European Commission

SCAR
Standing Committee on Agricultural Research

ONLINE ANNEXES[1]

"Facts & Figures" reports

of the 5th SCAR Foresight Exercise

Natural resources and food systems:
Transitions towards a 'safe and just' operating space

September 2020

[1] As part of their work, the 5th SCAR Foresight Exercise experts prepared a series of specialist papers on topics related to the 5th SCAR Foresight Exercise report. They were an important part of the process by which the 5th SCAR Foresight Exercise expert group reached its conclusions, and reflect the expertise of the members who wrote them. The views expressed in the "Facts and Figures" reports are of the authors and do not necessarily reflect those of the 5th SCAR Foresight Exercise expert group, SCAR or of the European Commission.

Research and Innovation

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1. Introduction

The Standing Committee on Agricultural Research was established by EU Council regulation in 1974 to help guide and coordinate R&D under the Common Agricultural Policy; and its scope expanded in 2012 to include forestry, fisheries and the bioeconomy. The SCAR Foresight Group, mandated by the SCAR Plenary, monitors and steers foresight that feeds into EU strategic planning, and initiates foresight expert groups such as the present one. There have been four SCAR expert foresight reports so far.

For this, the 5th SCAR Foresight report, our topic is "natural resources and food systems: transitions toward a safe and just operating space." We consider the use of natural resources, waste as a resource, the move from linear to circular economy, the bioeconomy, research priorities and organisation – all with a focus on Europe, but with an eye towards the international context in which Europe operates. To fill this with content, we applied a new method combination in order to identify transitions towards a safe and just operating space. We tried to identify enablers and lock-ins, and ask the question: How can research and innovation contribute to the transitions? Our aim is to provide ground for decisions of the member states and Commission, helping set the agenda and priorities especially for the European Research Area and CAP.

Given that SCAR focuses on research and innovation, our R&I recommendations are in the focus. Are competitive funding calls the root of excellence? What of missions, or beyond? How could we involve the public, or get their support? Should Eurostat develop an indicator for food waste? Is money enough? Only too often in foresight exercises do we end up with things that are politically impossible, therefore, here we included different actors into the workshops who act as multipliers for spreading the information and maybe amplifiers for change. On the one hand, they contributed to the methodology and the discussions, on the other hand, they take the findings into their daily environment. For example, the private sector has a big role to play, maybe the discussion of business models may contain ideas. We also look at agents of change: how do we align their investment goals with those of society? How can civil society help? What is the role and image of farmers and agriculture? We looked beyond the EU, Europe is bigger than the EU. The following sections describe the **procedure and the methodological** setting. The full results are described in the final report of the SCAR 5th Foresight expert group. In the last section, we hint at lessons learnt and draw some methodological conclusions.

2. Foresight: A conceptual framework

The concept of foresight has evolved rapidly over the past 20 years, some already name it a "discipline". We regard Foresight as the systematic debate about different futures[2] - with a long-term view and involving heterogeneous actor groups but of course going back to the present and discussing the potential decisions of today. As an expert group, we applied a certain set of methods with care – and in this report, we summarise the major ideas and methods used in play. To start with, our terms of reference highlighted three concepts on which the report should focus:

1. *System approaches*. In foresight work, system approaches look at the interdependency between phenomena, rather than reducing them to their simplest terms and isolating them from their context. System approaches consider the possibility that any action may have a multiplicity of outcomes. System approaches are particularly relevant when problems – the gaps between the expected and current state of affairs – involve interaction between different realms, such as the social and the biophysical.
2. *Transitions.* A focus of work is analyzing and describing how, as a society, we will get from here to there, from our current imperiled world to the "safe and just operating space" we seek. That requires that we look at the constraints to change. These constraints can be in the *landscape:* the set of drivers affecting the system but not controlled by the system, such as global warming. They can be in the *regime:* the core rules, actors and technologies that regulate the functioning and stability of the system, such as the structure of the agricultural industry. And they can be in the *niches:* subsystems that operate under rules alternative to the ones provided by the regime and that test new solutions to emerging challenges, such as the growth of the organic food sector[3]. These constraints explain why

[2] Cuhls, Kerstin: Horizon Scanning in Foresight - Why Horizon Scanning is only a part of the game, in: Futures and Foresight Science, 2019. DOI: 10.1002/ffo2.23, or European Commission (Hg.): Strategic Foresight in EU R&I Policy. Wider Use – More Impact. Report of the Expert Group 'Strategic Foresight for R&I Policy in Horizon 2020'. Brüssel 2017, https://ec.europa.eu/research/foresight/index.cfm?pg=fb_policy.

[3] Geels, Frank W. (Technological Transitions and System Innovations. A Co-Evolutionary and Socio-Technical Analysis. Edward Elgar: Cheltenham (UK) and Northampton, M.A. (USA) 2005 or Frank W Geels & Johan Schot: Typology of sociotechnical transition pathways, in: Research policy, 36 (2007) 3, 399-417 or Schot, J. & Geels, F.W. 2008. Strategic niche management and sustainable innovation journeys: theory, findings, research

technology alone cannot solve societal problems; the impact of technologies will depend on the social context, in which they are embedded, and setting "missions" for R&D can have varied effects[4]. Furthermore, transitions are usually non-linear; and in complex systems, unpredictable major transitions may occur. For any desired transition, "lock-ins" – social or technical barriers to change – must be overcome. As a result, future innovation policies need to consider the whole system, in which desired transitions would occur, and concentrate resources where constraints are stronger or opportunities are most promising. Foresight thus draws the attention to the potential.

3. *Safe operating space. The concept of a safe operating space was introduced by Rockström et al.* in 2009[5] to help develop policies from the study of the impact of human activities on Earth's biogeochemical cycles and ecosystems. It considers "alert indicators" and thresholds for these biophysical indicators (called "planetary boundaries"[6]); when trespassed, these boundaries destabilize and harm global ecosystems. In light of the UN Agenda 2030 goals, other scholars have adapted the concept and proposed a safe and just operating space (Raworth, 2017a, 2017b[7]) that includes minimum social standards, such as nutrition and health indicators. The recent EAT-Lancet Commission Report[8] provides a quantitative assessment of a number of primary sector-relevant planet boundaries, which may be taken into consideration as targets for the scenarios of the foresight exercise.

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agenda, and policy. Technology, in: Analysis & Strategic Management: Special issue "The dynamics of sustainable innovation journeys" 20(5), 537–554.

[4] Mazzucato, Mariana (2018): Mission-Oriented Research & Innovation in the European Union MISSIONS. A problem-solving approach to fuel innovation-led growth. Luxembourg. doi:10.2777/36546

[5] Rockström et al., 2009. Planetary boundaries: exploring the safe operating space for humanity. Ecology and Society 14(2): 32. http://www.ecologyandsociety.org/vol14/iss2/art32/

[6] Steffen, Will; Richardson, Katherine; Rockström, Johan; Cornell, Sarah E.; Fetzer, Ingo; Bennett, Elena M. et al. (2015): Sustainability. Planetary boundaries: guiding human development on a changing planet. In: Science (New York, N.Y.) 347 (6223), S. 1259855. DOI: 10.1126/science.1259855.

[7] Raworth K., 2017a. *Doughnut Economics: seven ways to think like a 21st century economist*. Raworth K., 2017b. *A Doughnut for the Anthropocene: humanity's compass in the 21st century.* www.thelancet.com/pdfs/journals/lanplh/PIIS2542-5196(17)30028-1.pdf

[8] The EAT-Lancet Commission on Food, Planet, Health, https://eatforum.org/eat-lancet-commission/.

With all this in mind, we adopted a conceptual framework showing how ideas, trends, single developments, technologies and other factors interact to produce desired transitions.

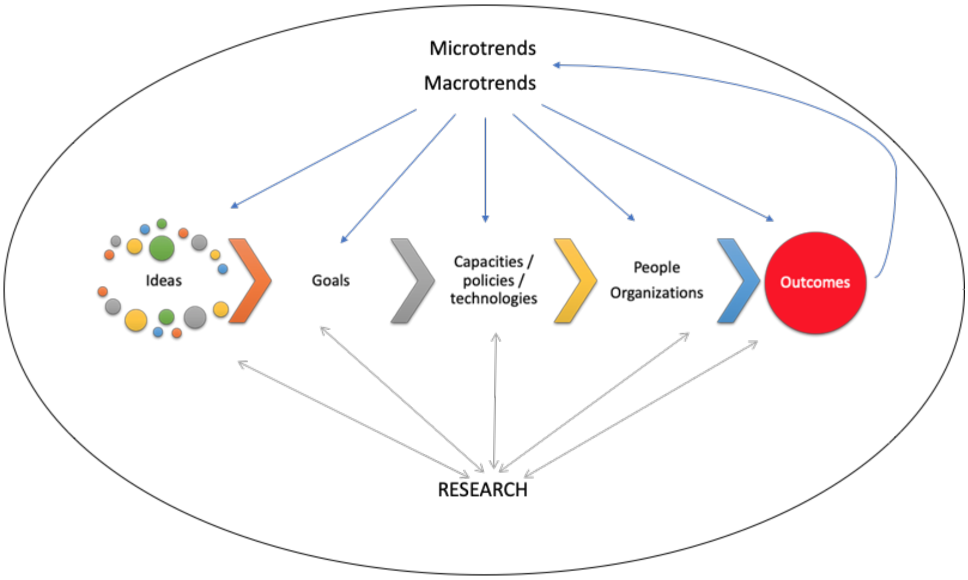

Figure 1: Overview of the process flow

The diagram illustrates transition as a complex process. Different ideas – ethical principles, visions of the world, scientific paradigms, methodological approaches – lead to different goals or interpretations of those goals, such as the UN's Sustainable Development Goals. The different ideas may lead to different solutions in term of capacities, policies and technologies. What happens with these ideas and capacities depends on real-world people and organizations: lifestyles, business models, organizational patterns. In order to figure out how a goal can be achieved, it is necessary to imagine how the broad goals (e.g. the SDGs) will be translated into people's, industry and farms' daily life. Some broad inputs also come into play. Our methods thus concentrated on the long-term future but always went back to the present (Backcasting, see figure 2) to be able to describe full paths in the end.

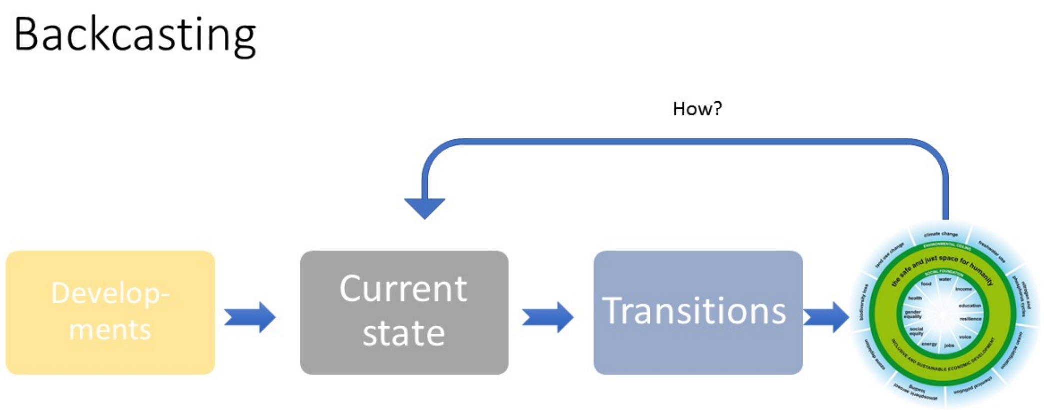

Figure 2: Working mode as a frame for the methodology

To define the terminology was difficult: We use the term “(broad) developments” to identify trends (micro, macro, mega and meta trends) as already ongoing and stable developments, but also included single developments, emerging issues, disruptive development and radical innovation in our searches and discussions. Macro/ megatrends – demographics, climate change, for instance – affect the system. So, too, do research and innovation, by generating new ideas and technologies, clarifying the goals or improving knowledge of what drives change. Altogether, the change from old to new practices is a process that may create resistance and opposition, as well as winners and losers. Change will require imagination of a clear picture, building capacities, designing and implementing consistent policies, developing appropriate technologies and reforming society.

3. Major questions for the 5th SCAR Foresight

Asking or identifying the right questions is one of the major tasks in Foresight. Here, we list some of the major questions that we were starting with when performing the Foresight.

1. What are the SDG indicators and the available data in Europe?[9],[10],[11]

[9] http://sdgindex.org/assets/files/2018/Methodological%20Paper_v1_gst_jmm_Aug2018__FINAL_rev10_09.pdf

[10] https://unstats.un.org/sdgs/indicators/database/

[11] https://ec.europa.eu/eurostat/web/sdi/indicators

2. *How to turn SDGs into targets relevant to Europe*? Not all SDGs are equally urgent in every part of the world; they need translation into local conditions. Some EU countries have already translated the SDGs into a relevant assessment framework (e.g., Germany's SD strategy, IDDRI's work on assessing France's progress on SDGs, Evaluation of Finland´s SDG policy[12] Finnish SDG policy evaluation, Italian statistics on the implementation of SDGs[13]).

3. What are the key elements that might be missing in the SDGs?

4. What are the main tensions and trade-offs between competing targets? A consistent vision of a sustainable future for Europe might not be able to rely on win/win (or synergies) among the 17 SDGs; there will be trade-offs. Obvious areas of tension are between economic development and environmental SDGs, between staying within planetary boundaries and still enabling a good life for all Europeans, including those most vulnerable.

5. How fast can change happen? As already underlined in the third SCAR foresight report[14], time is scarce if we want to stay within the planetary boundaries[15]. But the capacity of our societies to change is low – especially in energy, agriculture, cities, transportation and other complex systems. Government also moves at different speeds. It took more than 20 years to reach the Paris Agreement, and that is only a basic framework for national action. SDGs are supposed to be reached in 2030; but for many of them, and climate in particular, that is just an intermediary target on a 2050 pathway.

4. Identifying Trends, Developments and Transitions: Lock-ins, enablers and costs

To answer these questions, we started with an analysis of megatrends, macrotrends, and single - sometimes disruptive or newly emerging - developments as desk research. Here we made a synthesis of existing foresight exercises[16] and of the drivers chosen,

[12] PATH2030 – An Evaluation of Finland's Sustainable Development Policy. Berg, Annukka; Lähteenoja, Satu; Ylönen, Matti; Korhonen-Kurki, Kaisa; Linko, Tyyra; Lonkila, Kirsi-Marja; Lyytimäki, Jari; Salmivaara, Anna; Salo, Hanna; Schönach, Paula; Suutarinen, Ira (2019)http://urn.fi/URN:ISBN:978-952-287-655-3

[13] ISTAT. 2019. 2019 SDGs Report: Statistical Information for 2030 Agenda in Italy. ISBN 978-88-458-1984-1. © 2019 Istituto nazionale di statistica, Roma. https://www.istat.it/it/files/2019/08/SDGs-2019_inglese.pdf

[14] European Commission. 2011. Sustainable food consumption and production in a resource-constrained world - The 3rd SCAR Foresight Exercise. 232 pp. ISBN 978-92-79-19723-9. doi 10.2777/49719. https://ec.europa.eu/research/scar/pdf/scar_3rd-foresight_2011.pdf

[15] Steffen et al. 2015

[16] Bisoffi, Stefano (2019): A meta-analysis of recent foresight documents in support of the 5th SCAR Foresight Exercise" (124pp) and "A meta-analysis of recent foresight documents in support of the 5th

highlighting those that are relatively new compared to past SCAR foresight exercises and highlighting changing priorities. Meta-scenarios from BOHEMIA (European Commission[17], also figure 3) and the Delphi statements from the same project were used, too. For each broad trend, we considered the main indicators and projections to 2050; the contribution of agriculture, forestry and other land use to the trend; and the impact of land use on the trend, itself. An expert from the expert group summarized the findings in a Fact & Figures paper or an essay.

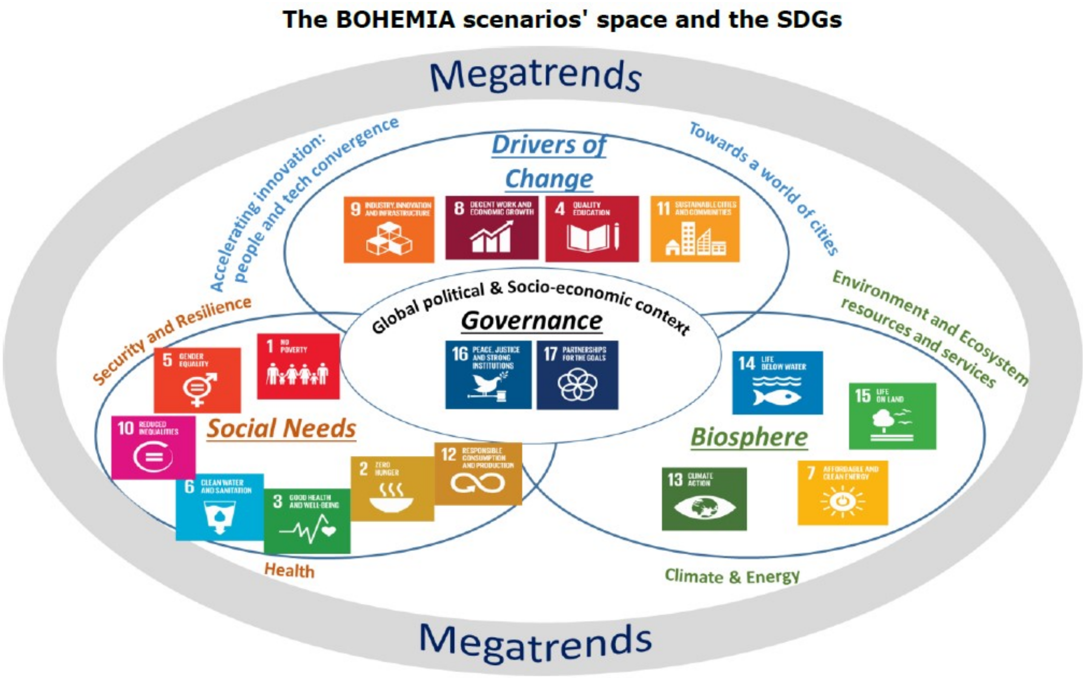

Figure 3: Connection of scenarios and SDGs

SCAR Foresight Exercise Second report: Livestock; Fisheries and aquaculture and Forestry" (133pp). Studies carried out under the Project "Support Action to a common agricultural and wider bioeconomy research agenda" (CASA, Contract 727486, Topic SFS-25-2016). https://scar-europe.org/images/FORESIGHT/CASA-Study-Meta-Analysis-Foresight-SUB.pdf.

[17] European Commission/ European Union (2018): Transitions at the Horizon: Perspectives for the European Union's future research- and innovation-related policies. https://ec.europa.eu/info/research-and-innovation/strategy/support-policy-making/support-eu-research-and-innovation-policy-making/foresight/activities/current/bohemia_en; and European Commission/ European Union (2017): New Horizons: Data from a Delphi Survey in Support of European Union Future Policies in Research and Innovation; Report KI-06-17-345-EN-N; doi:10.2777/654172 or https://ec.europa.eu/research/foresight/index.cfm; https://publications.europa.eu/en/publication-detail/-/publication/d1ea6c83-e538-11e7-9749-01aa75ed71a1/language-en/format-PDF/source-60761593

Source: European Commission (2017): New Horizons: Future Scenarios for Research & Innovation Policies in Europe, Brussels

We also examined a number of key trends and single developments specific to the food and agriculture sector. Information for this work was gathered in a data base. But most information stemmed from the Foresight workshops performed (see below) and was refined through discussion. The prior selection of themes was based on the following principles:

- Selection, description of important categories, drivers, trends, new or disruptive developments and impacts to formulate alternatives in foresight
- Mapping issues and major developments or trends considered in Foresight exercises to identify what is new, what is prior, what is missing? (e.g. new trade policies, China as an actor...)
- Collection into a database, e.g. from existing foresight work (as a table or landscape)
- A broad frame, derived from the identified goals in demography, geopolitics or other fields
- Estimation of future developments that can already be observed in existing tendencies and countertendencies
- Avoiding a focus on averages solely, to consider as much as possible at inequalities, distributional impacts of trends, asymmetries and imbalances.
- Consideration of how broad (mega) trends translate unequally across Europe and the planet, as well as in a differentiated manner in society

For going further, we examined transitions and paid special attention to lock-ins and other obstacles to change, as well as enablers to accelerate change. We used a well-regarded methodology from transition research (the Geels/ Schot 2007 model of Multilevel Perspectives) adapted to Foresight as templates in workshops to help identify the systemic nature of lock-in situations, and to discuss how levers of change may be addressed systemically. We considered asymmetries in power, resources, evaluation and research capacity, path dependencies in technological systems, norms and standards, public policy, political economy, resistance to change and other factors.

The *multi-level framework* mainly looked at transitions from the point of view of scaling up niche innovations, but it also offered other models of transition (such as reconfiguration, hybridization, de-alignment and re-alignment). The multi-level perspective (MLP) facilitates the analysis of the emergence of a new system as an outcome of interaction of different actors and structures, and thus provides understanding of the dynamics of system innovation. One of the key features of the MLP is its focus on long-term thinking – here applied also for foresight, and not only for historical change analysis. Another is its explicit focus on the interconnectedness of technological and social systems, including governance models and institutions. The multi-level perspective stresses that technological systems change through the interplay between landscape, regime and niche-level processes. Socio-technical landscape refers to relatively stable, slow-changing factors such as cultural and normative values, long-term economic developments and societal trends. Socio-technical regime refers to the semi-coherent set of rules (e.g., agreements, directives, moral codes) carried by different actors (such as users, policymakers, scientists, and public authorities) and practices and action models based on these rules, and interaction between actors. Niches refer to initiatives and activities in special application areas or in bounded geographical areas.

Regimes tend to generate incremental innovations, while “radically new”, disruptive innovations are generated in niches, which are protected from ‘normal’ market selection. “Radically new” innovations need protection or support because their cost efficiency, technical performance and usability often need improving or to reach a minimum size to be viable. Niches provide locations for experiments and learning processes, and space to build the social networks, which support innovation. Geels (2004, 37) explains that radical innovations break from the niche-level when the external circumstances are right, that is, when on-going processes at the levels of regime and landscape and timing create a window of opportunity. Particular attention is paid to the involvement of ‘forerunners’, i.e., representatives of innovative solutions that challenge the current socio-technical systems. On the basis of multi-level perspective, Geels & Kemp (2006; see also Geels & Schot 2007) have categorized phases of societal change processes. They distinguish between three different phases of societal changes – reproduction, transformation and transition.

In reproduction, there is almost no external pressure on the landscape level, and the system rebuilds itself inside the regime. In the transformation process phase, there are interacting dynamics at the regime and landscape levels, but incumbent regime actors try to find solutions how to answer the landscape-level pressure. In the transition process phase, the outside actors from the niche and landscape levels are shaping and creating the new regime. In order to achieve the Sustainable Development Goals, we should be aware of the complex system level changes in short- and long-term perspective[18]. Achieving transition is a major change, and the current discussions tend to end in the reproduction phase, although the ultimate goal may be on a system level transition. A key aspect of understanding change is putting the events onto a timeline. Often system transition is considered to be a giant amorphous process that just happens. Our approach was to look at this process from different angles and identify key parts of the change.

[18] Sharpe, B., A. Hodgson, G. Leicester, A. Lyon, and I. Fazey. 2016. Three horizons: a pathways practice for transformation. Ecology and Society 21(2):47. http://dx.doi.org/10.5751/ES-08388-210247

Defining how the changes relate to each other with regard to time helped clarify the transitions and paths towards the future.

One of the major barriers to change is the fear that the changes will be costly. Several questions are important in this regard:

Consideration of the cost of transition for an individual economic agent: Is her or his economic status or well-being after transition more or less profitable than before? If less profitable, does the difference in well-being have to be compensated by subsidies; is it feasible? To what extent is the difference in profitability linked to a failure to internalize environmental, health and social externalities? Could putting a price on externalities lead to the transition? If, by contrast, profits could be higher after transition, the problem could be in the upfront cost, the opportunity cost, the "valley of death" of an innovation, or the temporary lack of profitability in the first years of a transition (Consider, for example, the slow pace of conversion to organic agriculture.) In this case, how can the necessary investment be covered by financial actors, insurances, or mutuality mechanisms? Could fiscal policies overcome the transition costs?
Consideration of a regional development perspective. Transition costs might have to be considered in light of the specialization of regions. For example, regions phasing out a coal economy have important social costs to consider; they could be lowered through anticipation and requalification of the workforce, on top of other types of social compensation policies.
Consideration of the effect on a whole sector or country. The costs of transition should not be considered on average but in their distributional effects: who loses and who wins? It is also important to compare the socio-economic impact of the transition scenario with that of the "business as usual" scenario.

5. Four participatory foresight workshops and expert papers

We have applied transition management and screened participatory Foresight literature for compiling forward- looking multi-voice workshops to understand the „broad developments" (directions, including so-called "megatrends", trends, radical innovation or breakthroughs in science and technology), targets, key factors and finally the transition paths. Transition management is a multilevel model of governance, which shapes processes of co-evolution using visions, transition experiments and cycles of learning and adaptation. The literature suggests that socio-technical change can be enhanced by the establishment of a transition arena. In such an arena, selected participants of the governance process reflect the complexity of the transition at hand. They need to have basic competences and are willing to invest substantial amounts of time and energy on playing an active role in the transition arena process[19]. A transition arena offers a forum for discussion between different actors, through which new insights and a shared understanding may emerge. In this Foresight exercise, we had a series of workshops as a space for transition arenas.

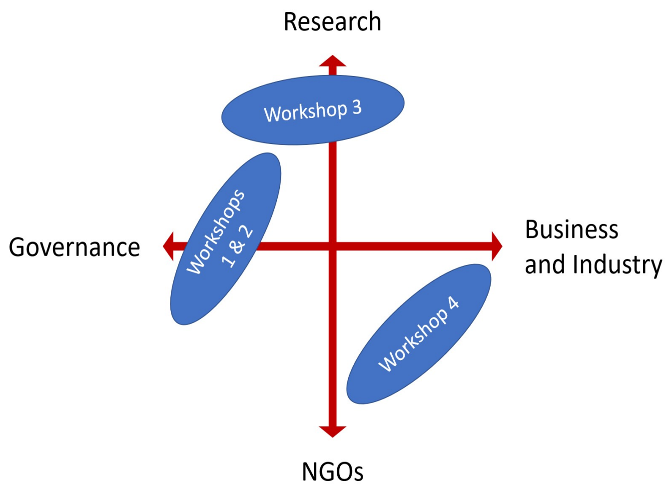

Figure 4: Actors involved in the workshops

Variable groups of stakeholders attended the workshops. In the beginning (Workshops 1 & 2), the bulk was made of representatives of Ministries (in general, of Agriculture) and by the European Commission's Directorates. The third workshop saw a range of experts from different disciplines present facts and figures related to the transitions and targets already identified, while the fourth workshop was opened up to representatives of industry, business, farmers, finance and NGOs. The Foresight experts had the main function of facilitating during the meeting and, subsequently, of processors of the wealth of information collected.

