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Digitalisation for a Sustainable Food System: Opportunities for Shaping Production and Consumption

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Executive Summary

Agricultural and food systems are currently facing comprehensive challenges: Avoidable and negative ecological consequences are apparent throughout the entire value chain of food production, from inputs, cultivation, and product processing and refining, to marketing and consumption. Diets have a significant influence on individual health, and an increasingly unbalanced dietary culture is leading to more diet-related diseases. In addition, as supply chains become more complex and globalized, there is an increasing risk of social problems arising.

Responsibility for and control of the transformation of food systems cannot be solely associated with either production or consumption. Instead, it requires techno-economic as well as socio-cultural change throughout the system. This is a task for society to undertake as a whole, involving all actors "from farm to fork", namely those in agriculture, food processing, trade, and out-of-home catering, as well as private consumers and politics.

Digitalisation can support the transformation and changes on three levels: Improve - Convert - Transform. These form the framework of our project "Shaping Digital Transformation - Digital solution systems for the sustainability transition", as an integrated approach.

Concrete starting points for digitalisation to achieve sustainability goals in the food sector are as follows:

Improve

Optimise resource use and minimise environmental impacts through digitalisation: Smart farming technologies, such as precision farming, can combat the adverse environmental impacts of agriculture by reducing the use of fertilisers and pesticides and optimising yields.

Support consumers through digital tools and assistance systems: The utilization of digital tools, like apps, can ensure consumers are given exactly the information they need at the right time in order to simplify sustainable purchasing decisions.

Recognise the risks of digitalisation and prevent undesirable developments: Digitalisation should not be an end in itself and its use should always be critically questioned in order to avoid rebound effects or undesirable side effects (e.g. one-sided structural change).

Convert

Consistently include sustainability indicators along the value chain, from farm to fork: Collecting data throughout the entire supply chain, ensuring it is consistently stored and used is the basis for sound sustainability assessments and can enable all actors to operate with certainty.

Networking of production and consumption processes within the value chain: The horizontal and vertical networking of companies through shared data spaces and platforms opens the way to optimising production processes, developing new business models, and introducing niche innovations into the mainstream.

Transform

Framework conditions for new product and consumption systems: Digitisation can be a supporting tool for the two core tasks of the transformation - the restructuring of the economy and the creation of value, and the socio-ecological reorientation of society. However, a systemic transformation is also necessary, which must be accompanied by technological,

economic, cultural, and institutional framework. This framework must cover a reorientation of agricultural subsidies, and thus a shift in production incentives for agriculture, as well as the creation of food environments that enable consumers to change their diets.

Create conditions for the effective digitalisation of the food system: Successfully realising the potential of digitalisation will require the support of incentive systems, regulations, and framework conditions. This includes necessary technical infrastructure, the standardisation of data and interfaces, assistance for companies, especially smaller ones, with high investments to help avoid one-sided structural change, the integration of digitisation within education and training, and regulations for data protection, sovereignty, and security.

The positive effects of digitalisation are already evident to some extent in production and consumption at the Improve level. Effective scaling is needed here, for example, to realize the nitrogen efficiency of fertilization in the agricultural sector. New business models at the Convert level are already part of some approaches, and must now be expanded from niche markets to the mainstream. Legal regulations must make certain framework conditions, such as the inclusion of sustainability indicators, mandatory.

A comprehensive techno-economic and social transformation must create necessary institutional, social, and political framework conditions. Digital opportunities must be embedded in an "analogue" context, meaning that agricultural, environmental, food, consumer, and health policies must create the environment within which digitalisation can take effect.

Contents

List of abbreviations

API	Application Programming Interface
CO_2e	Carbon dioxide equivalent
CAP	European Common Agricultural Policy
DGE	German Nutrition Society e. V.
GPS	Global Positioning System
IT	Information Technology
VAT	Value added tax
5G	Fifth Generation of mobile communications

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1 Introduction

In 2021, greenhouse gas emissions in Germany saw an increase of 4.5 percent, following a significant decrease in 2020 as a result of the COVID-19 pandemic (UBA, 2022). Achieving the German government's climate protection goals by 2030 will require more ambition and an increased willingness to realize ecological sustainability.

Digitalisation can be a prerequisite for achieving ecological sustainability. Digital technologies and applications make it possible to both improve current procedures, processes and structures **(Improve)** and reorient existing business models and framework conditions **(Convert)**. Digitalisation must also be effectively applied to shift society towards more ecologically-sustainable lifestyles and contribute to further-reaching transformation of the economy and value creation **(Transform)** (Figure 1). The Transform level will be decisive for the success of the social-ecological transition, and should therefore be the focus of future debate. In addition, these three levels are closely interlinked and heavily influence each other, and must be holistically addressed together.

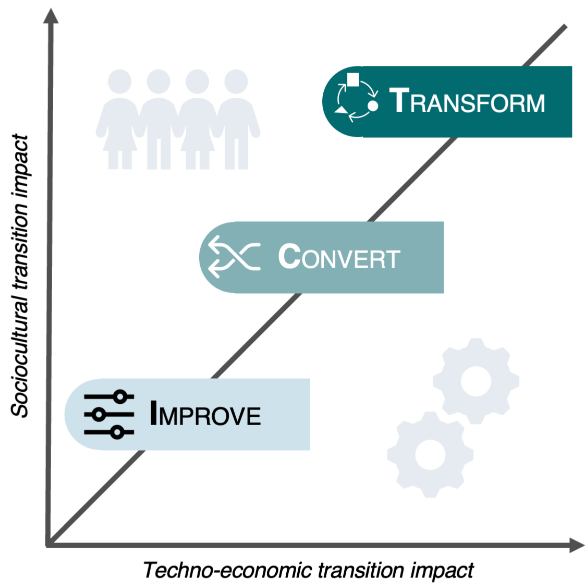

Figure 1: Impact levels of digitalisation for sustainability transformation (Source: Own illustration from (Ramesohl et al., 2021).

