literature analysis, *Meta-literature review*, Other Material
Shifts in diets and consumption patterns Food intake; consumer demand and behaviour; values related to diets and food culture; social and cultural shifts to a smaller extent	Basnet et al. (2020); EU (2017); FAO (2018); Grivins et al. (2020); Hauck et al. (2017) & Priess et al. (2018); Karlsson et al. (2018); Lehtonen et al. (2021); Le Mouël et al. (2018) & Mora et al. (2020); Lóránt & Allen (2019); M'barek et al. (2020); Mitter et al. (2019, 2020); Mylona et al. (2016); Poux & Aubert (2018); Röös et al. (2021); Searchinger et al. (2019); Sellberg et al. (2020); Spijkers et al. (2021); Springmann et al. (2018); WEF (2017); Öborn et al. (2011, 2013) *Bourgeois (2016); Godfray et al. (2010); Lentz (2021); Maggio et al. (2019); Reilly & Willenbockel (2010); van Dijk & Meijerink (2014); Zurek et al. (2021)* Expert food workshop 2020; Wood et al. (2020a,b,c; 2021)
Income growth Linked to consumption change	FAO (2018); Springmann et al. (2018) *Bourgeois (2016); van Dijk & Meijerink (2014)*
Food environment	Wood et al. (2020a,b,c; 2021)

Less featured drivers of change or themes
▪ Access to food determined by e.g. micro-level variables such as household income, household composition, education, waste and consumption behaviour (van Dijk & Meijerink, 2014) ▪ Alternative food sources (e.g. insects and algae) (van Dijk & Meijerink, 2014) ▪ Economic and social well being (Zurek et al., 2021) ▪ Food loss and waste (Godfray et al., 2010; van Dijk & Meijerink, 2014) ▪ Indigenous peoples - food cultures and diets (WP3 literature analysis) ▪ Nutritional and health aspects in global scenarios (Mora et al., 2020) ▪ Social and cultural drivers driving change in food consumption (e.g. cultural traditions and women's empowerment (Lentz, 2021) ▪ Socioeconomic trends that impact supply and demand (e.g. income, economic growth, liberalisation of market) (Godfray et al., 2010) ▪ Wild food (Godfray et al., 2010; WP3 literature analysis)

Climate and environment

Variables	Data source: Literature analysis, *Meta-literature review*, <u>Other Material</u>
Climate change - - - - - Impact on the food system	Basnet et al. (2020); FAO (2018); Haines-Young et al. (2011); Hauck et al. (2017) & Priess et al. (2018); Le Mouël et al. (2018) & Mora et al. (2020); Mylona et al. (2016); Spijkers et al. (2021); Öborn et al. (2011, 2013) *Bourgeois (2016); Bourgeois & Sette (2017); Godfray et al. (2010); Lentz (2021); Maggio et al.(2019); van Dijk & Meijerink (2014); Zurek et al. (2021)* <u>Expert food workshop 2020</u>
Natural resource availability, scarcity and depletion - - - - - Freshwater availability, biodiversity loss, potential for production and ecosystem services	FAO (2018); Lehtonen et al. (2021); Mitter et al. (2019, 2020); Merrie et al. (2018); Mylona et al. (2016); Spijkers et al. (2021); Springmann et al. (2018); Öborn et al. (2011, 2013) *Godfray et al. (2010); Maggio et al. (2019); Lentz (2021); van Dijk & Meijerink (2014); Zurek et al. (2021)*

Less featured drivers of change or themes
▪ Climate change, immediate impacts: impacts on crops, livestock pests and diseases as well as biotic pressures such as human disease and heat stress on labour (Lentz, 2021; Zurek et al., 2021). ▪ Freshwater (WP3 literature analysis)

Appendix 2. Scenario literature analysis

Reference list of the twenty-six food scenario studies that were examined in WP3's literature analysis and the nine studies examined in WP3's meta-literature review of food scenario studies.

Literature analysis

Basnet S., Fetzer I., Jansson T., Gordon L., Röös E., Ahlgren S., Wood A. & Woodhouse A. (2020). Pathways to Sustainable Land-Use and Food Systems in Sweden by 2050. In FABLE 2020, Pathways to Sustainable Land-Use and Food Systems, 2020 Report of the FABLE Consortium. Laxenburg and Paris: International Institute for Applied Systems Analysis (IIASA) and Sustainable Development Solutions Network (SDSN), pp. 595-625.

European Commission (EC) (2018). Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee, the Committee of the Regions, and the European Investment Bank, A Clean Planet for All. A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy, COM(2018) 773 final, Brussels, 28.11.2018.

FAO, (2018). The future of food and agriculture - Alternative pathways to 2050. Rome, Italy: Food and Agriculture Organization of the United Nations. 224 pp. Licence: CC BY-NC-SA 3.0 IGO.