In our workshops, we had nominated facilitators to lead and synthesize discussions with the aim of creating a shared understanding of the persistence of challenges at the different levels of systems. Participants were selected according to the individual objectives of the workshop:

- Identifying targets from the SDGs

[19] Markard, J., Raven, R., Truffer, B.: Sustainability transitions: an emerging field of research and its prospects, in: Research Policy, 41 (2012) 955-967; Kivimaa, Paula and Kern, Florian: Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions, in: Research Policy 45 (2016) 205-2017; Rogge, Karoline S. and Reichardt, Kristin: Policy mixes for sustainability transitions: An extended concept and framework for analysis, in: Research Policy 45 (2016) 1620-1635; Koehler, Jonathan et al.: An agenda for sustainability transitions research: State of the art and future directions, in: Environmental Innovation and Societal Transitions 31 (2019) 1–32.

- Identifying broad trends and developments in natural resources and food systems
- Identifying transition points and paths (model: regimes, landscapes, niches)
- Formulating joint ‘visions’ or targets: Which kind of narrative is necessary?
- Defining the “boundaries” for the visions and targets (including planetary boundaries)
- Finding pathways, completing roadmaps and identifying barriers, lock-ins, contradictions and trade-offs, and formulating them in an easy-to-communicate manner
- Representing ‘visions’, transition points (points where changes occur) and paths with examples told in stories based on daily life
- Identifying actors to be involved (capacities, change makers, transition agents...)
- Thinking: There are always alternative futures!

Having the Multilevel Perspective (MLP) of Geels and Shot 2007 model in mind, we differentiated between the levels of regimes, landscapes and niches. In our approach, we started with the SDGs, the challenges of the EU and other targets from Foresight studies on the one hand, and the meta-trends and trends on the other hand, and then filled in the gaps. All targets were framed within the “planetary boundaries” that we identified: they marked the limits for the targets to be achieved. To frame and formulate the main goals, we needed discussions among our group and with external experts from the sectors concerned. We included different prospectives (futures, l’art de conjecture[20]) and perspectives as well as question-guided facilitation. Homework and desk research were conducted between the group meetings.

The **first and second workshop** in May 2019 were conducted together during two half days and started with the question: ***What are the targets derived from SDGs and other challenges that Europe should set?***

Participants were the internal group and experts in agriculture, generalists for the broad developments, Foresight Correspondents Network of the European Commission, other policy experts from EU and MS, maybe strategists from industry. As background: SDGs, European Union targets, strategic goals, targets in the literature were given. The purpose of the first part was to define “targets”. The procedure was the following

1. From SDGs to targets: open discussion to define targets for agriculture derived from the SDGs. Input: existing policies and strategy targets (from literature, EU papers).

[20] Jouvenel, Bertrand de: L’Art de Conjecture/ Die Kunst der Vorausschau. Luchterhand: Neuwied 1967

2. Environmental categories [driving forces or key factors formulated in a neutral way] of agriculture and food production in general. We would prepare a mapping of drivers as input, go through them and enhance the list, decide which are the most important, and define the level of granularity
3. Boundaries and limits

Input to the workshop were: a) Mapping of key categories b) State of SDGs, indicators and other targets; c) Targets for agriculture, food and other land uses suggested by the SDGs.

Output of the workshop: List of targets, list/ first mapping of categories/ boundaries mapping

Figure 5 SDGs as a puzzle: systems thinking is needed to achieve the sustainable development goals.

We have utilized the SDGs as a sort of puzzle[21] in our first workshop to understand the systems thinking. The solutions can be found where the pieces meet. Achieving "zero hunger" may require an understanding of "industry, innovation and infrastructure" coupled with "gender equality" and also special research of future "life on land" and the "climate actions", just to mention a couple of them on a very general level. Thinking in terms of a puzzle made us more aware of the possible cumulative impacts, possible trade-offs, but also the possibility of a more nexus-driven future thinking across the sectors and disciplines.

[21] Johanna Kohl, 2018: https://www.luke.fi/en/blog/sustainable-development-goals-sdg-are-more-than-just-nicely-coloured-icons-a-puzzle/

Figure 6 An example of the systems thinking for setting the targets and transitions needed.

SDGs are about researching future crops, animals, migration, warming climate, forest policy and social policy. All policies are needed to be dealt with separately, but also together in a big picture by someone having this kind of system level and forward-looking capability. Holistic sustainability not only includes all the sustainability aspects, but also system-level thinking.

Natural resource literacy can be embedded in each of the SDGs and the SDGs can be utilized to promote and target future research.

Workshop 2 was the second workshop day in May 2019. It started to identify the **d*evelopments to 2030 and 2050 - Scanning general developments, trends, possible game changers and the actors involved.***

Purpose of the workshop was out-of-the-box thinking, considering different options or alternative perspectives, collecting meta-trends and trends, identifying transformation points and paths, and seeds for the pathways (first ideas for actors, bottlenecks, enablers). The tasks were:

- Working out drivers and factors. Define up to five alternative developments for each category or key factor. They can be quantitative or descriptive. Describe and explain them.
- Name trends, new developments that are already strong signals of change.
- Identify and discuss the major contradictions
- Identify the point of change, the transition situation we are facing. Describe it.

Participants were the internal group and experts in agriculture, generalists for the broad developments, the Foresight Correspondents Network of the European Commission, other policy experts from EU and Member States, a few strategists from industry - and there was a different setting from the previous day.

The workshop started with the results from the day before which were grouped into three broader targets: 1. Biodiversity, 2. Food + Health Issues, 3. Circularity and avoiding waste. These three groups worked with the templates mentioned above.

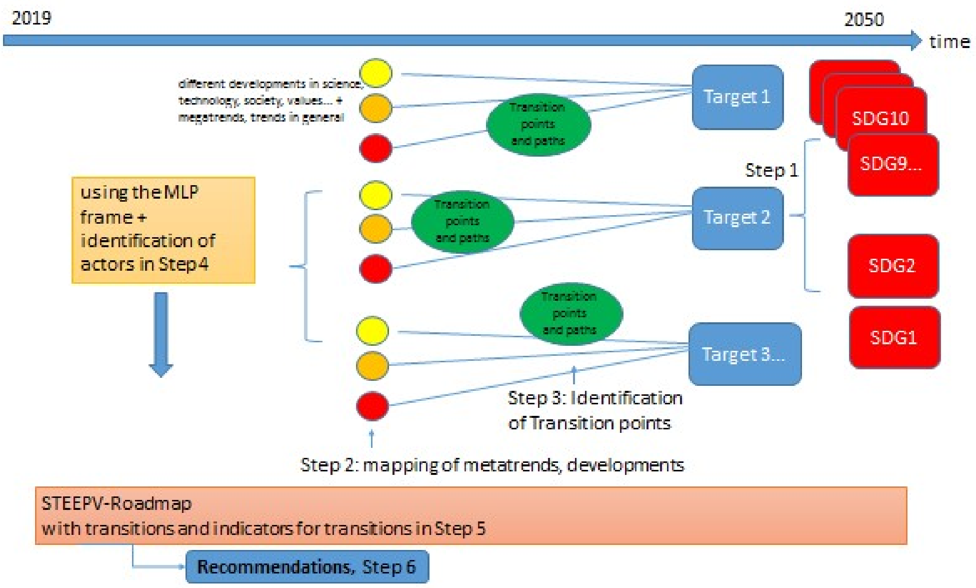


Figure 7: Working backwards from SDGs to targets, identifying Key Factors, alternative developments and points or paths of transition

The output was a picture with alternative options, different developments, the transition points and their short description, identification of consensus and dissent points.

Workshop 3 followed in July 2019. This workshop started with presentations from the European Commission institutions, SCAR members and scientists to give an overview of recent and upcoming research in the field. From these presentations and from additional expert papers written independently, the groups got an input to their discussion at this workshop and later during the course. Through this and the following workshop, also new experts of the 5th Foresight expert group helped the core group by a) compiling policy briefs related to ongoing developments (megatrends and trends); b) provide reflection papers c) participating in meetings.

The third workshop also served to fill the templates of the previous meetings with content. Different perspectives from different stakeholders were brought into the discussion when the expert group was expanded with this specialized knowledge. In the first part of the workshop, specialists of different disciplinary areas provided inputs to refine the targets and the sub-targets identified in the first and second workshop. In the second part, participants discussed the transition pathways (each of them identified by a broad target) in the three groups: Circularity, Diversity and Health derived from the first two workshops. This time, the focus of the discussion was on the transition points, carriers and barriers for the new paths, and on the role that existing meta trends, mega trends and micro trends may play.

During **Workshop 4** in October 2019, we asked the question: ***How to achieve the targets in 2030 and 2050?*** The workshop was about matching targets and developments: A focus on business models and social organization**.** Here we crossed the trends and developments with the targets and identified further transition points and measures. The key distinction of our approach from other Foresight activities is a focus on the transitions required to get from here to there – and for that, we needed to hear voices from the business world because they hold the key to any change. The discussion was starting with the pre-filled draft roadmaps. Participants had to fill the gaps and discussed the industry supply chain, the lock-ins and gatekeepers, and the new ideas that are (doubtless) being tried in various places.

Participants were from industrial-scale farming; agricultural suppliers including producers of fertilizers, seeds and equipment; food processors and distributors; food retailers; financiers of the ag/food supply chain; new service providers in agriculture and food; bio farmers; start-ups and testers of new approaches; new actors: from financing, crowdfunding, makers, game industry; experts on international trade in agriculture and food; experts on consumer behavior.

Input to the workshop were a) formulated targets from workshop 1 (qualitative descriptions, in some cases quantitative), b) analysis of transitions (output of workshop 2) and c) draft roadmaps.

The output was an in-depth analysis of transitions, visions and narratives for business models, social organization, consumer patterns; lock-ins and trade-offs, identification of consensus and dissent.

The internal **Meeting of the 5th SCAR Foresight expert group in January 2020** included a discussion about: What roadmaps for the transition? Recommendations were started. During this meeting, a cumulative and integrative ex-ante assessment of the material in a roadmap was performed, it was tried to identify gaps, and to derive recommendations from the transitions and the full roadmaps (backcasting approach). The final results should include:

- A qualitative or quantitative target related to the goals that were derived from the SDGs and discussing how to achieve them – based on the discussions in WS 3
- For each of these targets/ goals, a roadmap is filled that has MLP layers

- One roadmap for all transitions identified
- Selecting the transitions and developments that feed into the target
- Selecting micro developments (see below, external work) that can be helpful to achieve the targets (enablers), explanations why
- Discuss the barriers
- Recommendations
- Identify necessary stakeholders

After this meeting, the report writing was started and the three targets and transitions were formulated. In a meeting in January 2020, general recommendations for the final report were discussed in break-out groups.

Macrotrends

Stefano BISOFFI, 5th SCAR Foresight Exercise expert

1. Climate trends

Climate change and related extreme events were rated by the World Economic Forum 14th annual Risk Report as having a high likelihood and a high impact[22]. Greenhouse gases (GHG) are the main culprits for global warming and emissions due to human activities have reached the highest levels in history[23], increasing sharply after the years '70s of the last century, despite the mitigation efforts put in place after Kyoto. In 2017, globally averaged atmospheric concentrations of CO_2 were 405.6 ±0.1 ppm, CH_4 at 1859 ±2 parts per billion (ppb) and N_2O at 329.9 ±0.1 ppb. These values constitute, respectively, 146%, 257% and 122% of pre-industrial levels (pre-1750)[24].

The major sector responsible for GHG emissions in the world is energy production and use which accounts for approximately one third of GHG emissions[25]. Europe is slightly more "virtuous" than other major players, with a steady, if slow, decline in energy-related GHG emissions. Europe will achieve the target of a 20% reduction of net CO_2 emissions in the year 2020 with respect to 1990 levels but will likely miss the -40%

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22 Collins A (leading Author). 2019. The Global Risks Report 2019, 14th Edition. World Economic Forum. Geneva

23 Hart K., Allen B., Keenleyside C., Nanni S., Maréchal A., Paquel K., Nesbit M., Ziemann J. (Institute for European Environmental Policy). 2017. Research for Agri Committee – The Consequences of Climate Change for EU Agriculture. Follow-up to the COP21 – UN Paris Climate Change Conference. European Parliament – Directorate General for Internal Policies, Policy Department B: Structural and Cohesion Policies – Agriculture and Rural Development (ISBN 978-92-846-0646-7 doi:10.2861/295025. Available at: http://www.europarl.europa.eu/supporting-analyses.

24 United in science: http://public.wmo.int/en/resources/united_in_science.

25 IEA. 2015. Energy and Climate Change - World Energy Outlook Special Report. OECD/IEA, 2015, Paris, France (http://www.iea.org/publications/freepublications/publication/WEO2015SpecialReportonEnergyandClimateChangeExecutiveSummaryUKversionWEB.PDF, accessed 19 October 2018).

target for the year 2030, let alone the even more ambitious targets of COP21 of net zero emissions by 2055, unless drastic mitigation efforts are enforced[26].

The UNEP (United Nations Environment Programme) noted that the NDCs cover only about 1/3 of the emissions reductions that would be necessary to stay within the 2°C temperature increase, as decided in Paris in 2015. The gap between the reductions needed and the national pledges made in Paris is alarmingly high[27], let alone the advocated limit of 1.5°C. Averages, however, tell only part of the truth because significant regional variations have been observed. For instance, the temperature increase observed in the Arctic is two or three times the global average (currently around 1°C above pre-industrial levels).

The transitions needed to limit temperature growth within 1.5°C would require rapid and effective actions in many areas: energy production, transport, buildings, industries and other infrastructures. Most of them are not limited by the current availability of technologies but by the unprecedented scale of investments required that need a strong political will[28]. The signals coming from today's economies are not really encouraging. Despite the weakening of the correlation between growth (as measured by GDP) and emissions, these are constantly rising. Renewables are projected to represent over half the new investments after 2030, but the decline in fossil energy is much slower than would be necessary. Even coal as a source of energy declines slowly[29].

Seas and oceans currently absorb about a quarter of the carbon dioxide added to the atmosphere from human activities each year, thus moderating its effect on global temperature[30]. The higher the CO_2 concentration in the atmosphere, the higher the

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[26] EEA – European Environment Agency. 2017. Total greenhouse gas emission trends and projections - Indicator Assessment. 24 Nov 2017. https://www.eea.europa.eu/data-and-maps/indicators/greenhouse-gas-emission-trends-6/assessment-1 (accessed 17 October 2018).

[27] UNEP. 2017. The Emissions Gap Report 2017. United Nations Environment Programme (UNEP), Nairobi, Kenya

[28] IPCC – Intergovernmental Panel on Climate Change. 2018. Global Warming of 1.5°C; an IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty - Summary for Policymakers, Incheon, Republic of Korea, 6 October 2018.

[29] IEA. 2015. Energy and Climate Change - World Energy Outlook Special Report. OECD/IEA, 2015, Paris, France (http://www.iea.org/publications/freepublications/publication/WEO2015SpecialReportonEnergyandClimateChangeExecutiveSummaryUKversionWEB.PDF, accessed 19 October 2018)

[30] Steffen W., Broadgate W., Deutsch L., Gaffney O., Ludwig C. 2015. The trajectory of the Anthropocene: The Great Acceleration. The Anthropocene Review 2 (1), 81–98.

concentration of H_2CO_3 (carbonic acid) in water with direct negative effect on coral reefs and on shell molluscs. A less understood phenomenon, however is that the balance also acts the other way around: CO_2 would be returned from the oceans to the atmosphere in the desirable case of an effective global action achieving negative net CO_2 emissions, slowing down recovery.

2. Demographic trends

World population

Demographic projections are among the most reliable due to the inertia of reproductive cycles and the rather slow display of the effects of policy or cultural changes affecting human reproduction, unless unexpected dramatic events are considered (global wars, pandemics, sudden climatic alterations).

The current (2019) UN-DESA projections[31] (medium variant) predict a world population reaching 8.5 billion in 2030 and still growing to 9.7 in 2050 and 10.9 in 2100. However alarming these figures may appear with a view to "feeding the world", it is the distribution of the population that will likely be the main driving demographic factor. In 2050 79.9% of the world population will be located in Asia and Africa. Whereas China and India will reach a peak around 2030 and 2050, respectively, and then decline, African population will continue to grow until 2100. Africa will represent 39.3% of the world population in 2100, up from 17.0% today.

	2019	2030	2050	2100
World	7713	8548	9735	10875
Africa	1308	1688	2489	4280
Asia	4601	4947	5290	4720
Europe	747	741	710	630
Latin America and the Caribbean	648	706	762	680
Northern America	367	391	425	491
Oceania	42	48	57	75

[31] United Nations, Department of Economic and Social Affairs, Population Division (2019). World Population Prospects 2019 - Special Aggregates, Online Edition. Rev. 1.

The implications are evident on at least two aspects of the ongoing debates in Western societies: a) where and how to concentrate efforts to increase food production in order to ensure food and nutrition security to all (SDG n. 2: *"End hunger, achieve food security and improved nutrition and promote sustainable agriculture"*) and b) migrations; the population of Africa will increase from now to 2050 by the equivalent of 1.5 times the present population of Europe. Europe will face a numerical decline and will represent in 2050 a mere 7.3% of the world population (down from 9.7% today): fertility rates in Europe are expected to rise slightly until 2050, moving from 1.6 to 1.8 births per woman, but well below the natural replacement level of about 2.1. Low fertility rates and an age structure already poor of young classes, makes the decline of population an extremely reliable prediction.

Ageing

Life expectancy is increasing worldwide, although at a lower rate in developed countries, where it is already high, than in developing countries. The older fraction of the population is going to increase as a direct consequence of the age structure and of declining birth rates worldwide[32]. The ratio of working age people vs retirees can be an indicator of the "strain" on welfare systems (pensions as well as health services) determined by an ageing population: in 2017 Africa has 12.9 persons aged 20 to 64 for each person aged 65 or above; Asia has 7.4, Northern America 3.8 and Europe 3.3[33].

Urbanisation

Another strong demographic trend is a worldwide tendency for population to concentrate in cities. Urbanisation started already in the late 19th century in developed countries , but accelerated since the 1950's and the trend is now indeed higher in developing countries[34]. Two thirds of the world population will live in cities by 2050, about the same level Europe had around 1975.

Urbanisation may give rise to vibrant poles of innovation due to the concentration of people, wealth, knowledge, business opportunities; but there is a risk, in particular in developing countries of creating unmanageable agglomerations (slums) where food and water provision, sanitation, basic services become scarce and degrade any existing social fabric. The fragility of urban settlements with respect to food security is the consequence of households depending primarily on markets for accessing food. As such,

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[32] Ibid.

[33] Ibid.

[34] HLPE. 2017. Nutrition and food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. Rome, FAO

they are extremely vulnerable to weaknesses of supply chains and to price volatility; food riots often erupt first in urban areas, as was the case with the Arab Spring[35].

Only New York and Tokyo had more than 10 million people in in 1970; by 2014 there were 28 cities over that size and in 2030 there might be 41. However stunning the "megalopolis" phenomenon, still only 12 % of the urban population lives in megacities; more than half in cities of less than 500.000 inhabitants[36].

The footprint of cities extends far beyond its borders. At present a mere 2-3% of the land area is urbanized but 78 per cent of carbon emissions, 60 per cent of residential water use, and 76 per cent of wood used for industrial purposes are attributed to urban areas[37].

In Europe urban sprawl is the single biggest threat represented by cities with respect to the environment. New residential, industrial and commercial settlements are taking significant shares of what is usually highly productive land, thus sealing soil, polluting air and aquifers, destroying biodiversity. So far little success was achieved by attempts aimed at halting land take, as economic interests (land value, urbanisation taxes, new business, …) have prevailed in the decisions made by local and national authorities. According to the CORINE land cover (CLC) spatial databases, artificial areas covered 4.1%, 4.3% and 4.4% of EU territory in 1990, 2000 and 2006, respectively. This corresponds to an 8.8% increase of artificial surface in the EU in 1990 – 2006 period. In the same period, population increased by only 5%[38]. In 2006 – 2012 period, the annual land take in the European countries (EEA-39) assessed using CLC data was approximately 107 000 ha/year[39].

3. Food and nutrition trends

Food Security and Nutrition (FSN) is a matter of quantity as well as quality of food. Undernourishment (failure to reach a sufficient daily intake of calories) declined for

[35] FAO, IFAD, UNICEF, WFP, WHO. 2017. The State of Food Security and Nutrition in the World 2017. Building resilience for peace and food security. Rome, FAO

[36] UN (2014), 'World Urbanization Prospects: The 2014 Revision', United Nations Department of Economic and Social Affairs, New York, NY, US

[37] United Nations Convention to Combat Desertification. 2017. The Global Land Outlook, first edition. Bonn, Germany. 337 pp.

[38] ProkopG.,JobstmannH.,SchonbauerA.2011.Report on best practices for limiting soil sealing and mitigating its effects. Publisher: European Commission, Brussels, Technical Report–2011–050, ISBN: 978-92-79-20669-6

[39] https://www.deltares.nl/app/uploads/2019/04/Soils4EU_D1.3_PolicyBrief_DEF.pdf

several years in a row, albeit at a slower pace after 2010 than in the previous 5 years, but with a resurgence in 2016, 2017 and 2018, both in absolute and relative numbers[40]. Undernourished people are estimated at 821.6 million in 2018, or 10.8% of the world population[41]. Undernourishment affects in particular Africa (with a peak of one undernourished every three persons in Eastern Africa and one in four in Middle Africa) and southern Asia. Asia, due to its high population, has the highest absolute number of undernourished: 519.6 million, against 243.2 million in Africa. Outside Asia and Africa live less than 50 million undernourished people. Prevalence of undernourishment in Europe (in 2016) is almost everywhere under 2.5%, except Bulgaria (3.6), Moldova (8.5), Slovakia (3.1), Albania (4.9), Serbia (5.6) and Northern Macedonia (3.9)[42].

Undernourishment (coupled with lack of micronutrients) is responsible for the still high numbers of stunted and wasted children. The prevalence of stunted children declined almost everywhere in the world in the last decade (except Oceania). Asia comes first in absolute numbers (87 million), followed by Africa (59 million), despite higher percent values in the African continent[43].

Excess weight (BMI[44]>25) and obesity (BMI>30) affect over 2 billion people in all continents, that is 2.5 times the number of the undernourished; obesity rates among adults increased by 1% every three years between 2004 and 2014 with no sign of levelling off and no country in the world, so far, has succeeded in reducing its rates of obese people: obesity is often referred to as a new "epidemics" bringing along a burden of related non- communicable diseases (type II diabetes, high blood pressure, cardiovascular diseases, etc.).

Excess weight in children predisposes to obesity in adult life and shows an upward trend in the world. Prevalence was 5.3% in 2005; it raised to 6.0% in 2016.

In many developing countries (but also in segments of high-income countries undernourishment and obesity coexist. In upper-middle-income and high-income countries there is a positive correlation between adult obesity and the level of food insecurity. The most likely explanation is that food-insecure households are the most

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[40] FAO, IFAD, UNICEF, WFP, WHO. 2017. The State of Food Security and Nutrition in the World 2017. Building resilience for peace and food security. Rome, FAO.

[41] http://www.fao.org/sustainable-development-goals/indicators/211/en/, accessed 12 September 2019.

[42] FAO, IFAD, UNICEF, WFP, WHO. 2017. The State of Food Security and Nutrition in the World 2017. Building resilience for peace and food security. Rome, FAO.

[43] Ibid.

[44] BMI = Body Mass Index = Weight in kg / (Height in m)^2

exposed to cheap low-quality and calorie-rich food[45]. Ultra-processed foods and sugar-rich carbonated beverages are often cheaper (on a per-calorie basis) than unprocessed food and beverages also in developing countries and contribute to an increase in overweight and obese people worldwide. The current exponential trend in overweight and obese people is expected to continue, with negative individual and public health consequences.

Fruit and vegetables consumption stays below recommended WHO levels (400 g/day) in all the world, irrespective of income level. The only exception is East Asia that slightly exceeds the threshold.

Food Loss and Waste (FLW) is estimated at 1/3 of production potential worldwide (or 1.3 billion tonnes) and is a main cause of undernourishment and malnutrition as well as of damages to the environment and climate. FLW are around 30% for cereals, 40-50% for root crops, fruits and vegetables, 20% for oil seeds, meat and dairy and 35% for fish[46].

One third more food would "feed all the world" or, if wasted production had not been produced in the first place, the impact on climate and the environment would have been considerably reduced. It is commonly reported that if FLW were a country, it would be the third country responsible for GHG emissions after China and the US, due to the contribution to emissions of the primary and processing sectors involved in food that was lost or wasted.

Despite many possibilities to tackle the FLW problem in its multiple facets, a reduction but not elimination is to be expected. Some foods have a high seasonality that provokes production in excess of demand in peak season and/or do not tolerate extended storage. This is the case with many fruits and vegetable, especially when compared with cereals. Where storage is technically feasible, lack of costly infrastructures prevents their application.

Food availability forecasts based on current trends depict a future that is quite different from SDG #2. The Global Panel on Agriculture and Food Systems for Nutrition[47] predicts the existence of 653 million people undernourished in 2030 under a BaU scenario, with no reduction in Africa (actually a slight increase in absolute numbers with respect to the 2005-2007 base years) and a significant reduction in South and East Asia, but still insufficient to eradicate hunger in that part of the world. This forecast, however,

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[45] FAO, IFAD, UNICEF, WFP, WHO. 2017. The State of Food Security and Nutrition in the World 2017. Building resilience for peace and food security. Rome, FAO.

[46] http://www.fao.org/save-food/resources/keyfindings/en/, accessed 3 October 2019.

[47] Global Panel on Agriculture and Food Systems for Nutrition. 2016. Food systems and diets: Facing the challenges of the 21st century. London, UK.

is based on the undernourishment statistics of the year 2015 and does not take into account the increases occurred in 2016, 2017 and 2018. Therefore, the situation could be even worse.