This is where Huawei Technologies Germany believes that the "Shaping Digitalisation: Enabling Transformation to Sustainability" project can have the biggest impact. Through this project, we aim to highlight and discuss the opportunities that digitalisation can bring to Germany. We will focus on three particular stand-out areas where action is most needed in order to achieve ecological transformation: mobility, the circular economy, and agriculture and food (Ramesohl et al., 2021).

This report addresses the action field of a sustainable food system, while considering the various challenges involved in the related transition. Within this action field, there is a need to address ecological, social, and individual health challenges.

This will require not only the transformation of the agricultural sector, but also a change in the diets and lifestyles of consumers (Grethe et al. 2021). To overcome these challenges, every actor along the value chain has a responsibility to contribute to the transformation of the food system, with neither the production or consumption side holding the majority of the power (ZKL, 2021).

Achieving a fair, resource-efficient, and climate-neutral food system that provides healthy nutrition for all is a systemic task that must be undertaken by all of society (Grethe et al., 2021; ZKL, 2021; WBAE, 2020). Using, scaling, and further developing digital technological innovations offers ways to solve related challenges by optimising existing processes and achieving higher efficiency, supporting consumers through more sustainable consumption, and promoting new design of new product and consumption systems. For this purpose, chapter 2 first characterizes the initial situation of our current food system. Chapter 3 presents how the above challenges can be addressed. Subsequently, Chapters 4, 5 and 6 outline the opportunities that digitalisation can offer.

This report does not claim to be exhaustive in terms of the opportunities, challenges, and risks of digitalisation that it presents and does not provide any sort of systemic solution. Rather, various selected impulses and new approaches for a nutritional transition will be presented as examples. These will be classified and evaluated in particular from a systemic perspective along the entire value chain and linking consumption and production. Within this report, the findings of an interdisciplinary workshop (March 2022) on "Potentials of digitalisation for a more sustainable food system" are incorporated, in which various actors of the food system participated (see Acknowledgements). The workshop discussion the workshop discussion expands on current research findings related to the political, organisational, and technical framework conditions for an ecologically-effective and socially-balanced food transition.

2 Starting position and challenges

The way food is produced and our eating habits have far-reaching and multidimensional impacts on the environment, society, and our health.

Throughout the food production value chain, from inputs (seed and fertilisation production), cultivation, product processing and refining, to marketing and consumption, there are a multitude of avoidable, negative **ecological consequences** (UBA, 2021c). Agriculture is responsible for 13.4% of Germany's total greenhouse gas emissions, and if agriculture-related transport, processing, trade, and preparation are also included, this number rises to about 23% (Grethe et al., 2021). In addition to its impact on climate change, food production affects resources that are essential for the conservation of ecosystems: More than two thirds of the forecasted losses of terrestrial species will be caused by the intensification of agriculture (Secretariat of the Convention on Biological Diversity, 2014; Wezel et al., 2020). In addition, the excessive amounts of nitrogen used during agricultural fertilisation are harmful to biodiversity, air and water quality (BMU, 2016; UBA, 2014). In particular, the mass production of animal-based food and the associated production of animal feed is responsible for a significant share of the issues (Reisinger & Clark, 2018; ZKL, 2021).

Nutrition significantly impacts individual **health status, quality of life, and well-being**. In Western dietary culture, an increasingly unbalanced intake of fats, carbohydrates, sugar, and salt is leading to a rise in diet-related diseases, such as obesity, type 2 diabetes, and heart disease, leading to far-reaching risks for the health system and community resilience (Morze et al., 2020; RKI, 2015). Even in an economically prosperous country like Germany, malnutrition and nutritional deficiencies exist. A structural association exists between socioeconomic position and a healthy diet, which is therefore not self-evident or accessible to all population groups (Fekete & Weyers, 2016; RKI, 2018).

Food also fulfils important **social functions**. Our eating behaviour is firmly ingrained within our culture, shaping a large portion of our social connections, providing us with identity, and manifesting itself in traditions. As a key action field within everyday life, food shapes regular practices and routines (WBAE, 2020). In addition to its influence on our personal lives, food production affects the way our immediate living space is distributed. In Germany, over 50% of viable land is used for agriculture, significantly shaping rural areas and creating opportunities for leisure, tourism, and gastronomy (Limmer et al., 2019). In the future, urban farming and vertical farming will have a growing influence over urban environments. The social impact of our food stretches beyond national borders. Increasingly globalized and complex value chains are being accompanied by risks regarding working conditions, child labour, and market displacement of local smallholders through dumping or land grabs (De Schutter, 2017; Heydenreich & Paasch, 2020; Reichert, 2018).

Ultimately, the production and consumption of food is embedded within a global system. Vegetation zones, nutrient supply, economic considerations and, particularly in light of current crises, the security of supply have paved the way for new framework and possible changes in the food system. Therefore, agriculture, and the food system as a whole, must overcome unique and complex challenges in order to achieve related climate and sustainability goals. Against this backdrop, despite diverse interests, positions, and starting points, it is becoming clearer which goals must be prioritized. These are outlined in the following chapter.

3 Vision

The above challenges set a clear task: We need a social-ecologically optimised agriculture and food system that also ensures social justice throughout the value chain and promotes healthy eating patterns (Speck et al., 2021).