Grivins, M., Halloran, A., & Kale, M. (2020). Eight megatrends in Nordic-Baltic food systems. Copenhagen: Nordic Council of Ministers, 2020:453.

Haines-Young, R., Paterson, J.S., & Potschin, M. (2011). The UK NEA Scenarios: Development of Storylines and Analysis of Outcomes. In Brown, C. & Walpole M. (Eds.), The UK National Ecosystem Assessment Technical Report. Cambridge: UNEP-WCMC, pp. 1195-1264.

Hauck, J., Schleyer, C., Priess, J.A., Haines-Young, R., Harrison, P., Dunford, R., Kok, M., Young, J., Berry, P., Primmer, E., Veerkamp, C., Bela, G., Vadineanu, A., Dick, J., Alkemade, R., & Görg, C. (2017). Project Deliverable 2.5. Policy Scenarios of future change, EU FP7 OpenNESS Project. European Commission FP7.

Karlsson, J. O., Carlsson, G., Lindberg, M., Sjunnestrand, T., & Röös, E. (2018). Designing a future food vision for the Nordics through a participatory modeling approach', Agronomy for Sustainable Development, 38 (59). DOI: https://doi.org/10.1007/s13593-018-0528-0.

Karlsson, J., Parodi, A., van Zanten, H.H.E., Hansson, P. & Röös, E. (2021). Halting European Union soybean feed imports favours ruminants over pigs and poultry, Nature Food, 2, pp.38–46. DOI: https://doi.org/10.1038/s43016-020-00203-7.

Lehtonen, H.S., Aakkula, J., Fronzek, S., Helin, J., Hildén, M., Huttunen, S., Kaljonen, M., Niemi, J., Palosuo, T., Pirttioja, N., Rikkonen, P., Varho, V., & Carter, T. R. (2021). Shared socioeconomic pathways for climate change research in Finland: co-developing extended SSP narratives for agriculture, Regional Environmental Change, 21(7). DOI: https://doi.org/10.1007/s10113-020-01734-2.

Le Mouël, C., de Lattre-Gasquet, M., & Mora, O., eds. (2018). Land Use and Food Security in 2050: A Narrow Road. Agrimonde-Terra. Versailles Cedex, France: Quæ.

Lóránt, A. & Allen, B. (2019). Net-zero agriculture in 2050: how to get there? Brussels/London: Institute for European Environmental Policy.

M`barek, R., Barreiro Hurle, J., Boulanger, P., Caivano, A., Ciaian, P., Dudu, H., Espinosa Goded, M., Fellmann, T., Ferrari, E., Gomez Y Paloma, S., Gorrin Gonzalez, C., Himics, M., Elouhichi, K., Perni Llorente, A., Philippidis, G., Salputra, G., Witzke, H.P. & Genovese, G. (2020). Scenar 2030 - Pathways for the European agriculture and food sector beyond 2020 (re-edition). EUR 28797 EN. Luxembourg, Luxembourg: Publications Office of the European Union. DOI:10.2760/43791.

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Milestad, R., Svenfelt, Å., & Dreborg, K. H. (2014). Developing integrated explorative and normative scenarios: The case of future land use in a climate-neutral Sweden, Futures, 60, pp. 59-71. DOI: 10.1016/j.futures.2014.04.015.

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The scenario studies are listed below according to their project name or the title of the report or article.

Scenario project		Reference
Adaptation of the SSPs	EUR-Agri-SSPs	Mitter et al. (2019, 2020)
	Shared socioeconomic pathways for climate change research in Finland: co-developing extended SSP narratives for agriculture	Lehtonen et al. (2021)
Agrimonde-Terra		Le Mouël et al. (2018); Mora et al. (2020)
Delivering on EU Food Safety and Nutrition in 2050 - Future challenges and policy preparedness		Mylona et al. (2016)
Designing a future food vision for the Nordics through a participatory modeling approach		Karlsson et al. (2018)