Diets and nutrition. There is no universally agreed definition of what indicators can be used to define the quality of diets. However it is generally recognised that diverse diets that reach a calorie intake matching but not exceeding the energy consumption and provides quality nutrients usually found in fruit, vegetables (most vitamins and minerals), meat (iron, calcium, high quality proteins, B-group vitamins) and fish (vitamins, proteins, omega-3 fatty acids, iron, zinc, iodine).

Protein needs are a hotly debated topic that involves great economic interests (mainly of the livestock sector and animal source food industry) and individual lifestyles. Average requirements of protein (that ensure the maintenance of the body's nitrogen balance) are estimated at 0.66g/kg of body weight per day; an extra amount of protein is added to allow for variability of needs among different individuals bringing the recommended amount of protein daily intake to 0.80-0.83 g/kg of body weight for both men and women with modest levels of physical activity[48]. Higher amounts are needed for infants, children, lactating women, the elderly and with increased physical activity[49].

The common feature of diets in all continents is a lack of intake of fruit and vegetables and in particular of plant sources of proteins (legumes and nuts). Of the around seven thousand edible plant species that have been used and cultivated at some point in time, only six crops dominate today's agriculture: maize, rice, wheat, sugar cane, soybeans and oil palm with a progressive standardisation of food supplies worldwide. Of those six, maize, wheat and rice represent over half of the global food and feed supply from vegetal products[50].

EU-15 had, in 2013, the highest per-capita consumption of fruit and the lowest of vegetables. The different behaviour of Europeans towards fruits and vegetables is not easily explained, as both food classes share, more or less, the same problems as far as price, seasonality and shelf life are concerned. Both are at the same time nutritious

[48] WHO/ FAO/ UNU (2007) Protein and amino acid requirements in human nutrition; Report of a joint FAO/WHO/UNU Expert Consultation Technical Report Series No 935. WHO, Geneva

[49] As a mere crude example, the daily recommended protein intake for a 70 kg man with moderate physical activity would be 56 g of proteins that corresponds to around 180 of meat or 280 g of fish or 560 g of plants (notably pulses, cereals, seeds and nuts); with a mix representing the best option. Should meat contribute to half the recommended daily intake, that would correspond to around 33 kg per year: the current average European consumption is 2.4 times that figure and the American 3.3 times, whereas Asia and Africa stay below. In Asia, however, the Chinese have reached almost 60 kg per year and Indians, despite recent economic growth, stay at a mere 4 kg per year.

[50] HLPE. 2017. Nutrition and food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. Rome, FAO.

(vitamins, fibres and microelements) and frequent vectors of agents of food-borne diseases, requiring a healthy and controlled chain from the field to the household. This is also seen at a global level. Whereas fruit consumption increases with income, vegetables decrease[51].

4. Primary production systems and climate change

Agriculture

Agriculture is both affected by, and has an impact on, climate change, both positive and negative[52]. At a global scale, climate change is expected to hit the hardest at low latitudes. Agricultural production in Africa and Asia, i.e. the regions where most of the population growth will occur and where poverty is prevalent, will be the most severely affected[53]. Southern Europe will be negatively affected, whereas increases in productivity are expected at higher latitudes.

By 2050, climate change could reduce pro capita food availability by 3.2% and specifically by 4.0% in fruit and vegetables and 0.7% in red meat. Twice as many deaths would be associated with reduced fruit and vegetable consumption than with undernourishment[54].

Agriculture is also a major cause of climate change. It is estimated that around 25% of all GHG emissions into the atmosphere are caused directly by crop and animal production (especially methane by ruminants) and forestry (mainly through deforestation). A further 2% is attributable to agriculture but is usually accounted in

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[51] Ibid.

[52] Hart K., Allen B., Keenleyside C., Nanni S., Maréchal A., Paquel K., Nesbit M., Ziemann J. (Institute for European Environmental Policy). 2017. Research for Agri Committee – The Consequences of Climate Change for EU Agriculture. Follow-up to the COP21 – UN Paris Climate Change Conference. European Parliament – Directorate General for Internal Policies, Policy Department B: Structural and Cohesion Policies – Agriculture and Rural Development (ISBN 978-92-846-0646-7 doi:10.2861/295025. Available at: http://www.europarl.europa.eu/supporting-analyses.

[53] Brown ME, Antle JM, Backlund P, Carr ER, Easterling WE, Walsh MK, Ammann C., Attavanich W, Barrett CB, Bellemare MF, Dancheck V, Funk C, Grace K, Ingram JSI, Jiang H, Maletta H, Mata T, Murray A, Ngugi M, Ojima D, O'Neill B, Tebaldi C. 2015. Climate Change, Global Food Security, and the U.S. Food System. 146 pages. Online at:

http://www.usda.gov/oce/climate_change/FoodSecurity2015Assessment/FullAssessment.pdf.

[54] Springmann M, Mason-D'Croz D, Robinson S, Garnett T, Godfray HC, Gollin D, Rayner M, Ballon P, Scarborough P. 2016. Global and regional health effects of future food production under climate change: a modelling study. Lancet 387(10031), 1937-1946.

other sectors (industry, energy) and is due to the productions of fertilisers, herbicides and pesticides and to the energy employed for agricultural operations[55].

Agriculture is a sizeable GHG source in the EU as well, with enteric fermentation by ruminants in the front line, although with variations according to type and intensity of livestock management. Grazing land management, however, is at present a net CO_2 sink and is likely to remain a sink in the future[56]. The level of non-CO_2 (CH_4, N_2O) agriculture emissions declined in Europe from 1990 to 2014 (-21%). This is largely due to a decrease in livestock numbers, but also to improvements in livestock and farm management practices.

CAP environmental measures in the Rural Develoment Programme pillar have contributed to an improvement of the position of agriculture vis-à-vis climate change, albeit with considerable variations between MS and a "minimalist" approach in many countries and regions. The effort to effectively target agriculture in the context of climate change mitigation in the EU has not been really strong for a variety of reasons, including reticence of many MS to engage with the farmers' organisation on a divisive subject. Therefore, Europe has not developed explicit target for the reduction of GHG from agriculture, nor have Member States.

Efforts of the agricultural sector towards Climate Change mitigation are a sensitive issue also at the global scale, despite the general agreement on principles reached in Paris at COP21. A reason for the lack of agreement is the different attitude of developed and developing countries towards agriculture and its role on food security and rural livelihood. To put it bluntly, agriculture is a business in developed countries, a matter of survival in many developing countries.

Improving efficiency in the use of resources is crucial to sustainable agriculture (the principle of "sustainable intensification"), but a word of caution is needed: increased efficiency makes the use of the resource economically more convenient, which leads to an increase of use (the so called "Jevon's paradox" or "rebound effect").

Anthropogenic N sources now contribute more N to the Earth system than all natural terrestrial processes combined. The environmental costs of N losses in Europe have been estimated to outweigh the entire direct economic benefits of N in agriculture[57];

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[55] FAO. 2014. Building a common vision for sustainable food and agriculture. Principles and approaches. Rome

[56] EEA – European Environment Agency. 2017. Total greenhouse gas emission trends and projections - Indicator Assessment. 24 Nov 2017. https://www.eea.europa.eu/data-and-maps/indicators/greenhouse-gas-emission-trends-6/assessment-1 (accessed 17 October 2018).

[57] Sutton, M.A., Oenema, O., Erisman, J.W., Leip, A., van Grinsven, H. & Winiwarter, W. 2011. Too much of a good thing. Nature, 472(7342): 159–161. http://dx.doi.org/10.1038/472159aet al., 2011.

approximately half of the N applied to croplands is incorporated into plant biomass, while the rest is lost through leaching (16%), soil erosion (15%), and gaseous emission (14%)[58]. Phosphorus in Agriculture is responsible for >90% of P emissions.

Agriculture is responsible for 70% of all freshwater withdrawals (44% in OECD Countries) and withdrawals are growing at a rate that is twice as high as that of population[59]. Local variations are of paramount importance, due to climate (heat/rain) and limited transferability of water resources.

Species extinction, functional biodiversity loss, decline of pollinators, genetic uniformity, fragmented ecosystems are relevant threats to biosphere integrity. An estimated 75% of crop diversity has been already lost and up to 30% of domesticated animal breeds threatened of extinctions or already extinct[60]. "Industrial" agricultural models, based on specialisation, uniformity and economies of scale are major drivers of the loss of agro-biodiversity, as well as of livestock diversity. Alternative models (organic, regenerative, agroecology, biodynamic) would enhance both agro-biodiversity (through broader use of local varieties and breeds) and biodiversity in general (multiple crops, agroforestry, buffer zones, livestock integrated in cropping systems, etc.) but still face difficulties at moving from niches (albeit often economically successful) to mainstream.

Livestock

Livestock is the single sector with the highest fraction of land use: pastures, grasslands and feed crops occupy 40 percent of the Earth (except Greenland and Antarctica). In advanced economies, over 50% of the arable land is used to grow animal feed. In Europe an estimated 72% of agricultural surface dedicated to animal feeding; half of which is grassland (for ruminants) and the rest agricultural crops[61]; 58% of cereals and 67% of oil & protein crops raised in Europe are for animal use[62]. The growing dependence of many livestock systems on externally sourced feed (especially pigs,

58 Mosier, A.; Kroeze, C.; Nevison, C.; Oenema, O.; Seitzinger, S.; van Cleemput, O. Closing the global N_2O budget: Nitrous oxide emissions through the agricultural nitrogen cycle. Nutr. Cycl. Agroecosyst. 1998, 52, 225–248.

59 FAO. 2014. Building a common vision for sustainable food and agriculture. Principles and approaches. Rome

60 Ibid.

61 Buckwell, A. and Nadeu, E. 2018. What is the Safe Operating Space for EU Livestock? RISE Foundation, Brussels.

62 Poux X, Aubert P-M. 2018. Une Europe agroecologique en 2050: une agriculture multifonctionnelle pour une alimentation saine. Enseignements d'une modelisation du systeme alimentaire europeen. Iddri-AScA, Study N°09/18, Paris, France, 78 pp.

poultry and dairy) has pushed the level of production and trade of grains on a faster track than the growth of animal sourced products themselves[63]. Europe is almost self-sufficient in the production of grains used for feed, but largely dependent on imports for protein crops: almost totally for soybean (5% self sufficient) and largely, if total proteins are concerned (38% self sufficient).

The demand for meat (but also for other ASF products) is growing steadily, twice as fast as population (from around 85 million tonnes in 1965 to 335 in 2018[64] for meat alone). If the current trends continue, the global demand for ASF is anticipated to grow by 73 percent for meat and eggs and 58 in dairy products by the year 2050 with respect to 2011[65]. Europe is both an exporter and importer of meat and other ASF. It imports beef and poultry (main source is Brazil), sheep (New Zealand) and exports pig (mainly to China), poultry and veal. Despite higher production costs in Europe than the rest of the world, Europe is a net exporter (with a surplus of about 10%), mainly due to the high quality of its products and the high safety standards it guarantees[66]. Exports are expected to increase further as a consequence of diminishing domestic consumption and increasing international demand.

Livestock production reacted to increasing demand essentially by shifting from an extensive "backyard", mainly subsistence form to more intensive types, with higher animal concentrations, higher specialisation, higher investments, all leading to economies of scale and market orientation. This intensification and specialisation are particularly evident with pigs and poultry, mainly due to their high feed conversion efficiency and fast reproduction rates. The concentration of specialised systems that rely entirely on externally sourced feed often leads to an impoverishment of soils where intensive crops are raised and an excess of nutrients in the areas where animals are kept, leading to soil pollution and water eutrophication[67]. Concerns for the impact of the

[63] HLPE. 2016. Sustainable agricultural development for food security and nutrition: what roles for livestock? A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome.

[64] https://www.globalagriculture.org/whats-new/news/en/33468.html, accessed 3 October 2019.

[65] Committee on Considerations for the Future of Animal Science Research. 2015. Critical Role of Animal Science Research in Food Security and Sustainability. The National Academic Press. Washington, D.C.

[66] Buckwell, A. and Nadeu, E. 2018. What is the Safe Operating Space for EU Livestock? RISE Foundation, Brussels.

[67] Ibid.

livestock sector on the environment (especially N and P pollution[68]) and on its contribution to climate change are growing.

According to the IPCC[69], Agriculture, Forestry and Other Land Uses (AFOLU) are responsible for around 25% of all anthropogenic GHG emissions. Between 50 and 60% of that, or around 14,5% of all anthropogenic emissions, are caused by the livestock sector, including emissions by the animals themselves (especially CH_4 by ruminants), emissions due to the production of feed (CO_2 and N_2O) and emissions due to excreta (CH_4 and N_2O). A minor share of livestock-connected emissions is represented by energy[70]. Europe, as a major importer of soybean is indirectly contributing to considerable amounts of GHG emissions from land use changes outside its borders[71]. It is estimated that 35 million hectares of soybean are cultivated outside Europe to satisfy the European demand[72].

If we count GHG emissions by species (or group of species) cattle, including beef and dairy, takes the lion's share (4,6 billion tonnes CO_2 eq.), dwarfing all the rest (pigs 0,82; chicken 0,79). Also in terms of "emission intensity" of the unit of protein cattle is highest, pigs and chicken lowest; and meat production is more CO_2-eq intensive than either milk or eggs[73].

In beef and dairy systems the most efficient (lowest CO_2-eq intensity) are the intensive ones[74]; this is mainly due to the fact that enteric fermentation leading to CH_4 emissions is highest with coarse, less digestible feed that require more bacterial activity to decompose into digestible components, but also to higher losses, lower weight and older

[68] The estimate of manure production in the EU27 is around 1.4 billion tonnes (https://ec.europa.eu/environment/air/pdf/Final%20Report.pdf)

[69] IPCC. 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)). IPCC, Geneva, Switzerland, 151 pp.

[70] http://www.fao.org/gleam/results/en/, accessed 3 October 2019.

[71] Buckwell, A. and Nadeu, E. 2018. What is the Safe Operating Space for EU Livestock? RISE Foundation, Brussels.

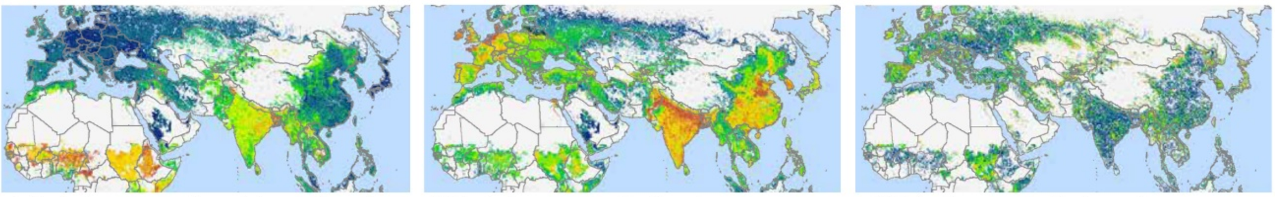
[72] Poux X, Aubert P-M. 2018. Une Europe agroecologique en 2050: une agriculture multifonctionnelle pour une alimentation saine. Enseignements d'une modelisation du systeme alimentaire europeen. Iddri-AScA, Study N°09/18, Paris, France, 78 pp.

[73] http://www.fao.org/gleam/results/en/, accessed 3 October 2019.

[74] Committee on Considerations for the Future of Animal Science Research. 2015. Critical Role of Animal Science Research in Food Security and Sustainability. The National Academic Press. Washington, D.C.

age at slaughter in extensive systems as well as more efficient manure management of specialised systems[75]. Indeed, the greatest contribution towards a reduction of global emissions would come from improvements of efficiency in developing countries rather than further efforts on already well performing management systems[76].

A visual representation of different criteria in the comparison of the contribution of livestock systems to GHG emissions is represented in the following figure where emissions are reported per unit protein produced (a), per unit of land (b) and per unit of people (c).



a) Emissions per unit protein produced b) Emissions per unit of land c) Emissions per unit of people

A broad range of mitigation options exist for the different sectors and regions, according to the species, the type of livestock system, the availability (technical, economical and legal) of solutions.

Animal health is fundamental per se, as a means to protect capital, incomes and trade, but also as a way to reduce impact on climate (loss of production and waste of the resources employed) and as a way to preserve human health, due to the many zoonoses that are shared by animals and humans. The burden of diseases is estimated at 6-15% of the total value of the industry[77], with cattle more affected than other animals, young animals more than adults and pastoral systems more than mixed or intensive ones.

One major concern is the excessive use and often erroneous use of antibiotics that leads to a loss of efficacy in the treatment of human diseases. Although many restrictions have been imposed by regulatory agencies in many parts of the world, AMR (Anti-Microbial Resistance) remains as a top priority in animal science. Most developed countries have posed restrictions on the use of antibiotics, especially as growth promoters, but many

[75] Gerber PJ, Steinfeld H, Henderson B, Mottet A, Opio C, Dijkman J, Falcucci A, Tempio G. 2013. Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities. Food and Agriculture Organization of the United Nations (FAO), Rome.

[76] FAO and GDP. 2018. Climate change and the global dairy cattle sector – The role of the dairy sector in a low-carbon future. Rome. 36 pp. Licence: CC BY-NC-SA- 3.0 IGO.

[77] HLPE. 2016. Sustainable agricultural development for food security and nutrition: what roles for livestock? A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome.

countries in the developing world are still massive users; it has been estimated that China alone consumes around one third of all the antibiotics produced in the world[78]

Fisheries and aquaculture

Over the last fifty years, the annual growth of fish (crustaceans, molluscs and other non mammal aquatic animals) consumption (3.2%) was higher than the rate of growth of the world population (1.6%) and of meat consumption (2.8%)[79]. Global captures stayed more or less stable since the mid-1990s (79.3 million tonnes in 2016) and aquaculture (inland and marine) filled the gap of increased consumption. Captures prevail in seas and oceans and aquaculture production inland. Average fish consumption per capita was 20.3 kg in 2016[80]. China takes by far the largest share (almost 20%) of the total captured fish. Only five European countries are in the group of the first 25 of the world (Norway, Iceland, Spain, UK and Denmark).

Between 80 and 90% of fish production is for human consumption. The second largest destination is as feed: primarily for farmed fish, but also for terrestrial animals (pigs and poultry), in the form of fishmeal and fish oil[81].

Asia has the leadership in inland captures (two thirds of the world total and China, again, the leader), followed by Africa (25%). Europe represents a mere 3.8% globally, but inland captures are a significant component of fisheries in Finland and, to a lesser extent, in Sweden[82].

The amount of fish produced annually (marine and inland together) equals captures and the trend is still pointing towards a further expansion of production, although at a slower pace than in the first decade of this century. If we restrict consideration to human consumption, aquaculture has surpassed captures in 2013 and still holds the leadership.

Aquaculture still represents a minor share of fish consumed in most continents (12% to 18% in Europe, the Americas, Africa and Oceania; 40% in Asia excluding China), but China, where 73.7% of fish comes from aquaculture (in 2016), by the sheer weight of

[78] Ibid.

[79] FAO. 2018. The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. Rome.

[80] Ibid.

[81] HLPE. 2014. Sustainable fisheries and aquaculture for food security and nutrition. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome 2014.

[82] FAO. 2018. The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. Rome.

population numbers, brings the world average to around 45%[83]. In the European Union, the leading position (by volume of production) is taken by Spain, followed by UK, France, Italy and Greece[84]. If the ranking is done on value, the UK comes first, thanks mainly a lucrative salmon farming sector. Norway, however, surpasses all EU countries, both in volume and in value.

Aquaculture is done both inland and in marine environment with an intermediate sector of coastal aquaculture (e.g. in lagoons) where freshwater and salt water often blend. Whereas inland aquaculture is mainly dedicated to the production of finfish and crustaceans, molluscs represent the most significant share of production from mariculture and coastal aquaculture (58%).

Feed is especially important for carnivorous species and it was traditionally derived from small pelagic fish, discarded fish or fish processing by-products (mainly fishmeal and fish oil). Decreasing by-catches through improved fishing techniques, the use of a higher part of captured fish as human food, as well as environmental concerns have pushed the feed industry towards a larger share of vegetables in industrial feed, also for typical carnivores such as salmons.

Seaweeds represent another very important share of aquaculture production (30 M tonnes in 2016) whose destinations are human consumption, the food industry (as additives or ingredients) and the feed industry. The two main producers are China and Indonesia, with 47.9% and 38.7% of the world production, respectively.

The development of aquaculture is not free from conflicts at the local level: a) competition between different forms of aquaculture; b) competition with fisheries (inland and marine); c) competition with other activities, including tourism and agriculture[85].

The state of fish resources is far from rosy: the share of overfished stocks is growing (33% in 2015) and underfished stocks declining rapidly (7%): the rest is harvested at the maximum sustainable level. The situation is particularly critical in the Mediterranean and Black Sea, where the overfished stocks are in excess of 60%.

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[83] Ibid.

[84] Ministerial Group for Sustainable Aquaculture. 2014. Aquaculture Science & Research Strategy. 85 pp.

[85] HLPE. 2014. Sustainable fisheries and aquaculture for food security and nutrition. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome 2014.

Fish is not on top of food consumption, providing, on average, only 2% of calories and 15% of proteins from animals[86] but it is a very important component of diets both in low-income countries and in advanced economies for its nutritional value. For 3.2 billion people, most of which belong to Developing Countries, fish is the source of more than 20% (in some cases more than 50%) of animal proteins in the diet.

As for livestock, a growing concern has been the rapid increase in therapeutic and prophylactic usage of antibiotics/antimicrobial agents in aquaculture operations. Antibiotics use is now the target of restrictions in many countries. Indeed, some advanced fish farming systems, such as the Norwegian salmon farming industry, have dramatically reduced the use of antibiotics already in the early 1990s, mainly by improved management techniques[87].

China and the USA are respectively the largest exporter and the largest importer of fish and both rank high also in the other group. The international trade balance shows a large deficit for the USA (imports about twice the exports in value), a large surplus for China (the other way around). Europe has a relatively small deficit, although this masks quite different situations among the different countries[88]. The European Union is the largest single market for imports, followed by the USA and Japan. Europe depends on imports for around 65% of its consumption[89]. Among European countries, the position of Norway is remarkable, ranking second in the world thanks both to a large and modern fishing fleet and to an important aquaculture sector, based especially on high value salmonids.

The effects of climate change on aquatic environments, marine and inland, are relatively easy to predict. Water bodies maintain a physical/chemical relationship with the atmosphere that keep carbonic acid (H_2CO_3) in water in balance with CO_2 in the atmosphere. The more carbon dioxide in the atmosphere, the higher the concentration of carbonic acid in water. From the point of view of the mitigation of the greenhouse effect this may sound positive, as a significant share of CO_2 emission are absorbed by the oceans, but increasing acidity puts living organisms building on carbonate salts at serious risk. This includes coral colonies and shell molluscs.

[86] Scientific Advice Mechanism. 2017. Food from the Oceans - How can more food and biomass be obtained from the oceans in a way that does not deprive future generations of their benefits? High Level Group of Scientific Advisors. Scientific Opinion No. 3/2017. EC/RTD.01 – SAM, Brussels

[87] OECD. 2015. Green Growth in Fisheries and Aquaculture. OECD Green Growth Studies. OECD Publishing. Paris. http://dx.doi.org/10.1787/9789264232143-en.

[88] FAO. 2018. The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. Rome.

[89] SCAR-Fish. 2013. Science in support of the European fisheries and aquaculture policy. Brussels

The increase of water temperature pushes fish populations towards the poles and to deeper waters, potentially depleting fishing areas that are essential for food supply in tropical and subtropical areas.

More research on species-specific responses to multiple stressors are recommended[90] by SAM-HLG.

The impact of aquaculture on climate change through emissions is considerably lower than that of terrestrial animals. The main differences lies in the conversion efficiency (weight growth per unit weight of feed) that is considerably higher for fish than beef and pork; the main advantages of fish is that they are cold-blooded and they float, thus spending less energy on temperature maintenance and movement[91]. Nitrogen and Phosphorus emissions are also much lower than is the case for terrestrial animals.

Future prospects of aquaculture development are, in particular: a) integrated multitrophic systems (fish+crustaceans+molluscs+algae), b) offshore (high sea) mariculture and c) on land confined closed systems.

Forests

Forests represent the second largest type of use of land: 3.999 M ha or 30.6% of land (excluding Antarctica and Greenland)[92]. The first is agriculture. The majority of forests (more than 90% of surface) are classified as "naturally regenerated", including both "primary" forests and "secondary" forests depending on the degree of human influence.

The following table reports the surface of natural and planted forests in the world in 2015 (million ha)[93].

Continent	Natural Forests	Planted Forests
Africa	600	16
Asia	462	129
Europe	929	83
N. & C.America	707	43
S.America	817	15
Oceania	169	4,4

[90] Scientific Advice Mechanism. 2017. Food from the Oceans - How can more food and biomass be obtained from the oceans in a way that does not deprive future generations of their benefits? High Level Group of Scientific Advisors. Scientific Opinion No. 3/2017. EC/RTD.01 – SAM, Brussels

[91] HLPE. 2014. Sustainable fisheries and aquaculture for food security and nutrition. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome 2014.

[92] FAO. 2016. Global Forest Resources Assessment 2015 - How are the world's forests changing? Second edition. FAO. Rome

[93] Ibid.

The area of planted forests is increasing in all continents at an annual expansion rate between 1.11% (Europe) and 2.55% (North and Central America). Despite the low share of land (around 7%), forest plantations provide around 45% of roundwood for industrial uses[94]. There is a broadly shared conviction that plantations contribute to decrease "pressure" on forests for the provision of industrial roundwood; however, dissenting voices are also heard, claiming that the high profitability of forest plantations is a driver of further de-forestation.

The global forest area decreased steadily since 1990, although at a slower annual rate in the last decade than in previous years. The global figures[95], however, mask a significant diversity across the world with ten countries (from S.America, tropical Asia and Africa) leading the loss of forest …

Country	Net forest loss 2010-2015(thousand hectares)
Brazil	984
Indonesia	684
Myanmar	546
Nigeria	410
Tanzania	372
Paraguay	325
Zimbabwe	312
D.R of the Congo	311
Argentina	297
Bolivia	289

… and ten countries (also from S.America, Asia and Africa, but also N.America and Europe) expressing the highest net gains of forest area, with China by far the leader of the group.

Country	Net forest gain 2010-2015 (thousand hectares)
China	1542
Australia	308
Chile	301
United States of America	275
Philippines	240
Gabon	200
Laos	189
India	178
Viet Nam	129
France	113

Forests are expanding in the temperate regions of the world and decreasing in the tropical regions, with boreal forests (mainly N.Europe and Canada) and subtropical

[94] HLPE. 2017. Sustainable forestry for food security and nutrition. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome

[95] FAO. 2016. Global Forest Resources Assessment 2015 - How are the world's forests changing? Second edition. FAO. Rome.

forests almost stable over the same period. Net forest loss is inversely correlated with income (i.e. the poorer the country, the highest the loss).