The starting point for building this system is agricultural production. In addition to the production of animal and plant-based food in accordance with the environment, an objective is to ensure a safe food supply. This includes ensuring all workers within the supply chain, both domestically and internationally, are fairly remunerated under socially just working conditions. Reducing greenhouse gas emissions within the agricultural sector also requires unique strategies. The strategy of simply replacing fossil fuels with renewable energy sources is works in other industries, but in agriculture, especially livestock production and intense use of fertilizer inherently results in high methane and nitrous oxide emissions. Agriculture also has other ecological impacts in addition to climate change. The only way to manage these impacts will be to develop new production processes. The cultivation will need to be managed in a way that better utilizes production resources such as fertilisers and pesticides. Better management methods must decrease the burden placed on water and nutrient cycles, reduce negative impacts on biodiversity, and maintain the general functionality of local ecosystems (Grethe et al., 2021; ZKL, 2021). The ecological optimisation of agricultural production will also require a continuous reduction in livestock numbers. The digestive processes of ruminants and the application of manure simply contribute too significantly to methane and nitrous oxide emissions in this sector (Grethe et al., 2021; ZKL, 2021).

Therefore, the negative externalities of food production cannot be mitigated without changes in consumption. Private consumers' dietary patterns also need to change (Poore & Nemecek, 2018; Willett et al., 2019). Scientific recommendations for sustainable and healthy diets that recommend increasing of the consumption of plant products such as pulses, fruits, and vegetables and reducing the consumption of animal products such as meat and dairy products will be important (Lukas et al., 2018; Willett et al., 2019). Furthermore, in Germany in particular, high food resource consumption is heavily linked with food waste from private consumers, with half of the 10 million tonnes of avoidable food losses that occur in Germany every year caused by private households (Noleppa & Cartsburg, 2015). These losses could be mitigated by, among other things, better planning of purchases (Noleppa & Cartsburg, 2015; Noleppa & von Witzke, 2012).

For private consumers to be able to make these changes, however, we will need a nutritional environment that actively supports new dietary patterns (WBAE, 2020).[1] The existing conditions actually favour unsustainable behaviours. For example, the excessive portrayal of unsustainable and unhealthy products in advertising increases the perception of these products and (WBAE, 2020). In addition, meat substitutes are often many times more expensive than meat. It is therefore necessary to include food retailing and out-of-home catering as a link between food production and consumption in the transformation as well (Speck et al., 2021).

[1] Nutritional environment is understood as all the influences that affect an individual's nutrition. These influences refer not only to the moment of decision, but also to all stages of the behavioural process: exposure (e.g. in advertising and social media, which determine which foods are present in our perception), access (determined by price, availability or social norms), choice (influenced by socio-economic aspects, preferences, habits, etc.), consumption (what, how much, when, where and with whom, etc.) (see WBAE, 2020).

Current ecological crisis and related social challenges highlight the need for more resilient value chains (Liedtke et al., 2020). For the food sector, this means - but is not limited to - developing regional economic logistics concepts, strengthening structures in rural areas and regionalizing economic cycles (BMNT, 2018). Diversified farming concepts, combined with the additional social services provided by agriculture (e.g. shaping of rural landscapes, leisure, tourism and catering services), can ensure the diversity of German agricultural structures and create a more resilient and sustainable agricultural system (ZKL, 2021).

Individual stakeholders cannot be made solely responsible for solving these problems. For example, the pressure to economize food production are largely created by increasing national and global competition, where social or environmental concerns can often not be taken into account by agriculture Schneidewind, 2018; ZKL, 2021). For private consumers, food offers great opportunity for sustainable action, as changes in consumption patterns, in theory, can be changed at any time. Such changes are also typically quite low cost and less dependent on external conditions, such as infrastructure (e.g. connections to public transport in terms of sustainable mobility), than other areas of demand. However, the way one eats is largely based on personal habits that are not always easy to change, especially if a more sustainable option is perceived as time-consuming and more costly (WBAE, 2020).

Due to the diversity and complexity of the food system and the multitude of environmental, social and health benefits it offers (see Figure 2), it is not conceivable to achieve the nutritional transition with a single approach or instrument (ZKL, 2021). Simultaneous transformation of our technological, economic, cultural and social systems will require multilayered technical, economic, cultural, and institutional conditions (Schneidewind, 2018). This represents a major challenge that must be mastered through a variety of measures. In the following sections, we will present some enablers and approaches to illustrate how digitalisation can support these solutions.