European Commission's scenarios of 'A Clean Planet for All'	EC (2018)
Exploring the future of fishery conflict through narrative scenarios	Spijkers et al. (2021)
FABLE 2020, Pathways to Sustainable Land-Use and Food Systems	Basnet et al. (2020)
FAO - The future of food and agriculture - Alternative pathways to 2050	FAO (2018)
Future Agriculture - livestock, crops and land use	Öborn et al. (2011, 2013)
Halting European Union soybean feed imports favours ruminants over pigs and poultry	Karlsson et al. (2021)
Institute for European Environmental Policy (IEEP)'s Net-zero agriculture in 2050: how to get there?	Lóránt & Allen (2019)
Limiting livestock production to pasture and by-products in a search for sustainable diets	Röös et al. (2016)
Nordic Council of Ministers' Eight megatrends in Nordic-Baltic food systems	Grivins et al. (2020)
Operationalisation of Natural Capital and Ecosystem Services (OpenNESS)	Hauck et al. (2017); Priess et al. (2018)
Options for keeping the food system within environmental limits	Springmann et al. (2018)
Radical Ocean Futures	Merrie et al. (2018)
Scenar 2030 - Pathways for the European agriculture and food sector beyond 2020	M'barek et al. (2020)
Scenarios of future land use in a climate-neutral Sweden	Milestad et al. (2014)
Seeds of Good Anthropocenes	Raudsepp-Hearne et al. (2020)
Shaping the future of global food systems: A Scenarios Analysis	WEF (2017)
Ten Years for Agroecology (TYFA)	Poux & Aubert (2018)
UK National Ecosystem Assessment (UK NEA) scenarios	Haines-Young et al. (2011)
UNISECO - Understanding and Improving the Sustainability of Agro-ecological Farming Systems in the EU	Röös et al. (2021)
Using local initiatives to envision sustainable and resilient food systems in the Stockholm city-region	Sellberg et al. (2020)
World Resources Report: Creating a sustainable food future. A Menu of Solutions to Feed Nearly 10 Billion People by 2050	Searchinger et al. (2019)

Appendix 3. References to trends overview

References to the food system trends presented in Figure 1. The trends marked with an asterisk have the two references listed that provide the numbers for the two years compared in the trend (e.g. 2010 and 2020). These sources do however not list all values for all the years between these two years (e.g. 2011–2019). If you wish to see the full yearly development of the trend, you can find the additional references in the yearly reports by the SBA, SwAM or Swedish National Board of Fisheries with the reference years between the first and final years of the trend. The full references can be found in the reference list.

Agricultural production

Size of average agricultural holding: SBA (2011b; 2021c)
Farms with other economic activities: SBA (2022b)
Share of agricultural holders over 65 years old: SBA (2022g)
Price of agricultural land: SBA (2022n)
Number of agricultural holdings: SBA (2022i)
Types of farms: SBA (2022h)
People working in agriculture: SBA (2022r)

Cropping and livestock

Extent of pasture and meadow (ha); arable land (ha): SBA (2022u)
Exploitation of agricultural land: SBA (2013a; 2017; 2021a)
Total crop production; yields per ha: SBA (2022f)
Production of beef, pork, poultry, sheep and lamb: SBA (2022m;2022e;2022l;2022k)
Animals (n); Farms with livestock (n): SBA (2022a)

Blue food production

Catches in inland waters: SwAM (2021b); Swedish National Board of Fisheries (2011a)*
Aquaculture production of edible fish: SBA (2022o)
People employed in aquaculture: SBA (2022s)
Share of commercial fishermen in inland waters, 65+ years: SBA (2020a, p.17)
Catches by Swedish sea fisheries: SwAM (2021a); Swedish National Board of Fisheries (2011b)*
Vessels in Swedish fleet (sea fisheries): SwAM (2020; 2021b)*
Fishing licences (n): SBA (2020a, p.12)

Processing

Farms that process and sell farm products (n): SBA (2022c)
Food companies, net sales and value added; Food companies (n); Value added of fish processing industry: People employed in drinks and tobacco industry; People employed in food industry: Statistics Sweden (2022)

Retail

Grocery e-commerce: PostNord et al. (2019, p.6); Swedish Food Retailers' Federation (2021a, b)
Market share of three largest retail actors: SBA (2012b, p.19); DLF et al. (2021)
Total value added of food retail companies: SBA (2021g, p.193).
Meal kit companies (n): Konrad (2015); Matkassarna (2021)
Organic food and drink products (value of sales): Statistics Sweden (2015; 2021b)
Grocery retail stores (n): Swedish Trade Federation (2019, p. 17; 2021, p.35)
Grocery retail companies (n): Swedish Trade Federation (2021, p.35)

Consumption

Total meat consumption: SBA (2022t)
Direct consumption: SBA (2022d)
Energy intake from food: SBA (2020b)
Plant-based protein (sales): Macklean (2020, p.7)
Food costs (share of expenses); Eating out and hotels (share of expenses): Ekonomifakta (2022)

Import and export

Swedish market share of onions, eggs, dairy, cheese: SBA (2021g)
Swedish market share of meat: SBA (2022q)
Trade deficit, processed goods: SBA (2014, p.126; 2021e)*
Trade deficit: SBA (2013b; 2021e)*

Appendix 4.
The WP3 expert group

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Jan Bengtsson
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U. Martin Persson
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Garry D. Peterson
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Elin Röös
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Ingo Fetzer
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MISTRA
FOOD FUTURES