Although with remarkable exceptions (e.g. Laos), forest loss is associated with poverty, hunger, population growth and the related pressure on agricultural expansion. Indeed, conversion to agriculture is the first global cause of forest loss and, indirectly, the main reason for the contribution of agriculture to net GHG emissions leading to climate change. On a global scale, deforestation, forest degradation, fires and other damages contribute to around 10% of carbon emissions but the sink effect (growth minus emissions from losses) offsets around 30% of the total emissions with temperate and boreal forests of the Northern hemisphere playing the major role[96].

The European forest area is clearly dominated by the Russian Federation, with almost 815 Million hectares (of course on a huge territory). Excluding the Russian Federation, European forests cover an area of 215 Mha, or 33% of its territory[97] (Forest Europe, 2015), with Sweden (28.1 Mha), Finland (22.2), Spain (18.4) and France (17,0) in the lead. Finland (first) and Sweden (second) also display the highest proportion of forest area with respect to total country surface. European forests are expanding in all countries with very few exceptions (Portugal, Estonia, Albania).

Forests, probably even more than agriculture, display a broad range of functions and services, typically simultaneously in the same area, that depend on the local climatic, ecological, demographic/ethnographic, social, and economic situation.

Forestry and logging (not considering downstream industrial transformation) contribute little to GDP; the higher the national income, the lower its share. Employment in forestry and logging parallels GDP: lowest in high income countries (largely due to mechanisation), higher in lower income countries: the perspectives are of further decline in developed countries.

In Europe the wood production component of forest economies amounts to around 135 G€ of annual gross value added[98], with the pulp and paper sector representing about 40% of that amount and the solid wood sector the other 60%. The contribution to GDP is on average low: about 1%, with a downward trend[99], a fact that often makes the forest

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[96] UNECE/FAO. 2015. Forests in the ECE Region - Trends and Challenges in Achieving the Global Objectives on Forests. ECE/TIM/SP/37. 212 pp.

[97] Forest Europe. 2015. State of Europe's Forests 2015. Ministerial Conference on the Protection of Forests in Europe. Madrid

[98] EEA. 2016. European forest ecosystems — State and trends. European Environment Agency. 123 pp.

[99] Forest Europe. 2015. State of Europe's Forests 2015. Ministerial Conference on the Protection of Forests in Europe. Madrid

sector to be considered marginal in most economies; notable exceptions are Latvia (6.5%), Finland and Estonia (4.3%), Sweden (2.9%) and Slovakia (2.4%)[100]. However, when the downstream industrial sectors depending on wood source material are considered, the figures rise considerably. The same can be said of employment, where forestry accounts for around one sixth of the whole forest sector.

The main trends observed in the international market of forest products is of an increase of sawn wood and panels vs roundwood, a decrease of the printing paper sector offset by an increase of cardboard for packaging. The market of wood chips for the production of energy is still volatile, as no clear position is so far broadly accepted on the role of forests as sources of renewable feedstock for biomass power plants[101].

The amount of wood harvested expressed as a ratio to annual increment is on average around 60% in Europe[102]. This shows that, in general, European forests are not subject to an impoverishment of its living biomass resources, but, rather, that they are progressively accumulating wood. However, this is not in itself the ultimate index of a good forest management and it represents an average value: areas of unsustainable harvesting may exist, along with areas harvested well below their potential production.

It is estimated that wood represents around 6% of total energy supply (or 40% of all renewable energy), with a share of up to 27% in Africa[103]. Wood for heating and, to a lesser extent, for cooking, is also important in high income countries: most of coppice forests of central and southern Europe produce fuelwood for private heating. Europe has seen a slow but steady increase in the production of fuelwood since 1990 and a dramatic increase of imports that have exceeded internal production since 2011[104].

Forests also provide food. In tropical/subtropical regions, forest is often a regular or occasional source of vegetable and animal food, integrating and improving the quality of diets. In high income countries, such as in Europe, non-wood forest products (NWFP) are locally important for economic, cultural and recreational purposes. Hunting, mainly

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[100] UNECE/FAO. 2015. Forests in the ECE Region - Trends and Challenges in Achieving the Global Objectives on Forests. ECE/TIM/SP/37. 212 pp.

[101] Viitanen J and Mutanen A Ed. 2017. Finnish Forest Sector Economic Outlook 2017–2018. Luke (Natural Resources Institute). Natural resources and bioeconomy studies 71/2017. Helsinki

[102] UNECE/FAO. 2015. Forests in the ECE Region - Trends and Challenges in Achieving the Global Objectives on Forests. ECE/TIM/SP/37. 212 pp.

[103] FAO. 2016. Global Forest Resources Assessment 2015 - How are the world's forests changing? Second edition. FAO. Rome

[104] EEA. 2016. European forest ecosystems — State and trends. European Environment Agency. 123 pp.

a recreational activity in Europe, is also a source of income to forest owners and public administration in the form of licences.

Ecosystem services (water regulation, erosion control, soil protection, nutrient circulation, biodiversity conservation, …) are all actions performed by forests in various degrees. The possible "payment for ecosystem services" (PES) is a recurrent subject of debate. There is a need for research that enable on the one hand an evaluation of the economic value of ecosystem services and on the other hand the costs of different management decisions[105].

Climate change is a central issue in the forest resources debate, as forests can be a major sink or source of CO_2, depending on management. The subject of carbon sequestration is open to debate. A typically mature unmanaged forest is most likely neutral, with a balance of carbon stocked in growing trees and lost as decaying biomass. Harvesting of logs (especially from plantations) has the potential to return the carbon to the atmosphere, albeit with a delay depending on use. In construction, wood can often replace concrete and steel, both energy intensive materials but the substitution effect is difficult to quantify[106].

Wood has attracted a great interest in the context of a circular approach to manufacturing, as it may keep most of its structural properties through a long chain of recycling. In line with a "cascading" principle, the first use of wood would be in the residential housing products that have typically a long life; subsequent steps could include reconstituted panels, then recovered and recycled to produce the interior core of industrial furniture, then pallets or other products with a short life. The final stage could be the direct (burning) or indirect (through pellets) transformation into energy. This long cycle would extend the duration of carbon storage (contributing to climate change mitigation) and act as a multiplier of industrial jobs, while decreasing the cost of feedstock for the downstream sectors[107]. Research initiatives are expected to broaden the range of possible pathways considerably.

More delicate is the issue of first-generation energy production by burning woody biomass; a zero-balance between carbon captured by growing trees and carbon released can never be reached due to energy employed or lost in the conversion; however, a "substitution" concept can be invoked, meaning that the alternative "fossil" energy would be significantly more negative in terms of net CO_2 emissions. The expectations of increasing extraction of biomass as renewable sources of energy and materials face an

[105] Ibid.

[106] UNECE/FAO. 2015. Forests in the ECE Region - Trends and Challenges in Achieving the Global Objectives on Forests. ECE/TIM/SP/37. 212 pp.

[107] EEA. 2016. European forest ecosystems — State and trends. European Environment Agency. 123 pp.

uncertainty on the "carrying capacity" of forest ecosystems, that is, the amount that can be safely withdrawn without compromising soil fertility and regeneration capacity. This area should be further investigated by research in different environmental contexts.

Carbon stocks in forest follow the dynamics of forest expansion/reduction in the different areas of the world. The global trend is downward. The situation, however, is very diverse in the different regions, with some contributing significantly to an increase of carbon stocks (Europe leading the way) and others to its depletions (South America and South and Southeast Asia *in primis*). The highest contribution of forests to the mitigation of climate change would come from a limitation of deforestation, more than from any other initiative aimed at increasing carbon storage.

The preservation of biodiversity of forests (by far the land environments richest in species of all phyla when compared to agricultural ecosystems of the same climatic regions) is satisfactory throughout Europe: in 2015 more than 30 Mha of forests were protected with the main objective to conserve biodiversity (and the trend is still pointing upwards); more than half a million ha of forests were managed primarily for genetic conservation and over a million ha for seed production[108].

The effect of climate change on forest ecosystems has been a matter of speculation rather than of conclusive evidence. A possible benefit to biomass production from increased CO_2 concentration and extended growing seasons is possible, especially at Northern latitudes. On the other hand, shifting climatic zones towards higher latitudes and altitudes threaten the ability of forest ecosystems to follow the trend, as the colonisation process of long living organisms might be slower than the climatic shift. The main threats from climate change, however, are higher frequencies of extreme climatic events and attacks from old and new pests[109].

[108] Forest Europe. 2015. State of Europe's Forests 2015. Ministerial Conference on the Protection of Forests in Europe. Madrid

[109] EEA. 2016. European forest ecosystems — State and trends. European Environment Agency. 123 pp.

FOOD PROCESSING TECHNOLOGIES

Lilia Ahrnè, 5th SCAR Foresight Exercise expert

1. **Analysis of the main emerging issues in the domain covered by the theme**

a.1 Main facts, figures and trends

Foods are complex biological structures well developed by nature. Few of them are consumed as nature serve them, like an apple, but a large majority needs to be transformed to be edible, safe, nutritious or attractive for consumption, like a potato, milk or cereals. Furthermore, many foods are composed of a variety of ingredients providing diversity, taste experiences and attractiveness, e.g. a soup, a biscuit or a sauce. The development of cities and increased distance between food production and consumption creates the need to process fresh foods to make them safe and conveniently available for consumption. This means, to extend their shelf-life assuring safety during distribution and commercialisation, while keeping sensorial and nutritional quality.

In this context, food processing started million years ago and fire cooking, drying and fermentation broaden the access to nutrients. It is well known that food processing can lead to improvements in, or damage to, the nutritional value of foods and therefore needs to be carefully selected and designed. For example, thermal processing of plant foods required to improve safety causes unavoidable damage to the plant cells, leading to leaching of essential vitamins and minerals, but also makes available many nutrients (e.g. lycopene from cooked tomato) or eradicated compounds of concern (e.g lectins in beans and grains).

Nowadays, foods are formulated and processed by a large variety of processes and ingredients. According to EU Food and drink industry, Data and Trends 2019, the EU food and drink industry employs 4.72 million people, generates a turnover of €1.2 trillion and €236 billion in value added, making it the largest manufacturing industry in the EU. In half of the EU's 28 Member States, the food and drink industry is the biggest manufacturing employer (figure 1) [1]. About ¾ of EU food and drink exports are destined for the Single Market. At the same time, the EU is the largest exporter of food and drink products in the world with extra-EU exports reaching €110 billion and a trade surplus of €36 billion.

Furthermore, processing of food is supported by a global food processing and handling equipment sector of USD 137.2 billion in 2019 that is projected to reach USD 196.6 billion by 2025 [2]. Advancements and innovation in processing technologies, and continuous growth in the demand for processed food as people move to urban areas are some factors that are expected to support the growth of the food & beverage processing equipment market.

More over, Food Packaging and Food transport are also two sectors of large importance in this context, as most food needs to be packed and transported before reaching the consumers. The Europe Food Packaging market size was estimated at US $3,718.2 million in 2020 and is expected to reach $4,890.6 million by 2025 [3], while the global food logistics market reached a value of US$ 100 Billion in 2018 and expected to reach around US$ 162 Billion by 2024 [4].

The national picture

A key industry in the economies of the EU Member States

#1 employer

The food and drink industry is the biggest manufacturing employer in half of the Member States

67%

Share of turnover of the EU's 5 largest food and drink producers

- The food and drink industry ranks among the top three manufacturing industries in terms of turnover and employment in most Member States.
- France, Germany, Italy, Spain and the UK are the largest EU food and drink producers by turnover.

Food and drink industry data by Member State[1] (2017)

	Employment ranking in manufacturing	Turnover (€ billion)	Value added (€ billion)	Number of employees (1,000)	Number of companies
Austria	1	23.7	6.1	85.3	3,977
Belgium	1	51.8	8.2	92.7	4,284
Bulgaria[2]	2	5.9	1.1	95.5	6,262
Croatia	1	5.5	1.3	60.6	3,248
Cyprus	1	1.6	0.4	12.7	925
Czechia	4	14.6	3.2	112.8	10,415
Denmark	2	25.1	4.2	53.7	1,635
Estonia	2	1.9	0.4	14.9	737
Finland	4	10.8	2.5	38.0	1,771
France	1	228.1	46.5	703.6	54,643
Germany	2	203.9	42.4	885.1	23,531
Greece[3]	1	14.6	3.0	114.6	17,123
Hungary	1	12.4	2.3	105.2	6,778
Ireland[4]	1	24.6	-	47.4	1,731
Italy	2	138.6	27.0	448.7	56,400
Latvia	2	1.9	0.4	23.7	1,184
Lithuania	1	4.2	0.8	41.1	1,619
Netherlands	1	76.7	13.0	140.0	6,611
Poland	1	62.4	13.0	426.0	15,154
Portugal	1	16.8	3.3	113.0	11,183
Romania[2]	2	12.5	7.4	183.2	9,134
Slovakia	-	4.5	0.8	42.4	3,911
Slovenia[5]	4	2.2	0.5	13.7	733
Spain	1	118.8	20.7	404.3	28,212
Sweden	3	20.0	4.8	51.0	4,488
United Kingdom	1	118.7	30.7	460.0	10,352

[1] As published by FoodDrinkEurope National Federations or by Eurostat (SBS)
[2] 2016 data for value added
[3] Small food and drink producers and family businesses included in the number of companies
[4] Only covering food products
[5] Only limited liability companies, joint stock companies or similar and self-employed
No data available for Luxembourg and Malta

FoodDrinkEurope DATA & TRENDS 2019

Figure 1. EU food and drink industry employs 4.72 million people, generates a turnover of €1.2 trillion and €236 billion in value added, making it the largest manufacturing industry in the EU (source: EU Food and drink industry, Data and Trends 2019)

Food industry has been changing from a "push system" driven by the producer's ability to generate commodities to a "pull system" driven by the consumer's needs. Further steps in this direction are expected to take place with advances in digitalisation and more connected and informed consumers. Food not only has to be safe, but it has also to satisfy consumer's needs for more healthy, tasty and convenient products. In addition, ethical issues such as organic production, environmental issues, such as reduction of waste and energy, and animal welfare, are of growing importance for food choices [5].

The importance of food to health has been demonstrated by several epidemiological studies [6], and it is now a key priority for authorities and food industry. More attractive healthy food products are expected to contribute to an increased consumption, and consequently reduce obesity and prevent or delay chronic diseases, saving billions of dollars in hospital costs and lost time at work.

Food processing equipment suppliers are focusing on providing efficient and advanced technologies to food industry to support a more effective use of water, energy or raw materials and the development of more healthy and convenience food products. Novel technologies are also being developed to support the manufacturing process by reducing production time, ingredient & food waste, and overall cost. In figure 2 is shown the main drivers of innovation and consumer trends. Pleasure continues to account for almost half of the drivers of food innovation, but heath continue to growth and the most dynamic driver is ethics, due to the increase of ecological concerns [1].

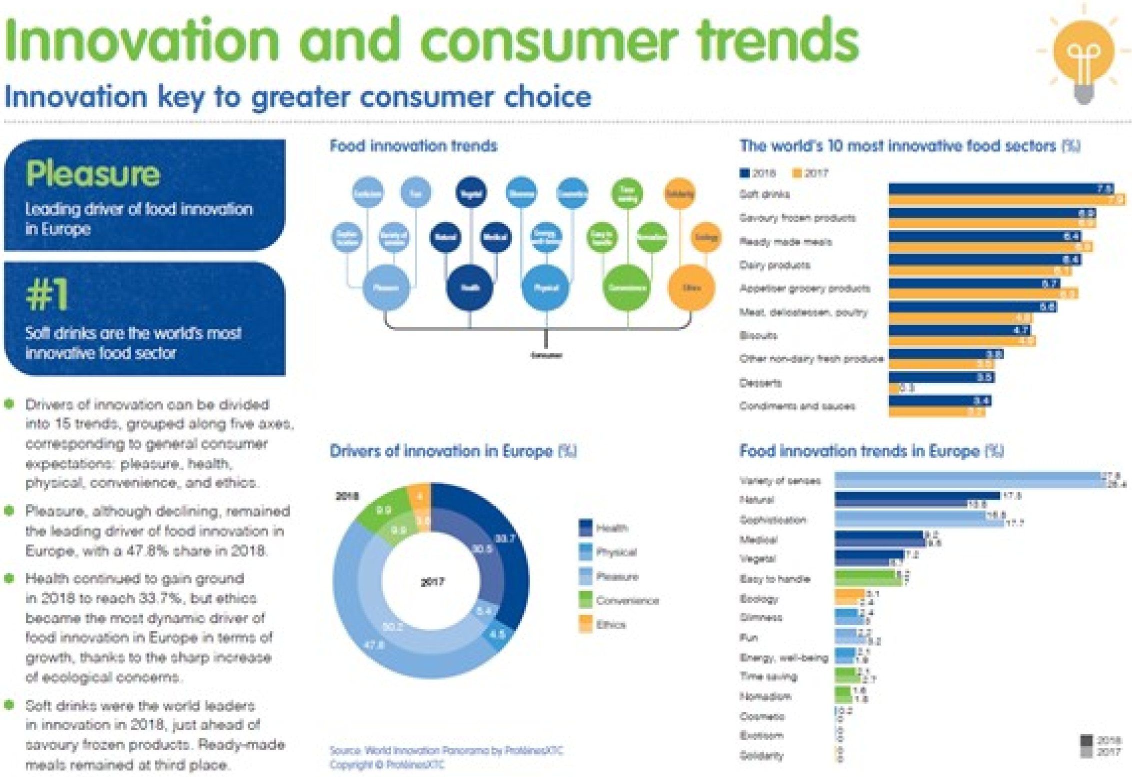

Figure 2. Innovation trends and Drivers for innovation in Food industry ((source: EU Food and drink industry, Data and Trends 2019)

a.2 Distance of 'Business as Usual' situation from SDG and Planet boundaries

"Bussiness as Usual" is no longer possible and it is well acknowledged by food industry that the way food is produced and packed needs to be reviewed. Figure 3 shows an illustration of the sustainability challenges in relation to SGD. The production and processing of foods accounts for more than three quarters of food related GHG emissions. Addressing hunger, malnutrion and obesity is a key to achieve SDGs, and as population and income growth will continue to drive food demand. A 50% increase in global production is expected by 2050 [1].

Thus, food processing technologies need to support the development of convenient and processed food that respond both to health challenges (nutritional balanced, e.g. less fat, sugar and salt; additives; rich in bioactive nutrients, fibers) and sustainability challenges (reducing food waste, side streams, packaging, energy and water, protein shift etc.). Efforts have been done in this direction but there is a long way to go.

Figure 3. Sustainability challenges in relation to SDG (source: EU Food and drink industry, Data and Trends 2019)

Reduction of water and energy and more efficient use of raw materials in food production has been high priority for food industry and equipment suppliers in the last years, and it is expected to continue in order to achieve the zero emission goals by 2050. Efforts regarding improving energy efficiency and increasing the use of renewable energy sources and natural refrigerant, besides water saving strategies and technologies to reuse processed water are ongoing, supported by a variety of EU programmes (eg SPIRE, BBI, etc).

Sustainable selection of raw materials, preventing food waste and implementing a circular approach to side-streams from food production is a key priority and probably far from the goals established. In this context, not only raw materials and circularity of nutrients are important but also selection of lean and more sustainable packaging solutions and the circularity of packaging material. As plastic is questionable, strong efforts are focusing of finding sustainable solutions that protect the properties of the food products until consumption as well as existing solutions are in preventing food waste due to spoilage or poor quality. In addition to processing, packaging has a very important role in keeping the product safety and quality attributes.

Biodiversity loss has accelerated in Europe and worldwide, and the number of processing lines commercially available to process raw materials is also limited to a few crops and animals. Efforts in this area are needed to process a variety of raw materials from large scale to small scale, especially the ones that have are more sustainable and nutritional rich. Cooperation with farmers is needed so the supply chain is not broken. Far away from the goals settled and probably very challenging as a holistic approach is needed from farm to fork.

Regarding health challenges, food industry is aware of challenges like sugar, fat and salt reduction, empty calories, limited amount of bioactive components, and significant innovations have merged from efforts in this direction. However, more still needs to be done to offer a wide choice of nutritious, tasty and sustainably produced foods taking into account consumer preferences, cultural differences, convenience and affordability. More healthy and tasty foods have to be available to become the easy choice. More collaboration between nutritionists and food scientists is needed to develop healthy and consumer attractive foods.

a.3 Environmental, health, economic, social and ethical emerging issues and controversies

Food processing needs to be transparent and better respond to consumer expectations with regard to processing methods. Education about food processing is needed to base discussions on scientific facts. Food processing needs to comply with circular economy and sustainability principles, while maintaining the nutritional value, safety and taste of the foods. Sustainability principles include ecological, social and economical aspects.

There is a number of misconceptions around food processing threatening consumer trust in foods. Terminologies like “ultra processed foods” are emerging in nutritional guidelines of some countries [7], as way to bane foods that cause obesity. However, the classification do not provide any help to food producers to improve their products or consumers to make better choices. The healthy aspects of foods is complex a constant area of controversy [8].

]There is a growing consumer demand for minimally (gentle) processed food [9] with naturally derived ingredients and additives instead of chemically synthesised additives, flavours and colorants. Traditional and handcraft type of processing is gaining momentum, as well as short food chains, although food safety risks might be increased. Therefore, it is worth to rethink food processing in a food system as well as nutritional and sustainability perspective.

Trend of plant based foods, creates the need to develop sustainable processing solutions for production of plant based ingredients and foods. Contrary to animal based food products, in which the agricultural production has a large environmental impact in the product life cycle, the processing and packaging steps of plant based products life cycle may have a large environmental impact than their agricultural production [10]. Thus, processing solutions have to be developed using sustainable technologies.

2. **Contribution of the theme to the three transitions**

Transition 1: Healthy and sustainable food for all

To design and manufacture healthy and sustainable foods with high consumer acceptance, in addition to a balance amount of macronutrients and high bioavailability of essential micronutrients or no harmful substances, also values of taste, flavour and texture must be included. In addition, these healthier products have to be produced from sustainable raw materials at competitive costs.

A bottleneck is the relatively low importance given to the nutritional value of foods and a tendency to over-processing to increase safety margins and reach far markets. Food supply chains for many products are long and products and ingredients may be twice or three times processed before assembled into a final food product. Nutritional aspects are often not considered and taste may be created by using flavour enhancers. The rising sales of more convenient foods with longer shelf life, which may be more sustainable, results often in a loss of nutritional value.

Nutrition research and food processing are two separated fields of research. More knowledge is needed about the effect of processing foods on nutrition and health, and consequently understanding how foods are digested in our human body. The existing manufacturing processes and processing technologies need to be reviewed in the context of nutritional and health aspects.

Transition 2: Full circularity of food systems

Minimising energy and water usage through process optimization for higher production efficiency will reduce the environmental impact of industrial food manufacturing. Cleaning is an important part of the daily/weekly production cycle and of the production costs; optimising cleaning typically reduces both costs and environmental impact [11]. Packaging technology is an integral part of food manufacturing, and innovations in packaging technology including a wider use of sustainable packaging materials or better circularity strategies will reduce the environmental impact.

Selection of more sustainable raw materials and their efficient use along processing schemes will contribute for the transition. Most of the companies do not use the full potential of side-streams from processing, often resulting in loss of nutrients and other compounds with high nutritional value. A bottleneck is price competition, which leads to food processing companies buying the raw materials on the global market, and therefore their efficient use or re-use of side streams may not be possible.

Ingredients such as sugars, proteins, and starches are often highly purified and fractioned, which makes them universally applicable in many products. However, fractionation and purification creates many side streams and consequently affect the sustainable use of raw materials, energy and water.

Thus, reduced waste downstream and improved utilisation of the raw material input through optimised processes will allow more food to be manufactured from the same amount of farmed produce, thereby reducing pressure on land use, irrigation water and also marine food resources

Introducing novel processes as well as optimising existing processes will decrease losses from spoilage while maintaining high standards of food safety and sensory quality.

Transition 3: Substantial increase of biological, social, and economic diversity

Biodiversity loss has accelerated in Europe and worldwide, fewer than a dozen species account for 80% of our diet and about 60% of population dietary energy requirements are provided by three main crops [12]. On the other side, there is a large diversity of crops and other underutilised food sources that are suitable for human consumption. Many of those have a very good nutritional profile and lower sustainability footprints but there are not produced or processed in sufficient amounts to be available for consumption. Processing lines commercially available are limited to a few crops and animals.

Availability of more diverse foods and diets can address food insecurity, malnutrition and the nutritional needs of urbanized population, as well as to support the production and consumption of foods with lower water and carbon footprints. Promoting food biodiversity of sustainable and nutritionally rich species and varieties will increase biological, social and economical diversity. This approach will trigger innovation effects along the food chain from the raw material production at farm (eg. crop diversification, algae, insects) to processing in food industry (new processes and new foods) and food consumption.

The vision could be to double the production of a diversity of crops, food from the sea or other edible raw materials well adapted to the European regions climate and consumer preferences, and create conditions for their sustainable processing into more diverse ingredients, food products and diets that will meet nutrition demands and in turn contribute to a reduction in greenhouse gas emissions.

Production of alternative crops or raw materials is undeveloped and new chains have to be developed from production to consumption. Consumer acceptability of some products, such as for example alternative protein sources is low and needs to be improved. Efforts in this area are needed to develop technologies to effectively process a variety of raw materials from large scale to small scale. Cooperation with farmers is needed so the supply chain is not broken.

The development of this area is far away from the goals settled and probably very challenging as an holistic approach is needed from farm to fork. Technologies suitable for on-farm processing or SMEs to produce final food products or semi-fabricated/intermediate products empower farmers and support the development of short and local food chains that are likely to be able to keep nutritional value and be more sustainable.