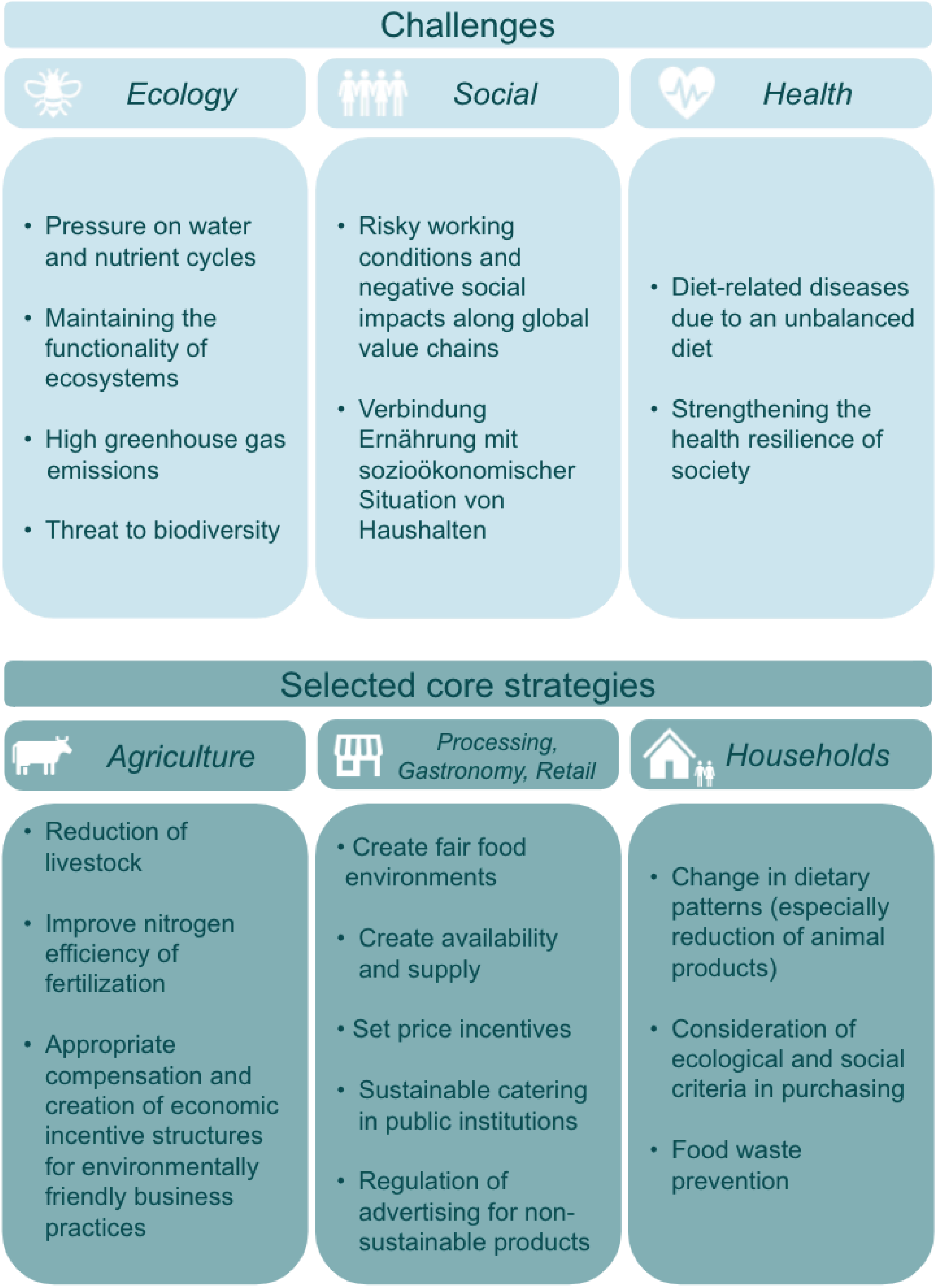

Figure 2: Challenges and vision of a sustainable food system (source: Wuppertal Institute)

4 Improve – Optimize production processes, support consumers

Digitalisation is not a new concept within the agricultural and food sector as it is already being used at many stages of the value chain. Today, individual technologies already make it possible to optimize procedures and processes. Below examples are given of how digital technologies are already being used on the production side to make agricultural processes more ecologically friendly as well as on the consumption side where digital applications support consumer decision-making by providing better information. In addition, this section will highlight possible undesirable side and rebound effects of digitalisation, which must be avoided.

4.1 Optimizing resource use and minimizing environmental impact

Throughout history, agriculture has been constantly transformed by technological progress. This progress enabled large increases in production and a significant improvement in the food security. Digital solutions as part of this technological progress are now an indispensable part of agriculture (DLG, 2018; Hertzberg, 2021). For example, around 80% of farms surveyed in a representative study carried out in 2020 stated that they used individual digital technologies such as automatic feeders or GPS-based agricultural technologies (Bitkom, 2020). However, farms tend to limit the scope of their application to individual technologies, meaning that intensive and comprehensive practical applications are not yet in full use (LfL, 2017). Obstacles and concerns within the agricultural sector are most frequently related to the high initial inivestments required to implement new technologies, the uncertain economic efficiency of new technologies, incompatibility between different systems, and data sovereignty and data protection. Less relevant are arguments such as technical vulnerability to faults and obstacles relating to complicated operation and a lack of IT expertise (Bitkom, 2020).

An elementary challenge that agriculture must face in the context of providing basic ecosystem services is to optimize the use of inputs. For example, more efficient use of nitrogen-based fertilizers and the more environmentally compatible use of pesticides will be needed to reduce agriculture's greenhouse gas emissions while also maintaining synergies with other goals, such as the preservation of biodiversity and water protection (Grethe et al., 2021; UBA, 2019a; ZKL, 2021). Various technologies, which can be grouped under the term “smart farming”, pursue this goal

One group of smart farming technologies is known as **Precision Farming**. This allows agricultural land to be farmed in a more targeted and thus more efficient manner. Agricultural robotics, like "Farmbots", can target weeds more effectively for removal, minimizing pesticide application. Automation through GPS-based guidance systems in combination with precision farming enables better resource utilization, like more precise and need-based applications of fertilizers and pesticides. Using satellite imaging of local vegetation to determine where fertilizer is most needed. Studies show that precision fertilizer application can reduce nitrogen residue in the soil by 30-50% (Kliem et al., 2022). Targeted pesticide application can reduce pesticides consumption by up to 80% in individual cases (European Parliament, 2016). One study even found that more efficient route planning could reduce fuel consumption by agricultural machinery by 17% (Saiz-Rubio & Rovira-Más, 2020). In addition, the use of automated small machines can increase crop diversity through catch cropping or strip cropping, which can improve soil quality through reduced compaction and have a positive impact on biodiversity and the population sizes of insects, birds, and small mammals (UBA, 2020a).

In addition to these solutions, **digital information management,** which is also part of smart farming, can optimize the handling of data and decisions. Agricultural decision-making is quite complex as it depends on my uncertain factors such as weather and soil conditions and volatile prices, to name a few. Decision algorithms can reduce these uncertainties and formalize actions (Hertzberg, 2021). For example, farm management information systems (FMIS) can improve data management by automatically documenting crop data. Specialized agricultural apps can also support decision-making by providing up-to-date information regarding the weather, market conditions, crop protections, and machinery settings and aligning those resources with site-specific conditions (BMNT, 2018).