3. **Policy conditions for the achievement of the targets**

In this section policy conditions – relevant to the domain – necessary to the transition should be analysed

- Focus on price – procurement based on price leads to low quality foods
- Side streams waste a number of nutrients that could be recovered
- Nutritional content of foods may be regulated
- Promoting cultivation of diverse crops
- Support the processing of sustainable food sources
- Support EFSA with evidence based data for assessment of novel technologies

4. **Challenges for research**

In order to reach transitions towards sustainable and healthy diets, full circularity of food systems and substantial increase of diversity, research should tackled the following challenges:

1. **Precision processing for healthy and sustainable foods**
   - Development and validation of new technologies (gentle processing) with regard to high functionality and consumer acceptance and little environmental impact and high nutritional quality.
   - Evaluate current processing practices and supply chains in terms of improvement of sustainability and nutritional value and impact on health of processed foods
   - Further development of traditional technologies (fermentation, cooling, drying, etc.) with less energy and water use while optimising the nutritional benefit (bioactive substances, etc.) based on new knowledge (e.g. nutrigenomics, human microbiome, food digestion).
   - Development of natural structured convenient and nutritionally personalised ready to eat food products.
   - Understand how bioavailability of macronutrients is affect by processing
   - Continuation of investments to reduce salt, sugar and fat in processed foods developing new ingredients or manufacturing technologies (e.g. 3D printing or assembly)
   - Relocation of food processing (near the field, city or at home), the traditional positioning of food processing in the chain, between production and distribution, is to be revisited from environmental and

consumer attitudes points of view. Processing at farm, at home using wireless controlled appliances, 3D printing, new technologies for restaurants. To make healthier foods more available.

- Explore the potential to minimise processing keeping safety by combining technologies, short food chains
- Fermented products and the role of microbiota on nutrition health

2. Processing solution and technologies improve the full circularity of food systems

- Zero waste of energy, water and raw materials by exploring ICT developments e.g. regarding robotics, numerical modelling, artificial intelligence, big data handling, process control and sensor technology
- Gentle fractionation and separation technologies, e.g. membrane filtration
- Development of sustainable and safe food ingredients from side streams
- New technologies to valorise side streams
- Increase of water re-use during food processing.
- Stronger linking agricultural production methods (choice of varieties, terroir, type of soil) with food quality parameters and processing requirements.

3. More biodiverse food systems

- Development of advanced technologies, based on the "cradle–to cradle" and circular approaches, to make better use of the diversity and complexity in raw materials and to facilitate their total use.
- To support the develop sustainable processing schemes from new food sources
- Understand how to improve and naturally enhance taste and culinary experiences of sustainable but underutilised food sources
- Scaled-down processing technological solutions for small-scale processing with local ingredient sourcing.
- Formulation of traditional foods with more sustainable ingredients

- Linking sensory quality research to agronomic research with regard to the choice of varieties and cultivation system

REFERENCES

1. (https://www.fooddrinkeurope.eu/uploads/publications_documents/FoodDrinkEurope_-_Data__Trends_2019.pdf).
2. https://www.marketsandmarkets.com/Market-Reports/food-processing-handling-equipment-market-145960225.html?gclid=EAIaIQobChMI39u466i05gIVxvhRCh2A3gdsEAAYAiAAEgI5GvD_BwE
3. https://www.marketdataforecast.com/market-reports/europe-food-packaging-market
4. https://www.globenewswire.com/news-release/2019/07/02/1877512/0/en/Global-162-Billion-Food-Logistics-Market-by-Transportation-Mode-Service-Type-Segment-Type-Product-Type-and-Region-Forecast-to-2024.html
5. Hannah Ritchie (2020) - "Environmental impacts of food production". Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/environmental-impacts-of-food' [Online Resource]
6. C Celis-Morales, KM Livingstone, F Petermann, S Navas-Carretero, R San-Cristobal, CB O'Donovan, G Moschonis, Y Manios, I Traczyk, CA Drevon, H Daniel, CFM Marsaux, WHM Saris, R Fallaize, AL Macready, JA Lovegrove, M Gibney, ER Gibney, M Walsh, L Brennan, JA Martinez, JC Mathers (2019) More frequent nutritional feedback and personalised advice produces larger behavioural changes: Findings from the European Food4Me internet-based randomized controlled trial, American Journal of Preventive Medicine, 57(2):209-219.
doi: 10.1016/j.amepre.2019.03.024. Epub 2019 Jun 25.
7. Michael J Gibney (2020) Ultraprocessed Foods and Their Application to Nutrition Policy, Journal Nutrition Today, 55(1):16-21
8. M Gibney, D Allison, D Bier, J Dwyer, Uncertainty in human nutrition researchNature Food 1 (5), 247-249
9. D Knorr and H Watzke (2019) Food Processing at a Crossroad, Front Nutr. 2019; 6: 85. doi: 10.3389/fnut.2019.00085
10. Foster, C., Green, K., Bleda, M, Dewick, P.; Evans, B. Flynn, A., Mylan, J. (20016) Environmental impacts of food production and consumption: A report to the departmnet for environment, food and rural affairs, Manchester Bussiness School. DEFRA, London

11. http://www.safefood360.com/resources/Cleaning.pdf?TB_iframe=true
12. Colin K. Khoury, Anne D. Bjorkman, Hannes Dempewolf, Julian Ramirez-Villegas, Luigi Guarino, Andy Jarvis, Loren H. Rieseberg, and Paul C. Struik (2014) Increasing homogeneity in global food supplies and the implications for food security, Proceedings of the National Academy of Sciences, https://doi.org/10.1073/pnas.1313490111

SOCIAL PRACTICES RELATED TO FOOD

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Reflection paper on the implications of technological, political, environmental, institutional change on consumption patterns and lifestyles, addressing issues related to all food-related practices and their evolution in relation to the socio-technical environment.

1. Interpretation of the theme

'Social practices related to food' in this report is understood as **consumer-citizen behaviour in relation to food**. This entails the choice of which type of diet to eat, which food to buy where and from which origin, how to transport it to the home, store it, prepare it, and dispose of the remains, as well as how and with whom to eat. It also covers or whether or not to, and how to, order food and meals or eat out for work or private purposes. The sum of these behaviours are observed as consumption patterns and lifestyles.

As a repeated, day-to-day behaviour often occurring alongside social interactions, **food and eating behaviour is strongly driven by habits and norms**; In addition, **food and meals serve multiple needs** - such as nutrition, satiety, health, physical or cognitive performance, satisfaction and well-being, pleasure, achievement, status, identity, and care in social relationships or for ethical issues [1]. Consumers might buy chocolate for pleasure or comfort, order a steak rooted in perception of identity, serve a costly wine for status reasons, buy convenience food to save time for other leisure activities, prepare their loved one´s preferred meal to express care, or they prefer food items with certified logos out of their value-driven ethical concerns.

In the *safe and just space concept* ([2], terms from the paper in italics), social practices related to food are the behaviours consumer-citizens engage in to fulfil the multiple food-related needs or *social outcomes*. Food and eating requires effort from the food supply chain or *provisioning system*, and the latter requires resources from the *biophysical resources* [2]. Given food and eating is not only the intake of nutrients, the **global food-related resource usage is extensive** – it contributes with 19-29% [3] or 30-35% of greenhouse gas emissions, and globally, agriculture covers 38% of the earth´s surface and withdraws 70% of freshwater [4]. All of the transgressed planetary boundaries of the earth system are particularly influenced by agricultural production, including livestock [5], and without change, the food system´s impact could increase by 50-90% [6].

The ‘IPAT’ formula from 1971 ([7]) proposes that the sum of the human footprint on earth is a function of how many we humans are (P=population), what we need (A=affluence), and the technologies that we use for that purpose (T=technology). The type and amount of need that we perceive defines the social practices that we engage in and the ‘affluence’ level that we aspire to. The formula pinpoints that **consumer-citizens behaviour, whether conscious and active or bounded by the context they are in, plays a crucial role in causing impact** on earth´s resources, and cannot be left unattended (e.g. by assuming technology alone can do it). Because impact is determined through the interplay of the three factors, the three factors have to be tackled jointly.

The word affluence in the formula stands for the demand originating from consumer-citizen behaviour. Affluence is often used synonymously for prosperity and welfare. Economic activity such as the gross domestic product (GDP, which is the sum of all individual economic exchanges) is often used as an indicator for a nation´s welfare. However, more economic activity and material consumption does not necessarily equal greater human need satisfaction. Research on happiness has shown that consumer-citizen´s satisfaction, happiness or well-being is influenced by many factors, what one needs is in part socially constructed and a matter of perception, and a prominent role for well-being is played by social relations [8]. Due to that, the factor of relevance ultimately is well-being (see figure 1).

These influence factors also hold for food. Therefore, a) what **consumer-citizens demand from the food provisioning system is not fixed to a certain level of resource use**, it has b) **great variability between individuals and cultures**, and c) **food-related demand changes with shifts in consumer-citizens values, perceptions and preferences, as well as the context in which they are**.

2. Analysis of the main emerging issues

All macro-environmental factors (often abbreviated PESTEL: political, economic, social-cultural and demographic, technological, environmental-physical, legal, [9]) as well as micro-environmental factors (the individual´s social relations and direct food surrounding (for example, the supermarket offer, the work canteen, etc.), [10]) have an influence on consumer-citizen behaviour, also in relation to food. The following issues are outlined because they constitute particular threats and/or opportunity for the three transformations.

Politicization and segmentation

Citizen beliefs about climate change have been found to be determined by cultural group identity, such as political orientation [11]. Climate, environment and food can be central issues in social or political differentiation.

That food and eating is often a subject of differentiation also holds for consumption patterns and lifestyle. Many dietary trends have been observed throughout the past years (low fat, low-carb, paleo diet, etc.), and some of these have an aspect of criticism of the current food system (clean label, sugar-free, veganism, etc.). There are also general consumer lifestyle trends which entail criticism of material orientation and consumerism, and call for social and environmental characteristics to be taken into account (such as 'cultural creatives', or LOHAS – lifestyle of health and sustainability, voluntary simplifiers, downshifters, etc.). Many food trends have become globalized, with certain consumer lifestyle groups across countries more similar to each other than compared to other citizens within their own country (for example, food trends in 'hip' city districts). The diversification of media, and digitalisation and social media use contributes to these trends and the formation of distinct consumer lifestyle segments.

While political discussion on food-related issues can lead to action, the politicisation and identity-defining role of food-related issues among consumer-citizens can also make it difficult to assess facts objectively and to reach agreement. Globalized consumer food trends and lifestyle group can contribute to the up-scaling and spreading of food innovations and behavioural trends, but they also exacerbate differences and misunderstanding between citizen-consumer segments, and separate consumer-citizens who each follow their own chosen trend and lifestyle.

Health problems and inequality in access and choice options

In developed countries, approximately half to two-third of adults are overweight or obese, and there is an increase of diet-related diseases [10]. This entails great public health costs and stands in contrast to the UN SDG of good health. It has also negative consequences for consumer-citizens perceived well-being. At the same time, there are many malnourished individuals or people suffering hunger, which stands in contrast to the UN SDG of ending hunger, and good health for all. Some (but not all) food waste definitions declare over-eating and inefficient nutrition, as is shown when individual´s unbalanced dietary choices lead to health problems, as a waste of food [12]. In this view, overweight also stand in contrast to the UN SDG of halving food waste.

Consumer-citizens, though, do not have equal chances to choose a healthy diet, or do not have equal chances to take sustainability concerns into account. Barriers stem from a lack of availability, accessibility, and affordability of such food choices [13], or when own ability or externally determined opportunity are not given [14]. In the extreme case, consumer-citizens in so called ‘food deserts’ do not have access to fresh produce if they live in a disadvantaged area and lack the economic means. For the majority, though, it is because the immediate environment they live in, and/or their social relations and perceived social norms act as a barrier to change [15–17]. This leads to a gap between motivation and attitude on the one hand, and behaviour on the other. For example, for many consumer-citizens healthier or more sustainable food is relatively more costly or inconvenient to purchase, or significant others among family and peers dislike the food or express negative attitudes towards the food or dietary choices and food-related behaviours.

There is an increasing inequality in income distribution in many societies. Many of the current healthy and/or sustainable consumer food-related lifestyles and food trends are more prominent in higher income groups, and the lifestyles and food trends are prominently characterised by food products that are relatively more costly [18,19]. This means that consumer-citizens have unequal options to engage in or envision a healthier or sustainable lifestyle. A well-earning ‘LOHAS’ consumer in a respectively gentrified city district has the economic means and an appealing food assortment available in comfortable walking distance, and most of her/his peers express the same mind-set and show the same food choices. Thus, there are barriers in most consumer-citizen´s environment (cost, inconvenience, etc.) that restrain greater uptake of healthier or relatively more sustainable foods.

Environmental mainstreaming and sufficiency and circular thinking

The past years have shown an increased societal interest for sustainability topics. This can be seen by media coverage, the increase of expressions of climate concern, more widespread self-report of decreased meat consumption, and the increased offer of food products regarded as sustainability-related (e.g. organic or alternatives to dairy or meat, [20]). The topic of environmental issues and sustainability appears to have moved from niche to mainstream, and norms are changing [21]. Amongst others, climate protests by the younger generation and temperature or climate extremes such as draughts, fires, floods and storms have increased focus on the topic. Climate change communication so far has been hampered by the fact that the topic is perceived as distant in time and space [22], but weather extremes contribute to consumer-citizens being able to envision the issue, fostering motivation and awareness.

In the wake of this, issues and ideas that are related to circularity in particular but also sufficiency (defined as avoidance of over- and under-consumption, reduction of material consumption in overall terms and a focus on human well-being, [23]) have also received more attention. General examples, for both circularity and sufficiency, are renewable energy, recycling, and circular economy, consumer-citizen practice examples are sharing economy, upcycling and do-it-yourself, voluntary simplifiers, abstaining from using flights, and food-related examples are slow food, food waste avoidance, plastic reduction, zero waste, community supported agriculture, food coops, food sharing, dumpster diving, and urban gardening, etc.

Environmental concern and sustainability has become more commonplace among consumer-citizens, and there are consumer-citizen practices which reflect attempts towards circularity and sufficiency. Both are concepts called for in order to keep within earths planetary boundaries [24]. This offers the opportunity that respective consumer-citizen behaviour related to food can receive greater upscaling on the one hand, and that respective consumer-citizen behaviours are of reduced resource use on the other hand. This is particular important given that many consumers who seek out healthy or more sustainable foods nevertheless live a lifestyle characterized by high overall resource consumption (for example, the organic avocado toast that the LOHAS consumer orders, has a relatively high environmental impact). Most are also not yet aware of the practical implications of fully circular food systems and cradle to cradle approaches [25].

Technological opportunities and digitalisation

Increasingly, consumers are met with new digital applications for their day to day life, or new food product innovations on the shelves. Many applications and innovations alleviate trade-offs that consumers perceive between their multiple food-related needs. An example for an innovation are meat alternatives with relatively lower environmental impact which nevertheless taste similar to meat or can be eaten in well-known and preferred meal contexts, such as burgers. An example for digital applications are convenient Apps which allow consumers to be aware of food otherwise wasted by restaurants or neighbouring citizens, which they can purchase for a low price or receive for free, or Apps that help consumers to better plan and organize their food handling through shopping lists, recipe suggestions, etc.

These technological opportunities in food processing and production and digital tools supporting food-chain to consumer or citizen to citizen interaction can reduce the attitude-behaviour gap for consumer-citizens on the one hand, but they might also lead to rebound effects in change of expectations and behaviour, or greater energy use.

Public and private sector engagement

Public and private sector action can crucially change the decisions making context for consumer-citizens. For example, the regulations, certification systems, and public information campaigns have had an important impact on how successful organic food markets have developed in various European countries [26].

Businesses have a mixture of reasons to look into actions that can further sustainability [27]. On the one hand, there are win-win situations (e.g. saving costs when reducing energy or waste), image gains from communicating corporate social responsibility activities to the public (e.g. leading to greater trust, customer loyalty, and stronger brands), and business opportunities and good business cases (e.g. in the market for products and services that are regarded as relatively more sustainable). On the other hand, businesses have noticed that they can attract more talented or engaged employees with responsible marketing that has the societal impact into consideration, or that business owners or managers themselves gain greater satisfaction from a ‘purpose driven’ business that tackles social and environmental issues for the improvement of society (as for example when Wholefoods or Unilever talk about ‘conscious capitalism’ or ‘brands with purpose’, [28]). Many start-up companies or social entrepreneurs focus on sustainability and engage in sustainability marketing, and large companies work towards contributing to the UN SDG´s. This is favourable towards achieving large-scale transition.

The businesses in the food area can alter the choice environment for consumer-citizens in order to ‘make the easy choice the healthy/sustainable choice’ by reducing the barriers. This can be via changing the price margins, altering the assortment (e.g. phasing out products with negative impact or underperforming – fish from depleted fish stocks, electrical appliances with low energy efficiency); It can also be changing the choice architecture and using nudging, or doing cause-marketing (connecting the sale of a certain product to a good cause, such as donating X per unit Y sold). Businesses can also communicate about sustainability, thus creating awareness and fostering social norm perceptions. In addition, businesses can collaborate with political decision makers on changes to the macro-environment (e.g. partaking and agreeing on voluntary standards, speaking in favour of certain regulations). When business activities are in collaboration with other stakeholders or certified and controlled by third parties, the trustfulness of their actions and claims can be ensured for consumer-citizens. This collaboration and third-party involvement is important in order to avoid a ‘green/-‘ or ‘rainbow-washing’ of business actions that only claim to, but do not or not significantly contribute to sustainability.

3. Contribution of the theme to the three transitions

Consumer behaviour and behaviour transformation theories as well as consumer research show that consumer-citizens most likely change their behaviour when all factors of influence (and not, for example, information provision alone) provide a reason, nudge, push or pull to do so.

Thus, for behaviour change, it is important the **individual thinks and/or feels it is a good idea** (he or she has knowledge, awareness, motivation and intention), **relevant others support, agree or do it** (close: family and peer group, distant: people you trust and respect, e.g. authorities or influencers), **it is easy and attractive to do** the change (one is able (knowledge, skills) and the individual has the opportunity (facility, no barriers), and there are individual benefits in doing so), and the **process of change has positive feedback** (characterized by following leading examples, taking small steps, timely encouraging feedback perceived, and the observation of collaborative responsibility and engagement).

This has been summarized in usefully memorable abbreviations such as MAOB (motivation, ability, opportunity, behaviour) [29,30], EAST (easy, attractive, timely, social) [31] or 4E (enable, encourage, engage, exemplify) [29]. It holds for consumer-citizen behaviour change in each of the transitions. When all factors of influence work towards change, societal tipping points are more likely.

A **social / societal tipping point** can be defined as the moment of change in behaviour within society where its characterisation switches from 'uphill struggle' to 'downhill roll' or having a 'snowball effect', thus a change with 'sufficient momentum' for positive re-enforcement effects (see also: [32]). This envisioned process takes departure in the innovation adoption curve (where the tipping point is reached when the late majority starts adopting, [33]), as well as the analogy to tipping points and feedback mechanism in earth systems (where a tipping point is the moment where changes and feedback mechanism alter a system radically, to arrive at a new equilibrium, [34]). A societal tipping point can be due to factors of effect on consumer behaviour influence supporting the change, and/or a sufficient number of individuals doing the change.

Transition 1: Healthy and sustainable food for all

Due to (issues outlined earlier in italics) *politicalness and segmentation* as well as *health problems and inequality in access and choice options*, only a share of consumer-citizens eat a healthy diet, only a number of consumer lifestyle groups are characterized by interest and behaviour in direction of sustainable food choice and diets, and the sum of their lifestyle choices is not necessarily low in environmental impact.

The transition to healthy and sustainable food for all needs dominant sustainability-oriented food-related lifestyles and food trends to include more elements of *sufficiency and circular thinking* and needs *environmental mainstreaming* to reach to the bulk of consumer-citizen groups.

Public and private sector engagement and *technological opportunities and digitalisation* can reduce consumer-citizen barriers, most prominently (in the short run) the price of relatively more sustainable food alternatives, and the convenience and attractiveness of purchasing and using these foods or following a respective diet. Concretely, that means sustainable diets (to a greater extent plant-based and diverse) should not cost more, and be as easy to use/follow, and similarly tasty.

At the same time (for the long run), *Public and private sector engagement* can internalize and promote *sufficiency and circular thinking* as a paradigm shift in the organisation and aspiration of society and consumer-citizen lifestyles. Aspirational lifestyles should transform to be low in resource demand and focused on experience and relations. Concretely, for food, that means consumer-citizens have internalized value and norm sets which cause that they derive a large share of need satisfaction and well-being from food-related activities, and that work hours and infrastructure of living spaces enable them to engage in these.

Transition 2: Full circularity of food systems

Currently, trends of sustainable products and sustainable lifestyles contain aspects of circularity only to a small extent, and consumer-citizens are not aware of what full circularity of a food system means, or are yet disposed to accept all its consequences. For example, many likely find foods from faraway 'pristine, natural environments' more appealing than food grown on fields fertilized with sludge from their own regional wastewater treatment plant.

Technological opportunities and digitalisation improve the business case for resource efficiency and upcycling of by-products and side-streams in the food supply chain. *Public and private sector engagement* in communicating and educating about these can increase consumer-citizen´s familiarity with *circular thinking* over time, and should provide consumer-citizen´s with easy ability to actively co-collaborate in circular systems. Concretely, that could mean public social marketing campaigns for the concept of circularity, or for example training on and systematic feedback on household´s waste and wastewater (e.g. knowing how to reduce toxics and sort waste, feedback and economic or other incentives for increasing quality of waste and wastewater for re-use), or installing local, collaborative compost and urban community farming.

Transition 3: Substantial increase of biological, social, and economic diversity

The transition to healthy and sustainable food for all needs to entail foods and diets diverse in plant- or animal species of origin of the food, in order to support a more diverse and resilient food and agricultural system. *Public sector engagement* can educate about and *private sector engagement* establish such diversity in food assortments, and *technological opportunities* enable food produced with ingredients of diverse origin. Such diversity in food and ingredients as well as the food system should be an integral and important part of transition 1 and 2, as diversity supports health and sustainability, can contribute to circularity, and interrelates with equity.

4. Policy conditions for the achievement of the targets

An upscaling and mainstreaming of healthy and sustainable food for all, based on diversity and circularity in the food system, is needed. With regard to consumer-citizen behaviour in relation to food, this **requires that most or all factors of influence (both from the individual and his/her context) provide a reason, nudge, push or pull to change food and diet choices**, in order for habits and norms to change, and a societal tipping point to materialise. Important factors are information (consistent, understandable and comparable information), the change of context (affordable and available), and how this is evaluated by the individual and others (appealing, peer influence).

Public and private stakeholders should collaborate in order to ensure that **public and private actions work in synergy**. For example, public procurement and favourable taxation/subsidies from the public side that allow private actors to find a better business case in broad, inexpensive assortments of healthy and sustainable food, or joint collaborations on furthering product development innovations, digital applications, service instead of product offers, or fully circular provisioning systems in collaboration of diverse local stakeholders. To alleviate segmentation and inequality and create a greater perception of 'we' instead of 'me' and more 'citizen' than 'consumer', **policy should support social cohesion**, e.g. through the education system, better organisation of neighbourhoods, or stronger public media and communication; It should also work towards reducing income inequalities. To further sufficiency thinking, measures of increasing social cohesion and a reduction of working hours should be promoted, and the **societal focus shifted towards well-being**, for example by measuring success with respective indicators, and education.

5. Challenges for research

Research needs to better **understand citizen-consumer behaviour change** with regard to food and the **factors leading to a emergence of societal tipping points** through conducting long-term, large-scale and real-life observations, experiments and interventions. It is important to identify how different citizen-consumer groups are characterized by **differing values, perceptions and preferences** and thus have to be approached by public and private sector actors in a different way. This should be done with a view to ensure nearly all / all factors of influence can be altered for most, so that the **factors provide a reason, nudge, push or pull to change** food and diet choices for the majority of consumer-citizens.

At the same time, upscaling and mainstreaming of healthy and sustainable food for all, based on diversity and circularity in the food system, requires research on how to **scale up and 'democratize' food trends** which currently are segmented and politicized, through education, communication, digitalisation, and synergistic public-private sector collaboration. Research into **furthering social cohesion around behaviour in relation to food** is needed, amongst others by positive narratives and communication towards a more joint societal vision.

Sustainable, diverse, and fully circular food systems need consumer-citizen´s acceptance as well as support and collaboration. Therefore, research should **explore consumer-citizen´s beliefs and behaviour towards circular systems** (e.g. a system using what now is perceived as ‘waste’ as an input in the food system, and thus not necessarily untouched), and research should identify the communication and infrastructure **conditions that further consumers active support and engagement**. This can be in e.g. diverse, localized food systems, where consumer-citizens have a crucial role for reducing food waste and avoiding toxics in the household, separating waste streams, and partaking in urban farming, etc.

Research should focus on which **factor determine creation of successful business models for sustainability**, and the factors enabling and supporting business engagement and collaboration, in order to improve upscaling and mainstreaming of innovations of for example by-product usage or upcycling, industrial symbiosis, digital technologies, sustainability and sufficiency marketing, and the **transformation from product to service-oriented business cases**.

Consumer-citizen satisfaction, happiness or well-being should ideally be derived to a greater extent than today from ‘being’ instead of ‘having’, and consist of consumption of service more than products. Research exploring how to establish and built a society with respective **consumer-citizen values, mind-sets and aspirations** is needed, e.g. via education, social marketing, norm shaping, and changing infrastructure such as work hours is needed. This research can look into for example new trends of frugality and sufficiency, and **how food-related experiences contribute to well-being** of consumer-citizens.

Figures

Figure 1. Humanity´s impact on the earth explained by three interrelated factors

Source: Own (based on [7])

REFERENCES

1. Shepherd R, Raats M (Eds): *The psychology of food choice.* Wallingford [G.-B.]. *Volume 3*: CABI; 2010.
2. O'Neill DW, Fanning AL, Lamb WF, Steinberger JK: **A good life for all within planetary boundaries**. *Nat Sustain* 2018, **1**:88-95.
3. Vermeulen SJ, Campbell BM, Ingram JSI: **Climate Change and Food Systems**. *Annu. Rev. Environ. Resour.* 2012, **37**:195-222.
4. Foley JA, Ramankutty N, Brauman KA, Cassidy ES, Gerber JS, Johnston M, Mueller ND, O'Connell C, Ray DK, West PC, Balzer C, Bennett EM, Carpenter SR, Hill J, Monfreda C, Polasky S, Rockström J, Sheehan J, Siebert S, Tilman D, Zaks DPM: **Solutions for a cultivated planet**. *Nature* 2011, **478**:337-342.
5. Steffen W, Richardson K, Rockström J, Cornell SE, Fetzer I, Bennett EM, Biggs R, Carpenter SR, Vries W de, Wit CA de, Folke C, Gerten D, Heinke J, Mace GM, Persson LM, Ramanathan V, Reyers B, Sörlin S: **Planetary boundaries: Guiding human development on a changing planet**. *Science* 2015, **347**:1259855.
6. Springmann M, Clark M, Mason-D'Croz D, Wiebe K, Bodirsky BL, Lassaletta L, Vries W de, Vermeulen SJ, Herrero M, Carlson KM, Jonell M, Troell M, DeClerck F, Gordon LJ, Zurayk R, Scarborough P, Rayner M, Loken B, Fanzo J, Godfray HCJ, Tilman D, Rockström J, Willett W: **Options for keeping the food system within environmental limits**. *Nature* 2018, **562**:519-525.
7. Ehrlich PR, Holdren JP: **Impact of Population Growth**. *Science* 1971, **171**:1212-1217.
8. Jackson T: *Prosperity without growth: Economics for a finite planet*. 2nd edition. Abingdon, Oxon, New York, NY: Routledge; 2017.
9. Kotler P, Keller KL: *Marketing management.* Harlow, Essex, England: Pearson; 2016.
10. HLPE: **Nutrition and food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security** [http://www.fao.org/3/a-i7846e.pdf].
11. Kahan DM, Peters E, Wittlin M, Slovic P, Ouellette LL, Braman D, Mandel G: **The polarizing impact of science literacy and numeracy on perceived climate change risks**. *Nature Clim Change* 2012, **2**:732-735.
12. Parfitt J, Barthel M, Macnaughton S: **Food waste within food supply chains: quantification and potential for change to 2050**. *Philosophical Transactions of the Royal Society B: Biological Sciences* 2010, **365**:3065-3081.
13. Reisch L, Eberle U, Lorek S: **SSPP: Sustainable Food Consumption: An Overview of Contemporary Issues and Policies**. *Sustainability: Science, Practice & Policy* 2013, **9**:7-25.
14. Thøgersen J: **Unsustainable Consumption**. *European Psychologist* 2014, **19**:84-95.

15. Vermeir I, Verbeke W: **Sustainable Food Consumption. Exploring the Consumer "Attitude – Behavioral Intention" Gap**. *J Agric Environ Ethics* 2006, **19**:169-194.
16. Ajzen I: **Perceived Behavioral Control, Self-Efficacy, Locus of Control, and the Theory of Planned Behavior**. *Journal of Applied Social Psychology* 2002, **32**:665-668.
17. Carrington MJ, Neville BA, Whitwell GJ: **Why Ethical Consumers Don't Walk Their Talk. Towards a Framework for Understanding the Gap Between the Ethical Purchase Intentions and Actual Buying Behaviour of Ethically Minded Consumers**. *J Bus Ethics* 2010, **97**:139-158.
18. Aschemann-Witzel J, Zielke S: **Can't Buy Me Green? A Review of Consumer Perceptions of and Behavior Toward the Price of Organic Food**. *J Consum Aff* 2017, **51**:211-251.
19. Aertsens J, Verbeke W, Mondelaers K, van Huylenbroeck G: **Personal determinants of organic food consumption. A review**. *British Food Journal* 2009, **111**:1140-1167.
20. Euromonitor International: **Driving forces behind plant-based diets: climate concern and meat reduction** [https://www.euromonitor.com/driving-forces-behind-plant-based-diets-climate-concern-and-meat-reduction/report].
21. Nyborg K, Anderies JM, Dannenberg A, Lindahl T, Schill C, Schlüter M, Adger WN, Arrow KJ, Barrett S, Carpenter S, Chapin FS, Crépin A-S, Daily G, Ehrlich P, Folke C, Jager W, Kautsky N, Levin SA, Madsen OJ, Polasky S, Scheffer M, Walker B, Weber EU, Wilen J, Xepapadeas A, Zeeuw A de: **Social norms as solutions**. *Science (New York, N.Y.)* 2016, **354**:42-43.
22. Morris BS, Chrysochou P, Christensen JD, Orquin JL, Barraza J, Zak PJ, Mitkidis P: **Stories vs. facts. Triggering emotion and action-taking on climate change**. *Climatic Change* 2019, **154**:19-36.
23. Gossen M, Ziesemer F, Schrader U: **Why and How Commercial Marketing Should Promote Sufficient Consumption. A Systematic Literature Review**. *Journal of Macromarketing* 2019, **39**:252-269.
24. Sachs JD, Schmidt-Traub G, Mazzucato M, Messner D, Nakicenovic N, Rockström J: **Six Transformations to achieve the Sustainable Development Goals**. *Nat Sustain* 2019, **2**:805-814.
25. Braungart M, McDonough W, Bollinger A: **Cradle-to-cradle design. Creating healthy emissions – a strategy for eco-effective product and system design**. *Journal of Cleaner Production* 2007, **15**:1337-1348.
26. Thøgersen J: **Country Differences in Sustainable Consumption. The Case of Organic Food**. *Journal of Macromarketing* 2010, **30**:171-185.
27. Carroll AB, Shabana KM: **The Business Case for Corporate Social Responsibility. A Review of Concepts, Research and Practice**. *International Journal of Management Reviews* 2010, **12**:85-105.

28. Mackey J: **What conscious capitalism really is**. *California Management Review* 2011, **53**:83-90.
29. WRAP: **Defra 4Es model** [http://www.wrap.org.uk/content/defra-4es-model].
30. Nielsen KR, Reisch LA, Thøgersen J: **Sustainable user innovation from a policy perspective. A systematic literature review**. *Journal of Cleaner Production* 2016, **133**:65-77.
31. Behavioural Insights Team: **EAST - Four simple ways to apply behavioural insights** [https://www.bi.team/publications/east-four-simple-ways-to-apply-behavioural-insights/].
32. Gladwell M: *The tipping point: How little things can make a big difference*. 1st edition. New York, NY: Back Bay Books; 2001.
33. Rogers EM: *Diffusion of innovations: 5th ed.* New York: Free Press; 2003.
34. Steffen W, Rockström J, Richardson K, Lenton TM, Folke C, Liverman D, Summerhayes CP, Barnosky AD, Cornell SE, Crucifix M, Donges JF, Fetzer I, Lade SJ, Scheffer M, Winkelmann R, Schellnhuber HJ: **Trajectories of the Earth System in the Anthropocene**. *Proceedings of the National Academy of Sciences of the United States of America* 2018, **115**:8252-8259.

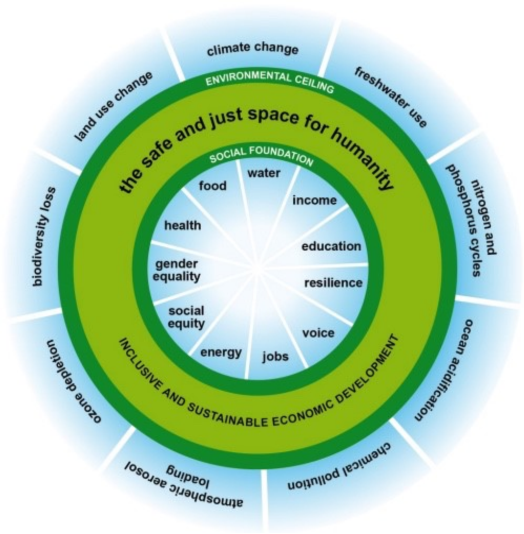
PLANETARY BOUNDARIES – THE NUMBERS OF TARGETS

András Báldi, 5th SCAR Foresight Exercise expert

The concept of “planetary boundaries” was introduced by Rockström et al. (2009) as an iconic definition of limits that should not be trespassed if living conditions in a “safe space” are to be ensured to future generations. As human wellbeing is linked to the use of resources, there must be a zone (or such a zone has to be created) in which acceptable levels of social development indicators are ensured and no planetary boundaries (PBs) are trespassed. The socio-economic aspects are clearly involved into the Sustainable Development Goals (SDGs). Both planetary boundaries and socio-economic aspects are essential components of human wellbeing, and define a space, the “safe and just operating space”, where wellbeing is achieved, while no planetary boundaries are trespassed. The aim of the 5th Foresight is therefore to explore the necessity and the impacts of different transitions in the use of natural resources and food systems taking into account humanity and the consequences of those transitions.[110]

The PB framework is widely applied in the EU policy area, including not only the environmental issues (e.g. SOER 2020), but even in assessing the performance of science (SPIR 2020). The first step, however, is to delineate and determine exactly where the transition should go, what are the environmental and socio-economic borders of the safe and just space, within which the integrity of ecosystems remains, and the needs of the society will be served. Without defining the borders, any transition would resemble a bottle dropped in the water: we know the start, and don’t know the end; thus, a lottery instead of knowledge.

[110] This paragraph is based on the text of the Term of Reference for the 5th foresight expert group.



The donut model, shows the safe and just operating space in green, the planetary indicators in the outer circle, and the socio-economic needs inside.

The 5th foresight excercise need to provide benchmark numbers for Europe – more exactly to EU+ countries, which refers to teh SCAR group here – and for the most important boundaries regarding agriculture. There are altogether nine PBs:

1. Climate change
2. Biosphere integrity (genetic diversity, functional diversity)
3. Land system change
4. Freshwater use
5. Biogeochemical flows (Nitrogen, Phosphorus)
6. Ocean acidification
7. Atmospheric aerosols
8. Stratospheric ozone depletion
9. Novel entities

(See details: https://www.stockholmresilience.org/research/planetary-boundaries/planetary-boundaries/about-the-research/the-nine-planetary-boundaries.html)

From these nine PBs, the following boundaries are most closely linked to agriculture, although others also have significant effects on it:

1. Climate change. Evidence suggests that the Earth has already transgressed the planetary boundary. Strictly speaking, agriculture is responsible for 10% of GHG

(e.g. CO_2) emission in the EU, which number did not include other food system emissions (like transportation, energy use, etc).

2. Biosphere integrity (genetic diversity, functional diversity). There are high rates of ecosystem damage (IPBES 2019, SOER 2020), which have to be reversed, and ecosystems restored. Ecosystem services, which are provided by living organisms of the ecosystems, are key for agriculture, providing pollination, pest control, soil fertility, among others.
3. Land system change. Most natural and semi-natural habitats have been converted to human dominated, intensive agricultural, tree plantation or urban land uses. Different challenges are there for marginal areas (abandonment), and productive areas (intensification) in Europe. Land system change is probably the most important driver of loss of biodiversity, fragmentation of habitats and distortion of water flows, biogeochemical cycles, etc (IPBES 2019).
4. Freshwater use. Freshwater will be increasingly scarce in the future, due to land system change, like agriculture, and climate change. Water is essential in agriculture (e.g. for irrigation), but can cause damages e.g. with soil erosion due to floods.
5. Biogeochemical flows (Nitrogen, Phosphorus). Nitrogen and phosphorus cycles were significantly changed due to industrialization and agriculture. Agricultural fertilizer use is probably the main issue here.
6. Novel entities and chemical pollutions. Agriculture uses an extreme amount of chemicals, like chemical pesticides, antibiotics, endocrine disruptors, antimicrobials, nanomaterials, etc, and other recently not used materials, which may have a cascading effect on human health and ecosystems functioning.

For these six boundaries, there are indicators, developed by the Stockholm Resilience Center and others:

	Planetary boundary	Indicator
1	**Climate change**	**CO_2-equivalent emission**
2	**Biosphere integrity (genetic diversity, functional diversity).**	**Species number, abundance of individuals**
3	**Land system change**	**Cover of forest/crop land; HANPP (Human**

		Appropriation of Net Primary Production)
4	**Freshwater use**	**Water withdrawal, blue water**
5	**Biogeochemical flows (Nitrogen, Phosphorus)**	**N and P applications**
6	**Novel entities and chemical pollutions**	**No global indicator was defined. For the purpose of this foresight we define it as chemical pesticides applications.**

To set baseline numbers (benchmarks) of these indicators for Europe should help us to understand the distance of recent situation from the target situation, and the efforts necessary to achieve it.

Several sources were used to define the target numbers. The **first source** is the planetary boundaries website of the Stockholm Resiliance Center, the developers of the planetary boundary concept:

https://www.stockholmresilience.org/research/planetary-boundaries/planetary-boundaries-data.html

The figures are shown in Appendix I, and are the European parts of those global maps which were presented on the Stockholm Resiliance Center's website. Original data sources are given with the maps. These maps show that large parts of Europe are well beyond the PBs, where transformative changes are necessary to reach the safe and just operating space: Western Europe for N and P; Meditterranean for water withdrawal; almost all of Europe (except the North) for biodiversity loss; etc.

Benchmarks of two indicators were defined for this foresight study as were missing from the literature. The indicator for PB „Biosphere integrity" is species number, more exactly it is the remaining mean species abundance (MSA) of original species number, relative to their abundance in pristine or primary vegetation, which are assumed to be not disturbed by human activities for a prolonged period (it is one if there is no human disturbance of pristine areas). The number for Europe is 0.45 for 2000, and predicted as 0.33 for 2050. The number of individuals was also addedd as an indicator. The year 2000 was defined for this study, as it is probably a realistic target. The indicator for PB „Novel entitites" has no global indicator. We defined chemical pesticide applications as an appropriate measure for agriculture.

The second data source is from the following publication:

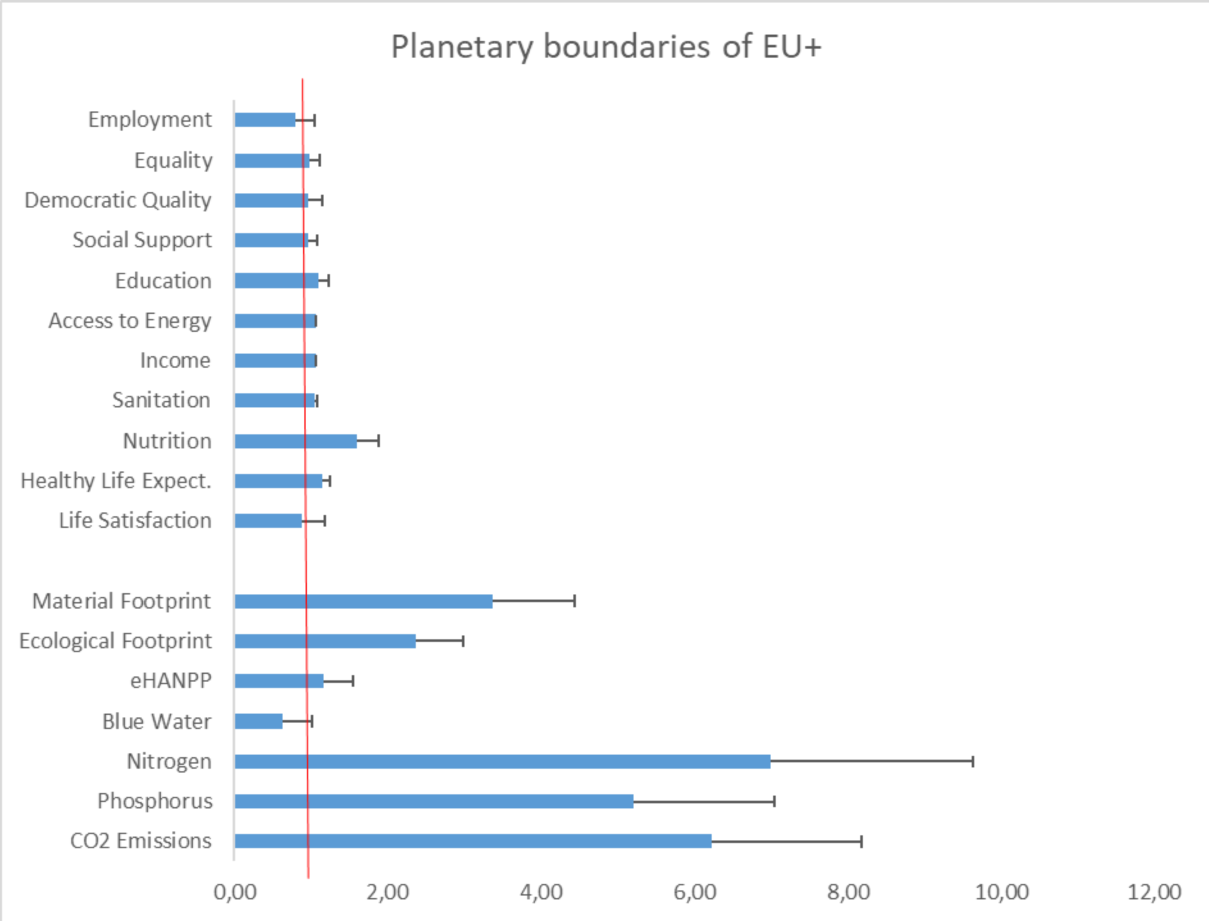
O'Neill, D.W., Fanning, A.L., Lamb, W.F., and Steinberger, J.K. (2018). A good life for all within planetary boundaries. Nature Sustainability 1, 88-95. doi: 10.1038/s41893-018-0021-4

It provides country level data for 7 biophysical and 11 social indicators generated in their analysis (https://goodlife.leeds.ac.uk/wp-content/uploads/sites/20/2018/01/GoodLifeWithinPB_SupplementaryData.xlsx). From that I averaged the values for the EU+ countries (members of SCAR group) for four agriculturally relevant planetary boundaries (two PBs from the above six are not available in this publication):

- climate change – CO_2,
- landsystem change - HANPP,
- freshwater use – blue water,
- biogeochemical flows – N and P.

The ecological footprint and material footprint are not part of the planetary boundaries framework, however, as they are widely reported measures of environmental pressure, I include them for comparison.

The following website, linked to this publication, provides comparions of PBs across countries in an interactive way: https://goodlife.leeds.ac.uk/countries/.



Value of 1 (red line) represents the biophysical boundary and also represents the threshold associated with a "good life".

If a biophysical variable is above the red line, it means it crossed the planetary boundary in the EU+. Most of the socio-economic variables are almost within the „just operating space", that is near the red line, showing a good life on average. For the environmental variables, however, the safe and just operating space are rather far in the recent situation.

Further data sources were also used, for example the recently released environmental outlook from the European Environment Agency (SOER 2020), the Hayha et al. (2018) report, and other publications.

Below are the data based target numbers for agriculture and food systems, what we should achieve in the next decades. IMPORTANT that these are based on the above resources (i.e. Stockholm Resilience Centre data, O'Neill et al. 2018, SOER 2020), and political declarations or policy strategies were not considered. Appendix II shows the final target numbers (benchamrks) of this foresight, which considers both the data based numbers (see below) and the policy targets in the recent EU Biodiversity Strategy and EU Farm to Fork Strategy.

	Planetary boundary / Indicator	Target number for 2050 for EU+
1	**Climate change / CO_2 emission**	**Reduce CO_2 equivalent (GHG) by 84 % in 2050.**
2	**Biosphere integrity / Species number; number of individuals**	**Restore declining biodiversity and their ecosystems. Reach the 2000 level.**
3	**Land system change / eHANPP; anthropised lands**	**Reduce eHANPP by 15% in 2050. Restore the ecosystems on 2/3rd of Europe's land.**
4	**Freshwater use / Blue water**	**Keep freshwater withdrawal at recent level.**
5	**Biogeochemical flows / Nitrogen and Phosphorus applications**	**Reduce N by 86 % in 2050,** **Reduce P by 81 % in 2050.**
6	**Novel entities and chemical pollutions / Chemical pesticide applications**	**Reducing chemical pesticides by 75% in 2050.**

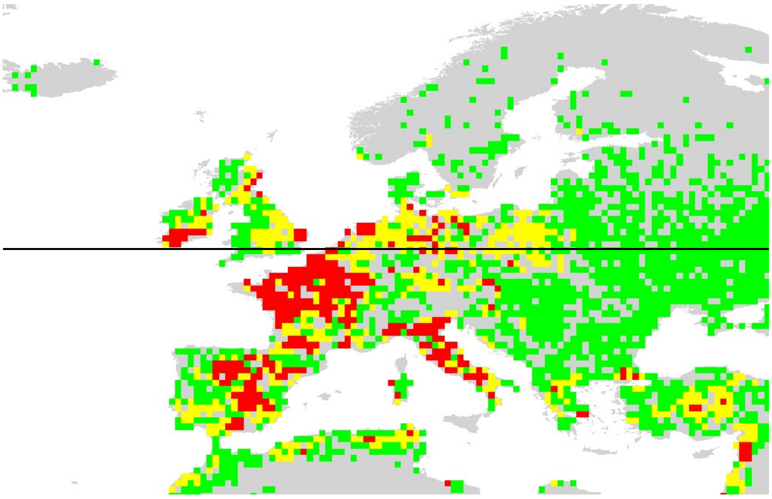
The main message of these data based numbers are to show the order of magnitude of changes needed to achieve the safe operating space. Updating and developing the indicator-set and the target values need continuous monitoring and evaluation works. These goals will need to be refined periodically as new information becomes available. For example, harmonized indicator for pesicides under development in the EU, and may provide new indicators and targets.

Appendix 1: maps of the Stockholm Resiliance Center on the Planetary Boundaries in Europe.

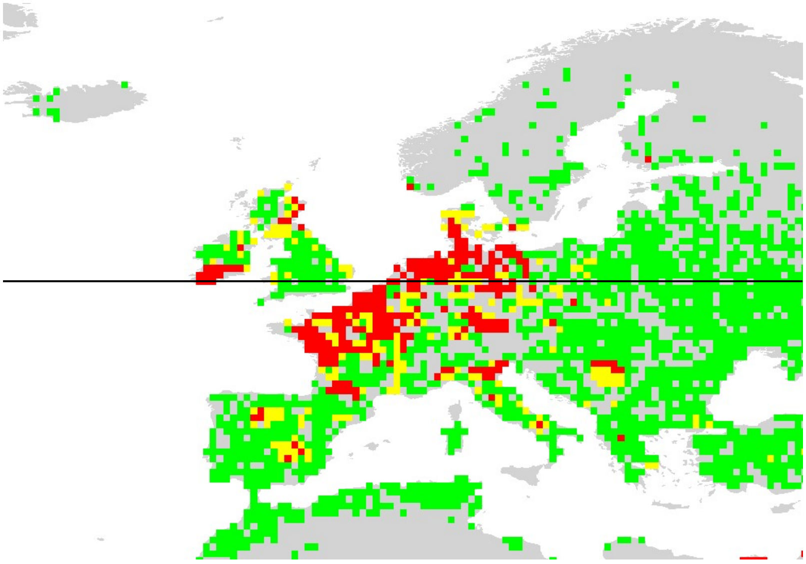
Red: Beyond zone of uncertainity (high risk)

Yellow: In zone of uncertainity (increasing risk)

Green: Below boundary (safe)



Geographical distribution of the control variable for **phosphorus** for the biogeochemical flows boundary, highlighting large agricultural zones where the P boundary is transgressed. Reference: P. Potter, N. Ramankutty, E.M. Bennett, S.D. Donner, Characterizing the spatial patterns of global fertilizer application and manure production. Earth Interact. 14, 1-22



Geographical distribution of the control variable for **nitrogen** for the biogeochemical flows boundary, highlighting large agricultural zones where the N boundary is transgressed. Reference: P. Potter, N. Ramankutty, E.M. Bennett, S.D. Donner, Characterizing the spatial patterns of global fertilizer application and manure production. Earth Interact. 14, 1-22

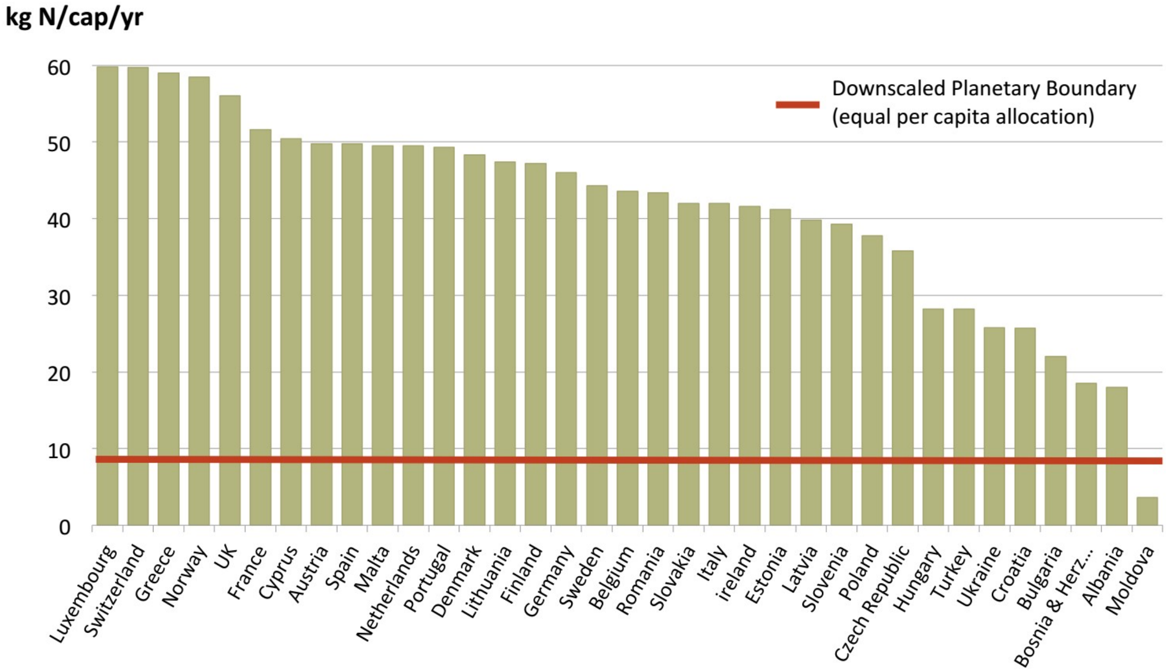
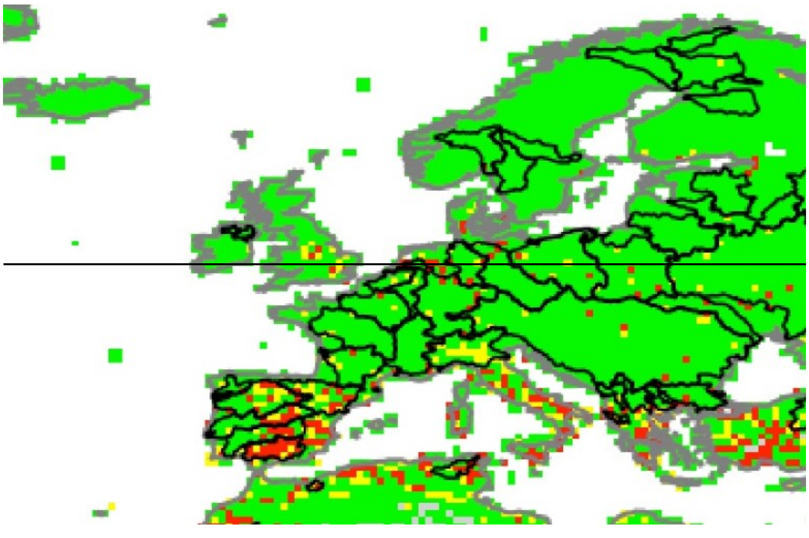
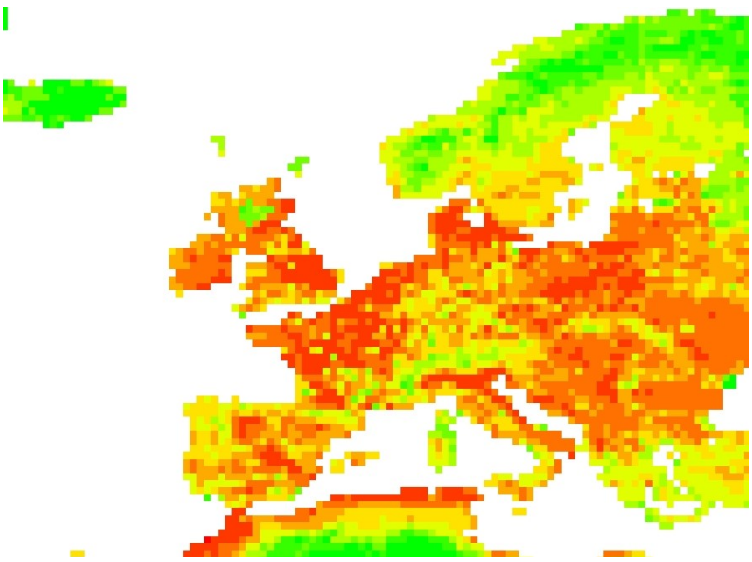


Figure 12. Per capita consumption-based N footprint of European countries according to Oita et al. (2016). Error bars of the original figure are not shown.