4.2 Supporting consumer decision-making with digital tools and assistance systems

Consumers almost always have a choice between various product alternatives. The cutlet from the regional butcher vs. a plastic-wrapped, industrially produced vegan one; an organic tomato from Spain vs. a conventionally produced tomato grown in the region. In some cases it is clear which decision is the more sustainable one, but in many cases it is necessary to weigh up a wide range of product attributes (price, packaging, origin, cultivation method, etc.). The environmental impact of food products is often over- or underestimated. For example, the plastic packaging of a product is often considered more relevant than the product itself (Camilleri et al., 2019; F.A.Z., 2019; UBA, 2021a). Food itself is often considered a "low-involvement" product, and consumers are often unable or unwilling to invest much time making purchasing decisions (Young et al., 2009). Consumers therefore want simple, clear information and decision-making aids or heuristics that provide immediate support at the moment of purchase (SVRV, 2021; Vlaeminck et al., 2014).

Digital tools for conveying information can contribute here (Kirchgeorg et al., n.d.). Smartphones in particular have become an indispensable part of everyday life and are available in almost every situation. Mobile apps can increase transparency in terms of sustainability by providing more complete and simplified product information at the point of sale (Schwarzinger et al., 2019). The acquisition of the necessary knowledge is thus made possible in a shorter amount of time and is associated with less effort. Studies show that the provision of information via apps can positively influence consumers to buy more sustainable products (Joerß et al., 2018; Schwarzinger et al., 2019).

There are already established applications on the market that scan a product's barcode to display additional product information. For example, the app CodeCheck already has 3.5 million users and has retrieved 100 million pieces of product information (CodeCheck, 2020). The information provided by the app is mainly health-related, such as nutritional content or allergens, or related to prices and reviews. Information about sustainability though is becoming increasingly common, such as the CodeCheck "climate score" assigned to many products. Applications like this could facilitate "smart shopping environments" that deliver personalized additional information, which could in turn address asymmetries resulting from information overload or a lack of information (Stieninger et al., 2019; SVRV, 2022).

4.3 The risks of digitalisation and other undesirable developments

Digitalisation offers a variety of opportunities and starting points for a transformation of the food system. At the same time, digital technologies can promote undesirable and even counterproductive developments that would not support the goals of a resource-efficient, GHG-neutral, and fair food system. Therefore, expanding the application of digital technologies in this field should never be a goal in and of itself. Instead, they should be critically examined in order to detect undesirable developments at an early stage, to take countermeasures and, if possible, to prevent them. (BMNT, 2018; WBGU, 2019).

One field of application that reflects both the opportunities and risks of digitalisation can be found in livestock farming. Sensors are currently being used to record animal-specific parameters, such as body temperature, feed intake, and more. This enables indoor climate management systems, systematic herd management, earlier disease detection, and more targeted veterinary treatments. It is clear these technologies can be used to improve general conditions for both husbandry and animal welfare (BMNT, 2018). Specific examples of how processes can be automated in animal husbandry include milking robots or milking carousels and automatic cleaning and feeding systems. As a result of automation, larger animal populations can be cared for by less labour and time (BMNT, 2018). However, radically improving the efficiency of animal husbandry by increasing automation raises ethical questions related to a change in the position of the animal from being an individual to being a system component or means of production (BMNT, 2018).

These risks apply not only to animal husbandry, but to agriculture in general. Automation technologies can clearly be used to intensify agricultural production. However, these efficiency gains could be used to solely increase production rather than to reduce the absolute use of pesticides and fertilisers, resulting in so-called rebound effects (Kliem et al., 2022). The capital-intensive acquisition of digital technologies, which may be more profitable for large farms, also increases the risk of reinforcing a lopsided structural change, with the risk of reinforcing a one-sided structural change to fewer, but increasingly larger and more uniform farms (BMEL, 2021). In this example, efficiency gains through economies of scale must be weighed against farm diversification. Digital technologies must therefore be used carefully and their application should not be a goal in and of itself. Application must come hand in hand with requirements to create a resource-light, climate-neutral und fair food system. These conflicting objectives must always be considered.

5 Convert – New Business Models and Framework Conditions

Selective technical improvements of different elements of the value chain can improve single structures within the food system. These can be optimizations of production technologies through more efficient use of resources or improved consumer information that can push socio-cultural change. However, many fundamental problems such as overproduction or food waste by households can only be addressed by technological solutions to a limited extent. This next section presents two approaches that use new business models and framework conditions to initiate profound changes in production processes and nutritional patterns.

5.1 Implementing sustainability indicators from field to plate

As in almost all industrial sectors, the food production value chain is becoming increasingly complex, competitive, and global (De Schutter, 2017; Schneidewind, 2018). Transparency and traceability along the value chain are key conditions for a sustainable food system. Compared to other sectors, the food sector is already a good example in terms of traceability (Härtel, 2017; Willers, 2016). The structures already in place for traceability provide a solid foundation for food sustainability assessments, which will be essential to optimising individual process stages and to enable all actors to act sustainably.

Starting with primary agricultural production, various institutions have long called for the implementation of individual farm nutrient balancing (material flow balancing or farm gate balancing ("Hoftorbilanzierung")) (Löw et al., 2021; UBA, 2020b; WBA & WBD, 2013). However, the necessary infrastructural framework conditions such as software solutions to fully implement this individual farm nutrient balancing are missing (Grethe et al., 2021). Automatic **digital recording of nutrient balances** would also make it possible to more effectively link public funds to the provision of public services within the framework of the economic incentive system of the European Common Agricultural Policy (CAP). This would ensure farmers are remunerated for providing products and services necessary to the public good and keeping public resources "intact". For example, farmers could be compensated for supporting the health of the local nutrient cycle or considering greenhouse gas emissions or biodiversity during their operations. This would help better integrate eco-action models into operating costs. The collection and utilisation of sustainability data should not stop at agriculture, but should be consistently implemented along the value chain and made available to all actors (Prause et al. 2021). Digital product passports for foodstuffs that automatically record the greenhouse gases generated at every stage of production could be possible with the appropriate digital infrastructure (e.g. digital farm registers at different level of agriculture or their integration into merchandise management systems for the catering industry) and the necessary interfaces (APIs).