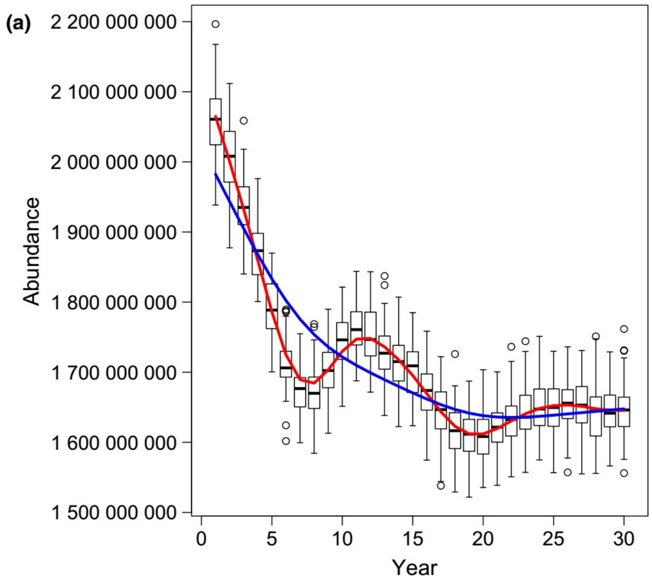
The country level N footprint of European countries (from Hayha et al 2018), showing that the European level PB need to be addressed at the country level due to large variations across states.



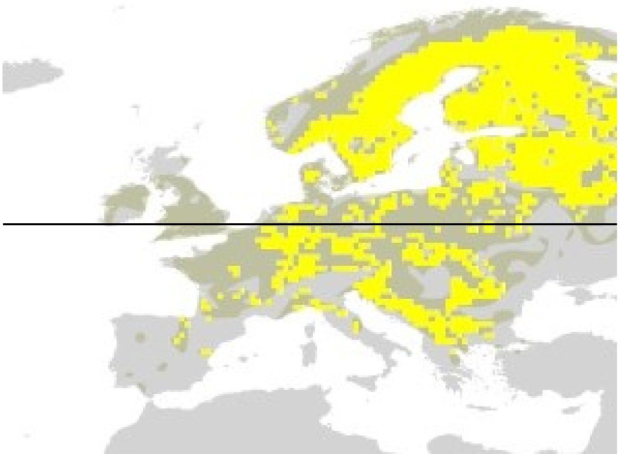
Transgression of the allowed monthly **water** withdrawals defined by EWF, plotted as the degree of exceedance (fraction of maximum allowed level) during months that show such an exceedance. Reference: A.V. Pastor et al., Hydrol. Earth Sys. Sci. 18, 5041-5059 (2014)



Biodiversity loss - species. Remaining mean species abundance (MSA) of original species, relative to their abundance in pristine or primary vegetation, which are assumed to be not disturbed by human activities for a prolonged period.



Biodiversity loss - individuals. Total changes in abundance and biomass of common breeding birds in Europe. Each point represents the totalled abundance estimates of 144 species from 1980 to 2009 (Inger R, Gregory R, Duffy JP, Stott I, Voříšek P, Gaston KJ. 2015. Common European birds are declining rapidly whilst less abundant species' numbers are rising. Ecology Letters 18: 28-36.).



Area of **forest cover** remaining in the world's major forest biomes compared to the potential forest cover, color-coded to show the position of the control variable (area of forest land remaining) with respect to the boundary. Reference (crop land cover): N. Ramankutty, J.A. Foley, Estimating historical changes in global land cover: Croplands from 1700 to 1992. Global Biogeochem. Cycles 13, 997-1027 (1999). doi: 10.1029/1999GB900046

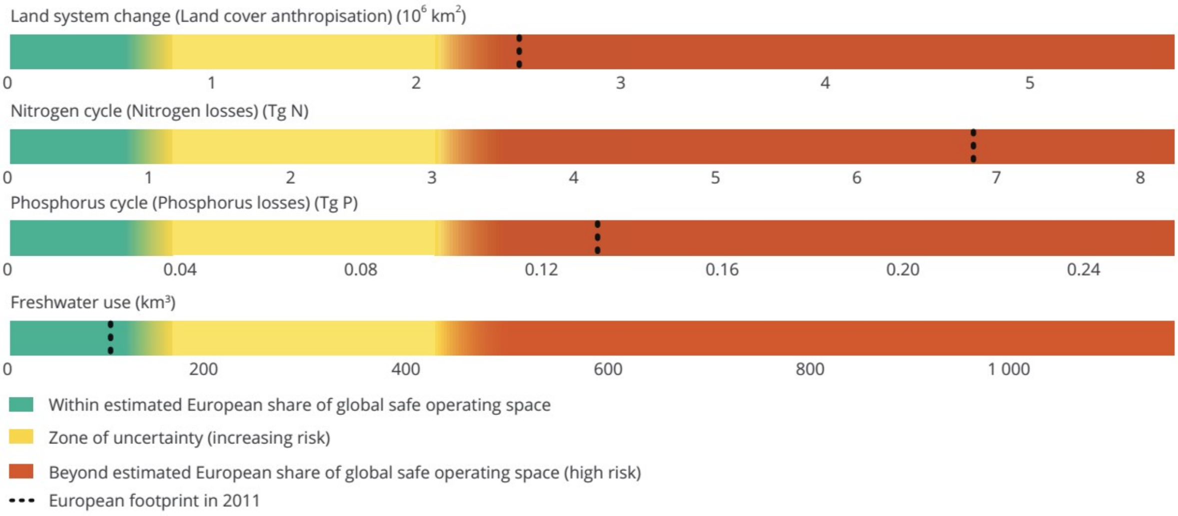
Data source: http://webmap.ornl.gov/wcsdown/dataset.jsp?ds_id=961

Reference (vegetation cover): O. Arino et al., Global Land Cover Map for 2009 (GlobCover 2009). © (European Space Agency (ESA) & UniversitÈ catholique de Louvain (UCL), 2012). doi:10.1594/PANGAEA.787668

Data source: http://due.esrin.esa.int/globcover/

(The yellow on the light grey map indicated forest cover remains (30-50%). Dark grey: potential forest area)

FIGURE 1.9 European consumption-based performance for selected planetary boundaries



Notes: The yellow zone of uncertainty represents the average range across the six principles to allocate a European share of the global safe operating space.

The study takes a conservative approach, as it calculates the European share based on the lower end values of the global zone of uncertainty defined by Steen et al. (2015). For example, the global zone of uncertainty for freshwater is defined as 4 000-6 000 km³ in Steffen et al. (2015). This study uses 4 000 km³ as the basis for calculating the European share. In some cases (indicated in brackets) slightly different control variables have been used than in Steffen et al. (2015).

Figure showing planetary boundaries for Europe (source: SOER 2020). Based on this figure, land cover anthropisation (anthropised land: agricultural and urbanised (sealed) land) is at 2.5 instead of c 0.8; nitrogen cycle is at 6.9 instead of 1; phosphorus cycle is at 0.13 instead of 0.03; freshwater use, however, within the boundary. It suggests that 2/3rd of Europe's land needs ecosystem restoration, and a decrease of 86% in nitrogen and 77% in phosphorus. These numbers are in good overlap with the other sources.

Appendix II. Details of targets of PBs – these target numbers (benchmarks) inlcude the data based numbers and the policy targets as well, and consider only the more radical one (*c.f.* data-based numbers above). Target numbers, descriptions, facts and sources are given.

Target number for EU+ by 2050	**Planetary Boundary**	**Description**	**Facts and figures**	**Sources, references**
Zero CO2-equivalent net emissions by 2050	Climate change	The European Green Deal pledges net-zero greenhouse gas emissions by 2050.	In 2017 net emissions of agriculture were 80.9 million tonnes.	EU Biodiversity Strategy https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer
Restore declining biodiversity and their ecosystems. Reach at least the 2000 numbers	Biosphere integrity, biodiversity loss	Biodiversity is defined as the remaining mean number of original species, relative to their number in pristine or primary ecosystems, which are assumed to be not disturbed by human activities for a prolonged period. The index for Europe was 0.45 for 2000 (base year), and is predicted to decline to 0.33 in 2050. Besides species number, the number of individuals is also declining rapidly, and need to be restored.	Mean Species Abundance is 1 in the absence of human society, which can not be a realistic target. I may propose arbitrary to set it to 0.5, which is rather close to what we had for 2000. (Note that in this source Europe was given, and no country level data were available, therefore this is not the same geographic coverge as SCAR countries.) Every 5th individual disappeared in the last decades.	Alkemade R. et al. (2009). GLOBIO3: A Framework to Investigate Options for Reducing Global Terrestrial Biodiversity Loss. Ecosystems 12: 374–390. https://link.springer.com/article/10.1007/s10021-009-9229-5 IPBES 2019

Reduce eHANPP by 15 % in 2050	Land-system change	The land-system change boundary is defined in terms of the amount of forest cover remaining, but this study use a more nuanced indicator, namely "human appropriation of net primary production" (HANPP). HANPP measures the amount of biomass harvested through agriculture and forestry, as well as biomass that is killed during harvest but not used, and biomass that is lost due to land use change.	National HANPP data were obtained from Kastner et al. for the year 2007 (the most recent year available), and measure the embodied human appropriation of net primary production (eHANPP). These data reflect the consumption-based allocation of HANPP to final biomass products from agriculture and forestry, where trade is accounted for using physical bilateral trade matrices.	O'Neill, D., et al. (2018). A good life for all within planetary boundaries. Nature Sustainability, 1: 88-95. https://www.nature.com/articles/s41893-018-0021-4
2/3rd of Europe's land needs ecosystem restoration	Land-system change	Land system change is accelerating due to human interventions, mainly intensive farming, and expansion of urban and built-up areas. Such changes deteriorates the natural capital and ecosystem services.	Nearly all of Europe's land is under human pressure, almost no wilderness areas remained. 30% of the EU need to reach favourable conservation status, 25,000 km of free-flowing rivers are restored, 10% of agricultural area is under high-diversity landscape features.	SOER 2020 EU Biodiversity Strategy (EU Nature Restoration Plan: key commitments by 2030)

Keep freshwater use at recent level	Freshwater use	The original planetary boundary for freshwater use was specified as a maximum global withdrawal of 4,000 km3/year of blue water from rivers, lakes, reservoirs, and renewable groundwater stores. The estimate of this study from the planetary boundaries framework is that humanity is currently consuming 65% of the global freshwater boundary. Water extraction for agriculture in Europe is 97,200 million m3/year, with large variations across countries.	"National water use data were obtained from the Water Footprint Network, and are an average for the period 1996–2005 (the most recent period available). The data measure the consumption and pollution of blue water related to the domestic water supply, plus virtual-water imports, minus virtual-water exports (and are thus a measure of apparent consumption)." In several European countries the freshwater PB is crossed already, there are big local variations. Climate trends in Europe predicts increasing use of irrigation to combat drought. Thus this target should be considered in the foresight.	O'Neill, D., et al. (2018). A good life for all within planetary boundaries. Nature Sustainability, 1: 88-95. https://www.nature.com/articles/s41893-018-0021-4 SOER 2020
Reduce P by 81 % in 2050 77% based on SOER	Biogeochemical flows	The planetary boundaries framework provides two sub-boundaries for biogeochemical flows, one for the phosphorus cycle and the other for the nitrogen cycle. National phosphorus and nitrogen footprint data were obtained from the Eora MRIO database.	5.21 is the average for SCAR countries on a scale, where value of 1 represents the boundary. • Phosphate in rivers (mg/litere) 2016: 0.007 • Gross phosphate balance 2013-15: 1.2 kg/ha • Gross nitrogen balance 2013-15; 49 kg/ha	O'Neill, D., et al. (2018). A good life for all within planetary boundaries. Nature Sustainability, 1: 88-95. https://www.nature.com/articles/s41893-018-0021-4 SOER 2020 https://ec.europa.eu/eurostat/databrowser/view/sdg_06_50/default/ta

				ble?lang=en https://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_risk_of_pollution_by_phosphorus https://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_gross_nitrogen_balance
Reduce N by 86 % in 2050	Biogeochemical flows	The planetary boundaries framework provides two sub-boundaries for biogeochemical flows, one for the phosphorus cycle and the other for the nitrogen cycle. National phosphorus and nitrogen footprint data were obtained from the Eora MRIO database.	7.00 is the average for SCAR countries on a scale, where value of 1 represents the boundary. Similarly significant reduction is supported by the FAO, which reports that between 1961-2014, the amount of cattle manure-N left on pasture increased by 85 percent worldwide.	O'Neill, D., et al. (2018). A good life for all within planetary boundaries. Nature Sustainability, 1: 88-95. https://www.nature.com/articles/s41893-018-0021-4 FAO. 2018. Nitrogen inputs to agricultural soils from livestock manure - New statistics. FAO, Rome.

				SOER 2020
Reducing chemical pesticides by 75% in 2050	Novel entities: chemical pesticides, antibiotics, plastics	The novel entities PB targets the environmental release of new substances that can fundamentally disrupt the functioning of ecosystems. There is no commonly agreed indicator yet. For this foresight, chemical pesticide was selected. There is a variety of targets based on different sources, and 75% was defined for this study. "Pesticides are an important component of the agricultural intensification. Modern farming methods rely heavily on pesticides to defend crops from a host of invertebrate and fungal pests and diseases, and to control weeds. Because of their intrinsic properties, pesticides can pose risks to humans, animals and the environment. Pesticide exposure is linked to various diseases including cancer, hormone disruption, asthma, allergies, and hypersensitivity. A line of evidence also exists for the negative impacts of pesticide exposure leading to birth defects, reduced birth weight, fetal death, etc. Soil contamination by pesticide residues has become an issue of increasing concern due to some pesticides' high soil persistence and toxicity to non-target species."	Pesticide use is expanding fast, valued at USD 65.3 billion in 2015 and predicted to continue growing annually at about 6 per cent until 2020. Strick regulations and drastic steps are needed as even reduced applications will still contribute to further accumulation. Ambitious country plans to reduce pesticide use are in France and Denmark: France, the Ecophyto II+: cutting chemical pesticide use in half by 2025. Denmark: The overall goal is to reduce the pesticide load by 40 % by the end of 2015	Steffen et al. 2015; Van Maele-Fabry et al., 2010; Silva et al. 2019; Kim et al. 2017 SOER 2020 https://www.politico.eu/pro/france-launches-committee-to-cut-pesticide-use-in-half-by-2025/ Protect water, nature and human health. Pesticides strategy 2013-2015. Danish Ministry of the Environment Communication from EC,

			compared with 2011. New Green Deal of Europe: „zero pollution action plan” to be deliver in 2021 The EU Farm to Fork Strategy plans a 50% cut by 2030	https://ec.europa.eu/info/sites/info/files/european-green-deal-communication-annex-roadmap_en.pdf EU Farm to Fork Strategy

European
Commission

Research and
Innovation

Important resources:

Häyhä, T., Cornell, S.E., Hoff, H., Lucas, P., van Vuuren, D., 2018. Operationalizing the concept of a safe operating space at the EU level – first steps and explorations. Stockholm Resilience Centre Technical Report, prepared in collaboration with Stockholm Environment Institute (SEI) and PBL Netherlands Environmental Assessment Agency. Stockholm Resilience Centre, Stockholm University, Sweden. https://www.stockholmresilience.org/publications/artiklar/2018-07-03-operationalizing-the-concept-of-a-safe-operating-space-at-the-eu-level---first-steps-and-explorations.html

IPBES. 2019. Global assessment report on biodiversity and ecosystem services, Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany. https://www.ipbes.net/global-assessment-reportbiodiversity-ecosystem-services

O'Neill, D., et al. (2018). A good life for all within planetary boundaries. Nature Sustainability, 1: 88-95. https://www.nature.com/articles/s41893-018-0021-4

SOER 2020. 2019. The European environment - state and outlook 2020. Knowledge for transition to a sustainable Europe. European Environment Agency. https://www.eea.europa.eu/soer-2020

SPIR 2020. Science, Research and Innovation Performance of the EU 2020. A fair, green and digital Europe. European Commission. https://ec.europa.eu/research/srip/interactive/

Steffen, W., et al., 2015. Planetary boundaries: guiding human development on a changing planet. Science 347(6223), p. 1259855

The nine planetary boundaries. https://www.stockholmresilience.org/research/planetary-boundaries/planetary-boundaries/about-the-research/the-nine-planetary-boundaries.html

The EU Biodiversity Strategy. https://ec.europa.eu/environment/nature/biodiversity/strategy/index_en.htm

The EU Farm to Fork Strategy. https://ec.europa.eu/food/farm2fork_en

References in the table, not detailed above:

Van Maele-Fabry, G., Lantin, A.C., Hoet, P. & Lison, D. 2010. Childhood leukaemia and parental occupational exposure to pesticides: a synthetic review and meta-analysis. Cancer Causes Control 21: 787-809.

Silva, V., Mol, Hans, G.J., Zomer, P., Tienstra, M., Ritsema, C.J. & Geissen, V. 2019. Pesticide residues in European agricultural soils – A hidden reality unfolded. Science of the Total Environment 653: 1532-1545.

Kim, K-H., Kabir, E. & Jahan, S.A. 2017. Exposure to pesticides and the associated human health effects. Science of the Total Environment 575: 525-535.

DIGITALIZATION IN AGRICULTURE AND RURAL AREAS

Gianluca Brunori, 5th SCAR Foresight Exercise expert

1. Scope

ICT technologies are related to two macro processes:

- ***Datafication****: low-cost capture of data on a range of production processes. Datafication improves decision-making by allowing the tailoring of decisions to the specificities of the context of intervention.*
- ***Digitization****: existing data and knowledge (perhaps traditionally recorded in paper-based systems) is translated into digital format and made storable, communicable, integrable with other data. Digitization allows to accelerate and dematerialize all information-related human activities.*
- ***Digitalization****: a process of socio-economic change related to digitization*

Digitalization covers a wide range of technologies:

- **Platforms**: Digital platforms collate information and promote broader access to, and more effective use of, a range of information and services, including software and collaborative workspaces
- **Sensors**: Sensors measure multiple properties of the physical world and transform them into digital data.
- **Global Positioning Systems:** connect people and things to satellites to identify their exact position
- **The Internet of Things**: devices and objects connected to each other via the Internet
- **Robots**: Devices that can perform physical operations under data control
- **UAV/Drones/Unmanned machines**: Devices with autonomous mobility
- **Big Data**: data sets the magnitude of which allows the identification of patterns and models with high-level accuracy through new analytical tools
- **Cloud computing**: (Wikipedia) on-demand availability of computer system resources, especially data storage and computing power, without direct active management by the user.
- **Artificial Intelligence**: the ability of machines and systems to acquire and apply knowledge and to carry out intelligent behaviour

- **Blockchain:** distributed database, replicated across many locations and operated jointly by all users
- **3D printing**: creation of tridimensional object under computer control, based on stratification and solidification of layers of liquid materials

These technologies are normally combined into **cyber-physical systems** that allow ‘smart processes’. The meaning of ‘smart’ is related to the capacity to adopt flexible decisions and carry out fine-tuned operations based on data interpretation. Smart processes enhance sensing and monitoring, analysis and planning, control, cloud-based events and data management. Cyber-physical systems affect also the social sphere, as they change the patterns of interaction between users, thus creating **socio-cyber-physical systems**.

2. Main facts, figures, trends

Internet coverage

- Broadband was used by 85 % of the households in the EU-28 in 2017, approximately double the share recorded in 2007 (42 %)
- By 2017, the share of EU-28 households with internet access had risen to 87 %, 32 percentage points higher than in 2007[i]. Less than two thirds (62 %) of the EU-28 population living in rural areas accessed the internet on a daily basis in 2016; this share rose to 72 % for people living in towns and suburbs and peaked at three quarters (75 %) of the population among city-dwellers[ii].
- In 25 out of the 28 EU Member States in 2016, people living in rural areas usually recorded the lowest share of internet access. In Greece this share was 42%, in Bulgaria and Romania only about 35% of rural population had access to the internet. Differences in the daily use of the internet may be attributed to a lack of infrastructure in rural areas, general levels of literacy, education, computer skills and language skills (in particular English) or cultural factors.

Smart farming

- The global market size of smart agriculture is expected to grow from approximately 9.58 billion U.S. dollars in 2017 to 23.14 billion U.S. dollars by 2022 (BIS research, 2018, Global Smart Farming Market-2017-2022).
- In 2016, 36 million agricultural IoT devices was be shipped globally. This number is forecasted to grow up to 75 millions by 2020 (BI intelligence, for statista.com)

3. Analysis of the main emerging issues in the domain covered by the working group

ICTs are meta-technologies that have the power of controlling the generation and the evolution of all other technologies. The effects of digitization have thus to be assessed in relation to the ecosystem of existing technologies and the related social patterns.

Expected impacts in the bioeconomy

At Farm level

Digitalisation is supposed to bring to farmers several benefits. **Productivity gains**[iii] can be obtained through better insights into production variables and dynamics, informed decision-making based on insights and scenario analyses, increased labour productivity and quality of work with automation, robotisation and enhanced control systems. Digitization can improve access to markets by improving product quality and available information to customers, and by allowing disintermediation from traditional intermediaries. Digitization in fact allows small farms to improve their communication with consumers. **Benefits to the environment** are also envisaged as digitization improves the efficiency of use of external inputs and the monitoring of the impact of agricultural practices on GHG emissions and other environmental indicators.

At Agricultural Knowledge and Innovation system level

AI, big data and cloud computing make many functions of traditional AKIS obsolete. Advisors will be increasingly needed to move from information brokering to data analysis. As data management will be increasingly relevant for farmers, AKIS and cooperatives will change their functions as data managers, analysts, brokers. In fact, traditional dealers are transforming themselves in data managers, and machinery and input suppliers are now “connected” to farmers through goods and services. New service providers propose new digital services alternative to the conventional ones.

ICT change in depth also research practices. Advanced molecular biology can be considered a branch of IT; big data revolutionize the relation between theory and empirical analysis. Lack of skills in this field may create a barrier to advancement of knowledge in many fields, and at the same time new ethical issues emerge in the field of science.

At Food value chain level

Data availability allows the reduction of ‘information friction’ between actors of the value chain, improving the processes of traceability, conserving the identity of the products along the chain, reducing the costs of certification and improving its accuracy. This will give more and more power to actors who have greater capacity to collect and analyse data.

Disintermediation from traditional intermediaries will reshape value chain patterns: Farmers can have direct access to distant markets and to consumers, and many will develop new business models supported by platforms. Improvement in logistics may foster new organizational patterns. 3D printing may generate a reorganization of the food industry, and create a divide between low cost, 3d printed and ‘authentic’ food.

At consumer level

Consumers will have access to a great deal of information about the product they buy, enhancing their power of choice but on the other hand being overstrained by too many choices. Increased information increases responsibility of actors, as information allows to anticipate consequences of choice: footprinting (Big Data, Blockchain), information on sustainability and nutrition parameters (Platforms, Big Data, AI), personalized nutrition (IOT). Information to consumers will shape the competition between firms and their business models.

At rural level

Digitalisation reconfigures spatial patterns (settlements, mobility, resource flows, communication), disrupts goods and services provision, opens new opportunities for natural resources and ecosystem services management. In theory, digitization has the potential to reduce the role of one of the weaknesses of rural areas, long distance. In practice, market-led digitization enlarges the gulf between rural and urban areas, as it amplifies the role of the poles of innovation. To revert this trend and to make rural areas fully get the opportunities offered by digitization, a strong effort to rethink the role and importance rural areas is needed.

At Policy level

Digitization offers a multiplicity of tools that policy-makers can use to improve the efficiency and effectiveness of policies. Improved communication between farmers and administrations will reduce the transaction costs and reduce the intermediaries. Information about production processes will allow to grant a 'licence to produce' in a more accurate way. Environmental monitoring systems will allow to implement performance-based policies. Food storage monitoring system will improve food safety. New media will allow to explore 'nudging systems' to orient consumers toward healthy and sustainable diets.

Potential risks

New generation of ICTs are potential game changers. Their embodiment into existing socio-technical systems will change societal organization, generating winners, losers and opponents. We can identify three types of risks related to digitization:

- **Design-related risks** are inherent to the quality of the technology design. *For example, technologies may 'nudge' users to specific patterns of behaviour, supporting existing unsustainable industrial agricultural models (eg. monoculture, heavy use of external inputs, high degree of mechanization); could be vulnerable to cyber-attacks, it may have in-built bias, it could give inaccurate responses, it could lead to missed opportunities, it could be characterized by fast* *obsolescence, it could breach privacy. Especially in a first phase of adoption of these technologies, costs (maintenance, assistance, upgrade) may be higher than benefits*.