Clear target values combined with **sustainability indicators can also provide guidance to actors of downstream stages of the value chain.** One example can be found in the public catering. With a large number of hundreds to thousands of menus served per kitchen, they can achieve significant leverage. Even the smallest changes in recipes, such as reducing the meat content of a dish, can generate significant savings potentials (Speck et al., 2020). To this end, responsible actors need defined directions and clear targets, like 600g of CO_2 equivalents per lunch set, as suggested by Speck et al. (2021a). The integration of sustainability indicators into a company's own commodity management system makes it feasible to retrieve these indicators in the same standardised way as is already possible with nutritional data, like caloric density, nutrient content, and allergens. This is a prerequisite for taking greenhouse gas emissions into account when developing menus.

Tenders for public sector catering facilities (such as day care and school catering) could even incorporate sustainability criteria if the sustainability of recipes is clearly assessed. At the level of food retailers, more informative labelling can be used as a decision aid for consumers at the point of sale and is already being implemented in for selective products.

5.2 Networking production and consumption processes

Ecological optimisation across farms can be achieved by using **common platforms and data spaces** to horizontally link several agricultural enterprises in a region. Better farm networking allows for the implementation of regional nutrient concepts. Farms with higher nutrient outputs (e.g. manure and slurry) can coordinate their activities with farms with a higher demand for fertilisers. Such raw material exchanges can bring together suppliers and users of unused secondary resources, like biomass and waste heat. Localizing raw material cycles and shortening transport routes can bring direct social and ecological benefits, and networking local businesses can contribute to regional value creation. Both of these can strengthen rural economies in the long term. (BMNT, 2018; UBA, 2020a).

Similarly, vertical networking of production processes across both upstream and downstream segments of the value chain can also provide ecological benefits by optimising logistics processes and increasing the reliability of planning (BVE, 2020). Digitalisation can significantly simplify the flow of information between different companies along the value chain and increase responsiveness and flexibility (Kersten et al., 2018). This is particularly important for food products, as the logistics chain requires a high degree of responsiveness and flexibility due to the perishable nature of many food products and variable nature of harvest times. In addition, digitisation can make information flows more efficient, reduce costs, and enable new business models to become profitable in the first place.

New business models that can be enabled by these kinds of digitalisation can be direct or regional marketing of seasonal and regional products via **digital platforms and web-based channels** (e.g. marktschwaermer.de, vegetable and cooking boxes or community-supported agriculture) or alternative sales opportunities for agriculture and processing companies (e.g. local bakeries and butchers). At the same time, digitalisation creates more opportunities for niche innovations to be popularized and brought into widespread use. One example of such an innovation is the distribution of food that is no longer needed via platforms like Foodsharing and ToGoodToGo that reduce food waste (UBA, 2019b).

6 Transform – Enable a Comprehensive Nutrition Transition

The previous chapters have shown that selective optimisation in production and consumption can improve existing systems (Improve) and thus provide solutions to clearly defined problems. Digitalisation also makes more innovative business models possible, which can help reorient the food system (Convert). The overall food system, however, needs a complete transformation, which will require more radical and systematic changes. Digital technologies can support and facilitate this process, but specific institutional, social, and political framework conditions will be essential for any such upheaval to yield the desired results. In this chapter, examples of such framework conditions are presented and discussed how digitalisation can contribute to this process through the measures proposed under *Improve* and *Convert*.

6.1 Framework conditions for new production and consumption systems

Two primary tasks are needed for the transformation of the food system: the restructuring of the economy and value creation, and the socio-ecological reorientation of society (Schneidewind, 2018). Digitalisation can be used at many points to support this process (see Figure 4).

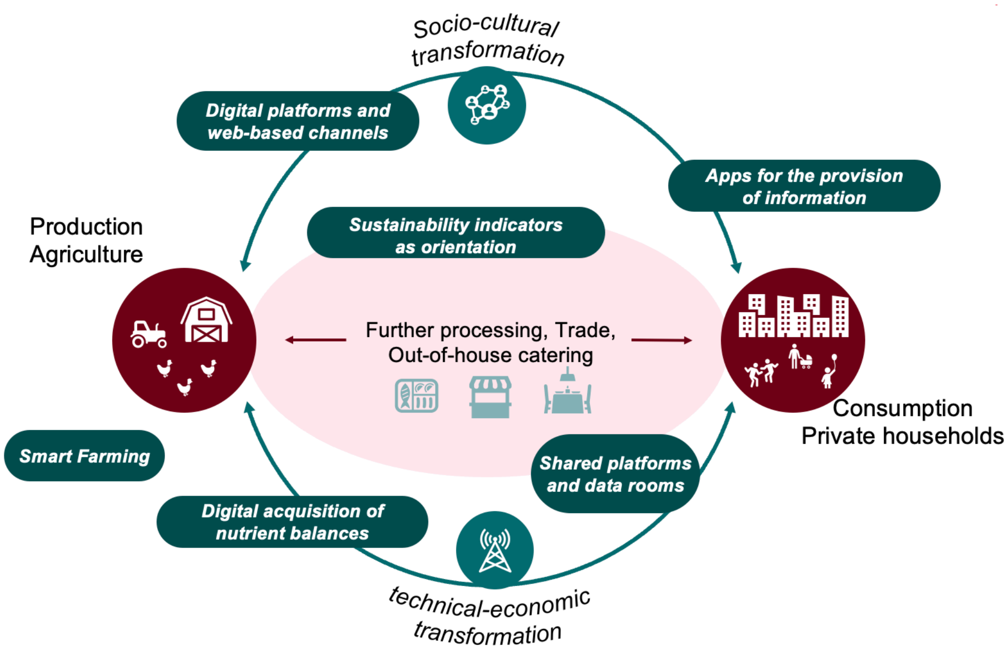

Figure 3: Approaches to digitalisation in the food system (source: Wuppertal Institute)

Basically, a systemic transformation will be necessary, and it must be accompanied by technological, economic, cultural and institutional framework conditions (Schneidewind, 2018). This is a responsibility of society as a whole, involving all stages of the value chains and the respective actors as well as regional social and economic structures (ZKL, 2021).

In production, especially agricultural production, economic production constraints must be reduced to create the space for farmers to take ecological and social aspects more into account during their operations (Schneidewind, 2018; ZKL, 2021). Under the CAP, agriculture operates within a clearly defined political framework. German farms derive almost half of their income from subsidies, which partially decouples them from the underlying market logic. As a result, subsidy policies have a substantial impact on agriculture (Federal

Agricultural Information Centre (Bundesinformationszentrum Landwirtschaft), 2019). Therefore, agricultural transformation can only be initiated with a targeted reorienting of the CAP to incentivize preserving the social and ecological services of agriculture (ZKL, 2021). The amount of subsidies, the level of claims and the minimum requirements for receiving direct payments for the eco-scheme programs planned from 2022 play a key role in previous reform attempts[2] (Grethe et al., 2021). The main stimulus for the agricultural transition has to result from the redesign of the political framework conditions, while digitization can subsequently support the implementation. For example, a digitalised and automated monitoring can be used to map nutrient cycles on individual farms and can align the receipt of direct payments or eco-schemes with the nutrient cycles (see Chapter 5.1).

Similarly, a nutrition transition cannot be achieved solely through increased productivity and consistency. It will also require lifestyle shifts towards sufficiency (Speck et al. 2021; Lukas et al., 2018; Schneidewind, 2018). At the individual level, food choices can be leveraged to reduce ecological impacts and need to be promoted as such, hence the need for fundamental changes in dietary practices. Nutrition is subject to regularly changing conditions and demands on private lifestyles (e.g. the gender division of household in relation to professional employment) (Schlegel-Matthies, 2018). It is also closely linked to demand and consumption in other areas. For example, the choice of shopping location is strongly related to mobility (Pfeiffer et al., 2017). The following example of a neighborhood food hub illustrates how digitization can enable new, cross-sector consumption systems.

However, in addition to reshaping the way we eat through new digital possibilities for promoting sustainable consumption (like apps cf. chapter 4.2 or the presented Food Hub), the basic conditions of the food environment will also have to change. Political support and the creation of a fair food environment for sustainable consumption will be crucial (WBAE, 2020). An example of such support would be price incentives through a reduction of VAT rates on plant-based milk, which is currently in Germany taxed at a higher rate than cow's milk. Sustainable daycare and school catering (e.g. by implementing the quality standards of the German Nutrition Society e. V. (DGE)), in combination with the integration of nutrition education and education for sustainable development in the curricula, can lay the foundation for sustainable diets and lifestyles. Greater regulation of advertising of unhealthy products to children or promotions that use meat at dumping prices as bait offers can reduce the overrepresentation of these products.

In the long term, sustainable and healthy nutrition should become a matter of course and a standard that does not depend on income and educational level or can only be implemented by certain population groups, but rather is a general norm for society as a whole (WBAE, 2020).

[2] Within the framework of the CAP, the EU provides financial support to farmers and rural regions. So far, direct payments have played a major role in this. In addition to a basic payment, which is determined by the area of the farm, there are also additional payments for specific environmental services (previously known as greening, from 2022 eco-schemes), such as the preservation of permanent grassland. The distribution of direct payments is linked to the fulfillment of certain conditions (e.g. basic requirements for farm management and good agricultural and ecological condition).

A New Service System: The Neighbourhood Food Hub

Throughout the food logistics chain, the so-called "last mile" of the logistics route is usually covered by private consumer vehicles. This last mile is responsible in the largest share of transport-related emissions in food logistics (Stelwagen et al., 2021). During the COVID-19 pandemic, food delivery services and meal kits have experienced tremendous growth (BEVH, 2022; BVE, 2020). Whether these services will continue to develop remains to be seen, but inefficient route planning, like if deliveries are to be made in a particularly short time, can also lead to increased emissions (UBA, 2021b). To offset both effects, "Food Hubs" (see Figure 4) can be established in urban areas, similar to parcel stations. These hubs would come equipped with cabinets to store food from delivery services. Food hubs can also be located throughout residential areas and allow for daily delivery and food collection. This would allow for more efficient delivery service routes and people would be able to walk up and pick up food during their daily commute. Artificial intelligence could also be used to provide solutions that optimize deliveries and pickups based on the user's eating behaviour.

Figure 4: Food hub (source: Alica Assadi, Christoph Tochtrop, Folkwang University of the Arts)

6.2 Creating conditions for effective digitalisation in the food system

In order to successfully harness the potential of digitalisation, a system of political incentives and regulations will be needed to support both broad and targeted expansion of the technologies and business models presented in the chapters *Improve* and *Convert*. Similar support will also be needed for the conditions laid out in this *Transform* chapter. Ultimately, the success of this transformation will depend on the framework conditions that allow all actors to enact desirable developments and prevent undesirable developments.

Solid **technical communication infrastructure** will be a basic prerequisite for any digital transformation within food systems. As of right now, access to high-performance networks is still insufficient, especially in rural areas. This not only hinders the development of all economic sectors located there, but specifically hinders the development of Digital Agriculture 4.0 (DLG, 2018; Nüssel, 2018; UBA, 2018). Therefore, a nationwide expansion of 5G networks is necessary. Of particular importance is the consistency of the systems: The food industry is critical infrastructure, so temporary system failures must be prevented by all means (DLG, 2018).

So far, this vision of a fully networked value chain is still beyond our reach. In addition to the lack of data infrastructure, there is also a lack of **data interoperability**. It is not enough to simply collect data; data must also be merged and integrated so that it becomes usable. New possibilities for action can only be opened up through the collaborative use of data (Ramesohl et al., 2022). Barriers that previously restricted data flows must be removed and efficient cross-sectoral data use and exploitation must be made possible. This is the only way to connect value chains vertically and horizontally (see chapter 5.2) and to align the use of sustainability indicators (see chapter 5.1) (European Commission, 2018). However, our ability to achieve this level of interoperability is not a foregone conclusion. Policymakers will have to work with stakeholders to establish the necessary standards and data infrastructure.

Popular debates on **data protection, data sovereignty, and data security** are closely related to this topic. Producers, whether in agriculture, processing, or trade, cannot be “transparent enterprises”, nor can consumers be “transparent consumers”. Legally binding international framework conditions must allow relevant actors to have data sovereignty, i.e. “the ability of legal or natural persons to self-determine their data assets throughout the value chain” (Otto & Burmann, 2021). According to the German government's data strategy, we need data ecosystems for sustainable food and agriculture to support the interaction of “[...] various stakeholders, services and applications (software) that use and share data for economic or social purpose. [...] In this sense, the data ecosystem is a data-based system with an innovative, technical, organisational and regulatory system” (Federal Government, 2021).

In addition to these prerequisites for the realisation of a digital food system, further framework conditions and guidelines are needed to avoid undesirable developments and to steer digitalisation in the right direction.

In particular, the acquisition of digital technologies in agriculture can be associated with very high investments, while at the same time it can be difficult to prove the economic viability and concrete **economic benefits** to the users. (BMEL, 2021). In order to ensure the broader adoption of capital-intensive digital technologies, users must be made aware of their benefits (BMEL, 2021; BMNT, 2018; LfL, 2017). Larger farms often benefit from new technology applications as they are more willing to take risks and innovate. Small businesses often cannot afford these risks and are left behind (BMEL, 2021; Schmidt, 2018). Offsetting the lopsided structural changes in agriculture will require significant start-up capital and investment funds. Official and public data such as weather information, cadastral, and soil data (e.g. water holding capacity and road networks) should be made freely available to stakeholders in agriculture (DLG, 2018). The collaborative use of technologies on small farms (already common practice through “Maschinenring”, a form of farmers’ organisation) needs to be scaled up more consistently and the investment policies need to be rethought (Schmidt, 2018). Farmers’ field-specific capabilities cannot be used unchecked as the data base on cloud platforms for third-party business models. But farmers must also be able to economically benefit from making their data available (DLG, 2018).

Establishing digital technologies in food production and consumption processes as the new status quo necessary for sustainable development will require digital infrastructure that is accessible to, **accepted by, and used by the public**. The success of these efforts will depend not only on the dynamics of technological development, but also on the new social and societal competencies that will be needed achieve the permanent changes we seek (WBGU, 2019). These competencies will be particularly important in nutrition, as change in this area will require action from all generations and social strata. All actors, including companies from processing, trade, out-of-home catering, and (public) institutions, must have the ability to collect, process and use data. Digital technologies will therefore have to become a regular part of education (i.e. through adding programing languages to curriculums) in order to promote learnability and 'digital literacy' (DLG, 2018). The benefit of these skills will be seen both in agriculture, but also in other areas within the food system.

7 Conclusion

As described in this report, the impact of food production and consumption on the environment, social justice, and social health is multifaceted. A systemic transformation will be needed to build a truly sustainable and resilient food system.

Digitalisation builds the foundation for selective improvements to existing systems as well as new framework conditions and business models. These improvements can take the form of digital agricultural equipment like agricultural robots for smart farming that make agriculture more resource efficient. However, the collection, provision, and use of data flows along the entire value chain can play a greater role in the transformation of food system. Increased transparency and increasing the accuracy of sustainability indicators to reflect the entire supply chain's impact on greenhouse gas emissions and biodiversity will drive processing companies, caterers, and consumers to change actions and habits. Networking across process stages and connecting end consumers to original producers can provide new distribution channels or help popularise niche innovations. These solutions all support and facilitate a necessary nutritional transition.

In order for all this to happen, there are policy and regulatory frameworks that must exist prior. Infrastructure, standardised data and interfaces, as well as legal requirements for data security and data sovereignty will be essential to effectively applying new digital solutions. Heavy investment will be needed to achieving widespread economies of scale while also minimizing the negative side effects of digitalization in this sector, such as lopsided structural changes. The introduction and use of digital technologies should not be a goal in and of itself. It must be a tool we use to build a climate-neutral and resource-efficient food system. Losing sight of this goal risks accelerating contrary and harmful economic patterns (BMNT, 2018; WBGU, 2019). In addition to all of these economic concerns, we must also look at how digitalisation will fundamentally change our social interactions and the challenges it will raise (DLG, 2018; WBGU, 2019). Without a doubt, digitalisation will require increased digital literacy among all population groups (SVRV 2021).

Institutional, social, and political framework conditions will also play an important role in achieving coherent and comprehensive techno-economic and social-cultural transformation. Digital opportunities must be embedded in an “analogue” context, i.e. agricultural, environmental, food, consumer, and health policies must steer actors in the right direction and identify the dynamics of change that will enable digitalisation to take effect. For agriculture, this means, reorienting the economic incentive system within the CAP framework to reduce production constraints and better reward social and ecological contributions. If this prerequisite is met, digitalisation can, in turn, support the successful implementation of new incentive systems through improved and automated monitoring. At the same time, the conditions for sustainable consumption must be created for private consumers through appropriate food environments and pricing. This process can be supported by reducing information asymmetries through digital decision aids.

The transformation of the food system through the establishment of basic framework conditions must receive more attention and be managed in a politically sustainable manner. Only then will the many opportunities offered by digitalisation have a targeted effect.

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