- **Risks related to unequal access to digital opportunities**, that is the distribution of physical, social and human capital necessary to get access to digital opportunities. Non-adoption or late adoption may enlarge the gulf between social groups and territories, generating social and economic marginalization. This type of threat forms part of the phenomenon known as the digital divide. Agriculture and rural areas are domains where the digital divide has a high level of incidence. In rural areas, the risks of negative impacts are higher than in urban areas, as there are infrastructural, social and human capital reasons that contribute to create a deep digital divide between territories.
- **Systemic effects** are related to the dynamics activated by the introduction of a given technology into a socio-technical system. Impact may be related to delayed, cumulative, or indirect effects, or to feedback effect. Here, we also see the risk of betting on technologies and ignoring the full system. Literature already provides examples such as the Jevon's effect (increased use of resources as an effect of increased efficiency), path dependency (innovation evolution depends on the choices made at earlier stages), changes in social practices, relying too much on technology and facing problems of costly time-intensive permanent updates. For example, increased productivity at farm level may generate unemployment at industry level; available information on pollution may bring to social stigma on those who have, also accidentally, polluted; power imbalances related to data ownership may bring to creation of monopolies and loss of autonomy by weaker actor.

4. Contribution of digitization to the three transitions

4.1 Transition 1: Healthy and sustainable food for all

Table 1 provides a synthesis of the impacts of digitization on the sub-targets of transition 1.

Table 1 – Impacts of digitization on transition

Target	Impact of digitization	Risks
Healthy and sustainable diets	Educational tools Access to nutrition-related information Systems for Personalized nutrition (biometric data+food scanner+software) Shift from cure to prevention based on big	Inaccurate software design bringing to malnutrition Inequality between users and non-users "Nudging" tools affecting

	data and AI[iv] Big Data and advanced analytics can extend and make footprinting more reliable	individual freedom Standardisation of the "healthy diets", which may not be healthy for all Information overflow
Safe food	Educational tools Smart packaging and smart labelling Blockchain for improved coordination in the value chain Sensors to monitor processes	Environmental impact of dismissed sensors and of computing Displacement of artisanal food and small food business More waste because of early alarms
Diverse food	Decision support systems based on AI and advanced analytics Knowledge and resource-sharing Business to Consumer and Business to Business platforms	Inequality between small and large farms Disadvantages for small-scale agriculture Too high investments for small-scale farmers
Higher nutritional density	Education tools for farmers and consumers Food scanners, smart labelling	Inappropriate use of information Consumers do not know or do not understand
Biomass production within planet boundaries	Measurement of the carrying capacity of agro-ecosystems (satellite+drones+sensors+ cloud+analytics)	Inaccurate software design. Complexity of use and maintenance
Zero waste in the value chain	B2B platforms for knowledge and resource sharing Advanced analytics for optimizing	Inaccurate design. Shift of power to controllers Information inequalities

	cascading processes	No control
Exporting sustainable surpluses, importing sustainable commodities	Generalization of footprinting and link to trade policies Blockchain for greater transparency along the chain	Inappropriate use of information Control impossible

Healthy diets

Digitization offers a variety of solutions to improve dietary patterns. It can improve food education thanks to an easier access to educational tools, it can strongly facilitate the access to nutrition-related information (including gastronomy), it can foster personalized nutrition recommendations based on biometric data, it can support a shift from cure to prevention with the use of big data.

Improved footprinting[v] can give consumers information about the impact of the food they eat on the environment, guiding their choice towards more sustainable patterns.

Safe and diverse food, higher nutritional density

Food safety can be improved through sensors and smart packaging and through an improved coordination between actors of the chain made possible by blockchain technologies. (See WEF)

Diversity of available food can be made possible with increased access of farmers to education and knowledge related to biodiversity and to its use and with decision support systems. Digitization also supports the management of biodiversity-based value chains as it reduces the transaction costs between producers and consumers, and allows niches of production-consumption to thrive and to develop.

Biomass production within planet boundaries

Digitization makes it possible – through data availability thanks to satellites, drones, sensors- to measure the carrying capacity of agro-ecosystems, and therefore to identify locally-tailored sustainable yield standards and monitoring systems will be able to tell in a real time if overshooting local planet boundaries has occurred.

Zero waste in the value chain

Digitization (RFID systems, sensors, measuring) allows a rapid characterization of biomass processed and of the leftovers of the process. Sharing of this information between firms will reduce the transaction costs between firms. Big data will allow a real-time, locally based, assessment of hierarchies of value between biomass utilization, allowing a smart cascading approach.

Exporting sustainable surpluses

Digitization will allow a generalized use of footprinting, which will improve the awareness of the true cost of food among consumers and citizens and supporting policy making with enough evidence. Available information about the impact of distant production processes will allow the problematizaton of certain patterns of consumption and trade, and will increase the level of responsibility of firms, consumers, and policy makers.

4.2 Transition 2: Full circularity of food systems

A circular economy is based on a) design of the product and production processes to minimize waste and to extend the product life cycle; b) reduce the amount of 'funds' being used in the economy by shifting from 'goods' to 'services'; c) an industrial ecosystem with 'functional diversity' that allows industrial symbiosis; d) improving the processes of reuse and recycling e) improving cooperation between firms for reusing and recycling; f) reorganizing logistics for optimizing flows between firms, g) connecting the individual stakeholders of the system.

Knowledge development

Circular economy represents a new socio-techno-economic paradigm, alternative to the linear economy, as its main principles are related to the efforts to design the product, the processes and the legal/built environment around the optimization of reducing, reusing, and recycling activities.

Adopting this new paradigm is an effort that involves all actors of the economic system, including policy-makers, citizens and consumers. This requires strong efforts in the field of education, training, access to information and support services. Digital education and training courses, open source information, sharing experimental data, dedicated social media for peer-to-peer interaction can strongly support this process.

Redesign products and processes

A circular economy needs an alternative approach to product and process design. Product design should extend the life cycle of the product and minimize the costs of disassembling the product after use. In order to submit the recycling process in a right cascading order, a rapid characterization of feedstocks is required, to be shared with potential users.

Raising consumers' and citizens' awareness

A well-established circular economy depends on the efficient management of land and of material flows. Citizens and consumers have an important role in that, as they can choose the products with lower environmental footprint, and provide the first step of an appropriate classification and separation of domestic leftovers.

Encouraging diversity

Circular economy is based on 'functional diversity': diversity of input and output multiplies the possibilities that leftovers of one process are turned into input for another one. This principle is translated into the construction of industrial ecologies wherein the leftovers of production processes become the inputs for other firm' production processes. The focus of research is to reduce the friction between these transactions and optimize the connections. Frictions are related both at physical and information causes. Digitization can reduce substantially information friction by providing databases for open access to information, platforms for B2B collaboration, monitoring tools to explore the diversity of the system.

Market efficiency

Circular economy should be able to enhance competitiveness of firms. An efficient cascading process, based on sensors and shared databases, can optimize the value extracted from the biomass, and efficient leftover management can reduce substantially the 'biomass flow friction'. Robots, sensors, advanced analytics, Artificial Intelligence can increase sensibly the efficiency of these processes and improving the quality of labour. Efficiency of logistics can benefit from blockchain, sharing platforms, decision support systems.

Table 2

Target	**Impact of digitization**	**Risks**
Design of the product to minimize waste production and to extend its life cycle	Smart packaging and smart labelling[vi], design, simulations	Environmental costs of packaging and transport Disadvantages for small-scale farming
Reduce the amount of 'funds' being used in the economy by shifting from 'goods' to 'services'	B2C platforms to manage durable goods services [vii], B2B platforms for sharing durable goods	Insufficient skills to use the platform Platforms filter are not open access

An industrial ecosystem with 'functional diversity' fostering industrial symbiosis;	B2B platforms; Improved genetic screening of biodiversity[viii]. Improved analytics for system biology[ix]	Insufficient skills to use the platform Industry closed or cost-based system Inaccurate design of the systems generating unexpected consequences
Reorganizing rural areas	e-government; e-services;	Costs of complexity; lack of skills
Improving reuse and recycling processes	Robots, sensors, advanced analytics, artificial Intelligence... can be used by all	Costs of the equipment. Complexity of the systems bringing to maintenance and operating costs
Improving cooperation between firms for reusing and recycling	Joint databases, Big data for characterization of feedstocks, sharing platforms[8]	Shift of power to controllers No control
Reorganizing logistics for optimizing flows between firms.	Inter-firm Blockchain, Robotization, sharing platforms, IoT, linking transportation planning to agricultural sensors	Digital divide. Complexity of the systems bringing to maintenance and operating costs More energy needed
New consumption patterns	Footprinting, 'nudging' software, sensor to monitor waste, collaborative consumption platforms[x], RFID to follow consumers, all information available	Nudging tools affecting individual freedom Standardising consumption

4.3 Transition 3: Substantial increase of biological, social, and economic diversity

A substantial increase of biological, social, and economic diversity requires a change of technical paradigms, consumers and citizens' awareness; a system of interconnected biodiversity databases

monitoring biodiversity in the systems; an ecosystem of farms with 'functional diversity' surpluses;

and availability of market and technical alternatives. Digitization can give an important contribution to these efforts, as reported in Table 1.

Knowledge development

The current techno-economic paradigm of conventional agriculture is still influenced by the Fordist principle according to which efficiency is based on standardization. To revert this principle a deep transformation of production processes and business models is needed, also for more circularity in systems (see above). Digitization can foster education, access to information, training, technical support. Moreover, as information about functional diversity is key to its use, sharing about trial data can accelerate dissemination and exploitation of innovation.

Knowledge about diversity can be enhanced through systematic data collection (involving also citizens), open data and knowledge sharing platforms.

Raising consumers and citizens' awareness

A vibrant demand of diversity can foster new techno-economic models. Despite the variety of brands they can find in the supermarkets, consumers have scarce awareness of the variety of food that nature offers. Access to information can be improved through digital communication channels and through decision support systems installed on smartphones.

Building biodiversity-based value chains

The potential value of biodiversity needs to be turned into market value through appropriate value chains, that are able to preserve the identity of the product when proposed to consumers and remunerate adequately all actors of the chain (cf ecosystem services concept). On this regard, blockchain can help conserving identity of the genetic variety along the chain[xi], and e-commerce or B2B platforms can help farmers to find market channels appropriate to product size and characteristics. Sensors and improved analytics can make social responsibility reports more accurate[xii].

Supporting policies

Policies for biodiversity need appropriate data collection, analytics, and measurement methodologies to monitor diversity, mapping biodiversity distribution and risk, assessing the impact of policies, controlling individual practices.

Table 3

Target	Impact of digitization	Risk
A change of technical paradigms	Digitization can support education and access to information and training. Platforms to share trial data	Inadequate skills
Raising consumers and citizens' awareness	Social media to share knowledge; educational tools, support to decision tools	Inadequate skills. Inappropriate use of information
A system of interconnected biodiversity databases	Biodiversity digitization[xiii], Knowledge sharing platforms[xiv], Open Big data	Costs of complexity of systems. Quality of data
Monitoring biodiversity in the systems	Satellites+drones+sensors+cloud+advanced analytics; AI for decision support systems	Accountability of AI systems
An ecosystem of farms with 'functional diversity' surpluses;	Improved communication between firms: B2B platforms[9]	Inadequate skills Inadequate networking
Availability of market and technical alternatives	Digitization can substantially accelerate the phenotyping and genotyping (ICT applied to life sciences), improve the capacity to recognize and characterize genetic diversity (open database, AI), monitor biodiversity (sensors, citizens' science)[xv]. Decision support systems based on AI for recognition of biodiversity at farm level[xvi].	Concentration of data ownership Further standardization (opposite of the intention)
A change of business models	Blockchain can help conserving identity of the genetic variety along the chain[xvii]. Disintermediation can foster diversification	Concentration of power related to technology

	of the B2B relationships to find market channels appropriate to product size and characteristics. Sensors and improved analytics can make social responsibility reports more accurate[xviii].	ownership Blockchain needs a lot of energy
A change of consumers' practices	Education, Improved access to information (footprinting)	Inappropriate use of information
Supporting policies	Monitoring impact of policies, mapping biodiversity distribution and risk	Inadequate skills. Stigma to polluters

5. **What are the appropriate (quantified) targets - relevant to the domain – to achieve the goals?**

- 100% (physical, educational, economical) access to the web
- Big data 70% open
- Digitization of 80% of services and government procedures
- 50% teleworkers
- enough energy (e.g. for AI or blockchain)
- enough broadband volume (G5 or more)

6. **Policy conditions for the achievement of the targets**

To be channelled toward societal interest, digitalization will require a deep revision of the regulatory and governance contexts. As ICTs are game changers, anticipation of risks and benefits of digitization should be strongly encouraged at all level. When possible, regulation should avoid already known consequences, as breaches to privacy and concentration of power related to data ownership and analytical capacity.

A first area of intervention is digital divide. Besides the importance of giving access in all regions to broadband, it will be important to encourage the access of disadvantaged groups, and launch broad programmes of training to give all the opportunity to achieve basic ICT skills. Research and innovation policies should encourage the development of innovations tailored to small farming and small food business. Initiatives such as 'smart villages' aim at encouraging rural communities to look for digital solutions to their problems.

Regulation of industrial and intellectual property, data protection, protection of industrial secrets (competition), consumer protection, former protection as producer, and contracts are questioned by digitalization. GDPR is having a strong impact on business models, and it is giving a direction to innovation, as it provides mandatory rules relative to personal data, but there is a large number of non-regulated issues that will require attention, and not all can be regulated by ‘hard law’. In general, these issues can be related to unintended impacts (for example, 3D printing may change consumption habits, generating more waste), implications of delegation of tasks, safety and responsibility, privacy concerns, social relations (what if robots become emotionally involved?). Increasing attention is dedicated to the ‘code of ethics’ instrument, the nature of which is voluntary, but its adoption can be rewarded by policies.

A strong emphasis on **open data** would reduce substantially the cost of initiating start-ups providing services, and affordable technological solutions would be possible. Increased information availability, linked to a distributed capacity to produce, use and communicate knowledge, can increase the level of respons<<xibility of actors. Access to information is also the necessary premise of good quality education, that can benefit a lot from open access.

Finally, measures are necessary to increase the reliability of information released and to introduce mechanisms and institutions to validate it, as the easiness to produce information could also bring to manipulation.

7. Challenges for research

Technological advancement is so far largely separated from the assessment of socio-economic consequences. This is because the approach to technology design is based mainly on performance remunerated by the market. Ethical considerations should be embodied into innovation processes and legislation and governance should ensure that ethical concerns are not left just to individual innovators. More orientation towards the commons (what is commons? what is private?). Public-private partnerships have to be re-evaluated with a long-term view - most of them turned out to be very costly to the public.

References

1. https://ec.europa.eu/eurostat/statistics-explained/index.php/Digital_economy_and_society_statistics_-_households_and_individuals#Internet_access)

2. https://ec.europa.eu/eurostat/statistics-explained/index.php/Statistics_on_rural_areas_in_the_EU

3. Balafoutis, Athanasios, Bert Beck, Spyros Fountas, Jurgen Vangeyte, Tamme Van der Wal, Iria Soto, Manuel Gómez-Barbero, Andrew Barnes, e Vera Eory. 2017. «Precision Agriculture Technologies Positively Contributing to GHG Emissions Mitigation, Farm Productivity and Economics». Sustainability 9 (8): 1339. https://doi.org/10.3390/su9081339.

4. https://theconversation.com/to-create-a-sustainable-nhs-we-must-urgently-invest-in-cutting-edge-technology-121201

5. Magnin, C. (2016). How big data will revolutionize the global food chain. Digital McKinsey.

6. Skinner, G. A. (2015). Smart labelling of foods and beverages. In Advances in Food and Beverage Labelling (pp. 191-205). Woodhead Publishing.

7. Taranic, I., Behrens, A., & Topi, C. (2016). Understanding the circular economy in Europe, from resource efficiency to sharing platforms: The CEPS framework. CEPS Special Reports, (143).

8. Kuzmin, E., VanderSluis, B., Wang, W., Tan, G., Deshpande, R., Chen, Y., ... & Koch, E. N. (2018). Systematic analysis of complex genetic interactions. Science, 360(6386), eaao1729.

9. Kitano, H. (2002). Computational systems biology. Nature, 420(6912), 206.

10. Sposato, P., Preka, R., Cappellaro, F., & Cutaia, L. (2017). Sharing economy and circular economy. How technology and collaborative consumption innovations boost closing the loop strategies. Environmental Engineering & Management Journal (EEMJ), 16(8).

11. Antonucci, F., Figorilli, S., Costa, C., Pallottino, F., Raso, L., & Menesatti, P. (2019). A Review on blockchain applications in the agri-food sector. Journal of the Science of Food and Agriculture.

12. Efimova, O., & Rozhnova, O. (2018, October). The corporate reporting development in the digital economy. In The 2018 International Conference on Digital Science (pp. 71-80). Springer, Cham.

13. Edwards, J. L., Lane, M. A., & Nielsen, E. S. (2000). Interoperability of biodiversity databases: biodiversity information on every desktop. Science, 289(5488), 2312-2314.

14. Herz, A., Matray, S., Sharifova, H., Wolck, A., Sigsgaard, L., Penvern, S., ... & Kelderer, M. (2016). EBIO-Network: a web-based platform for knowledge sharing on functional agrobiodiversity in organic apple production. In Ecofruit. 17th International Conference on Organic Fruit-Growing: Proceedings, 15-17 February 2016, Hohenheim, Germany (pp. 277-278). Fördergemeinschaft Ökologischer Obstbau eV (FÖKO).

15. Duro, D. C., Coops, N. C., Wulder, M. A., & Han, T. (2007). Development of a large area biodiversity monitoring system driven by remote sensing. Progress in Physical Geography, 31(3), 235-260.

16. Steenweg, R., Hebblewhite, M., Kays, R., Ahumada, J., Fisher, J. T., Burton, C., ... & Brodie, J. (2017). Scaling-up camera traps: Monitoring the planet's biodiversity with networks of remote sensors. Frontiers in Ecology and the Environment, 15(1), 26-34.

17. Lin, C., Wang, J., & Ji, L. (2019). Notes of Life: A platform for recording species observations driven by artificial intelligence. Biodiversity Information Science and Standards, 3, e37010.

18. Antonucci, F., Figorilli, S., Costa, C., Pallottino, F., Raso, L., & Menesatti, P. (2019). A Review on blockchain applications in the agri-food sector. Journal of the Science of Food and Agriculture.

19. Efimova, O., & Rozhnova, O. (2018, October). The corporate reporting development in the digital economy. In The 2018 International Conference on Digital Science (pp. 71-80). Springer, Cham.

SOCIO-ECOLOGICAL SYSTEMS OF HEALTHY AND SUSTAINABLE FOOD SYSTEMS

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Introduction:

Growing scientific consensus makes the case that we have entered the Anthropocene, a new geological era where human actions have become the dominant geological force measurable on a planetary scale (Figure 1). While climate change is currently recognized as a global challenge, earth system scientists are equally signalling the measurable and worrying changes to other planetary biogeochemical cycles notably nitrogen, phosphorus, water, and carbon. Biodiversity is often also flagged as undergoing radical changes in composition, and distribution with important impacts not just on species richness and species of conservation concern, but with feedback impacts on the aforementioned biogeochemical processes changing the rhetoric from one that has been focused nearly exclusively on species conservation to one which recognizes the functional contribution to biodiversity to regulation earth system processes and reslience[1]. Which foods are produced, how they are produced, where they are produced and how much is lost and wasted have disproportionate impacts on planetary boundaries[2-4]. While tempting to consider such impacts solely on the basis of European production and consumption, European trade is an important exporter of environmental impacts which should be taken into consideration.

Food's impacts are not limited to planetary boundaries[5,6], but also have devastating impacts on human health[7]. Dietary related disease risks are collectively the largest driver of premature mortality globally, including in the European context[8]. While specific values will differ by country and by socio-economic context most countries demonstrate decreasing risks associated with malnutrition (though with some persistant challenges in poor, marginalized and immigrant/refugee communities) with sharp increases in risk of diabetes, and incidence of over-weight and obesity, including in children and youth.

Food as such, is thus largely failing Europe on both environmental and human health. This growing realization calls out the inconsistencies and incoherencies in European Agricultural policy[7,9]. Major trends emerging are growing awareness by both the public and policy makers of the extent to which the food system is not providing public goods and benefits with consumers demonstrating early shifts to healthy and more sustainably produced food options, public policy at the European Commission (European Green Deal), state, and city level (e.g. European Cities signing on the Milan Urban Food Policy Pact, or the EAT/C40 Food Cities Commitment), and the private sector expanding the range of offering of plant based foods.

Warning signs are also visible that the farming community and rural regions are most impacted by these transitions, that growing finger pointing to the farming community is placing tremendous strain and burden on producers whom are increasingly being asked to produce more food, better foods, and to protect the environment while faced with increasing technological lock-ins, and falling profit margins. There is an enormous risk that well-intentioned transitions to safe and just (and productive) food systems fail to consider implications of transitions on rural communities, that policies developed are overly specific and restrictive limiting innovation, diversity, and flexibility which are all hall-marks of resilience[10,11]. That rapidly shifting consumer demands vary at rates that are impossible for the production sector to respond to. And that innovative, yet high-specialized and expensive food production technologies create lock-ins that limit farmer flexibility in rapidly changing consumer, climate, and policy contexts.

1. Main emerging issues

Status of Health in the European Context

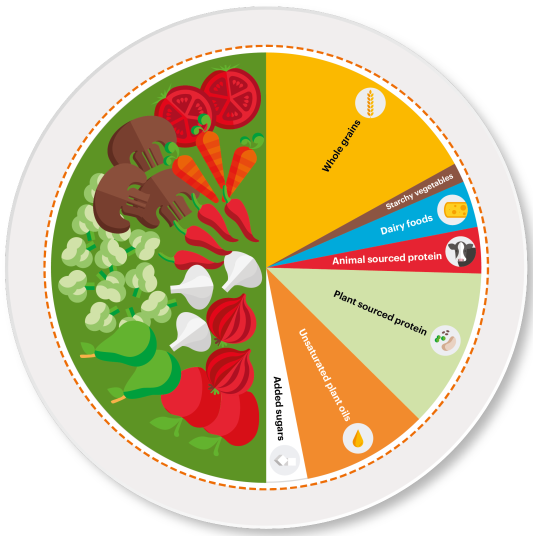
a.1 main facts, figures and trends

The EAT-Lancet Commission provides a global assessment of the safe operating space for food considering both planetary boundaries as environmental limits, and providing a universal definition of health diets which leave ample room for flexibility of local choice, cultural preferences and tastes (Figure x)[5]. The European public can be generalized as consuming a Western diet which is high caloric consumption, and high in meat consumption. In contrast it tends towards low consumption of protective foods.

The Global Burden of Disease Collaborative[8] provide an excellent summary regional and global food consumption trends (figure 2ab). This summary divides Europe into three regions: Central Europe, Eastern Europe, and Western Europe. It also provides a helpful comparison with other parts of the globe. In general, high-income countries significantly over-consume. The Global Burden of Disease Collaborative estimates that in high-income countries, individuals consume approximately 3700 kcal per day compared to the 2000-2500 kcal per capita per day recommended by most national dietary guidelines. This overconsumption, much of which comes from sugary beverages, is an important source of food waste fuelling both over-use of environmental resources, as well as driving dietary risks related to over-weight and obesity.

Figure x:

	Macronutrient intake grams per day (possible range)	Caloric intake kcal per day
Whole grains		
Rice, wheat, corn and other	**232**	**811**
Tubers or starchy vegetables		
Potatoes and cassava	**50** (0–100)	**39**
Vegetables		
All vegetables	**300** (200–600)	**78**
Fruits		
All fruits	**200** (100–300)	**126**
Dairy foods		
Whole milk or equivalents	**250** (0–500)	**153**
Protein sources		
Beef, lamb and pork	**14** (0–28)	**30**
Chicken and other poultry	**29** (0–58)	**62**
Eggs	**13** (0–25)	**19**
Fish	**28** (0–100)	**40**
Legumes	**75** (0–100)	**284**
Nuts	**50** (0–75)	**291**
Added fats		
Unsaturated oils	**40** (20–80)	**354**
Saturated oils	**11.8** (0-11.8)	**96**
Added sugars		
All sugars	**31** (0–31)	**120**



Food composition is the second important consideration regarding impacts of food on dietary health. The EAT-Lancet Commission[5] has proposed a “Planetary Health Diet” which if followed would reduce up to 11 million premature adult deaths per year. In an analysis of the Planetary Health Diet and dietary recommendations of G20 countries, we have found that the Planetary Health Diet and national guidelines of European countries are largely compatible, but that there are significant differences between dietary recommendations and actual food consumption patterns. While the Planetary Health Diet is a useful reference point, we find that national dietary guidelines, if followed, would have similar impacts on both human health and environment as the Planetary Health Diet generally. Thus either national dietary guidelines, WHO guidelines, or the EAT-Lancet Planetary Health guidelines all serve as useful targets for shifting consumer behaviour with powerful impacts on both improving human health and on bringing food within environmental limits.

In Europe the current situation can be summarized as such:

Total Calories: FAO estimates that on average Europeans consume 2600 kcal per day which is only slightly higher than the recommended 2500 kcal per day recommended. The share of undernourished in Europe is estimated at 2.5%, and the share of obese at 24.9% according to FAOStat (2019.)

Red Meat: consumption is 2-3 times greater than the upper limited recommended. Overconsumption is highest in Western Europe.

Processed Meat: 2-10 times greater than recommended though the nutrition community does not yet fully understand the origin of negative health impacts of processed meat and some methods may have significantly less negative impacts than others. Salt, nitrates, smoke and other preservatives are thought to be problematic but require greater attention. Overconsumption is highest in Western Europe.

Sugar Sweetened Beverages: over consumed by 20-100+ times above recommended daily allowance. Overconsumption is highest in Western Europe.

Fruits: Consumption is well below recommended levels and would need to increase 2-4 times to meat recommended consumption levels.

Vegetables: Under consumed throughout Europe though Eastern Europe is closest to the recommended consumption level. Vegetable consumption would need to increase 0.5-3 times in the region.

Legumes, Beans and Pulses: Grossly under-consumed throughout the European region with recommended 400-500% increases. In Europe, the private sector appears to be responding to this increased need though the production of milk and meat alternatives rather than through the increased consumption of beans, lentils and pulses as raw ingredients. Soy remains the dominant plant-based protein used.

Whole Grains: Most updated national dietary guidelines call for at least 50% consumption of whole grains. While grain consumption remains high in Europe, much of this is in the form of high refined wheat flour. Diversifying grains and increased consumption of whole grains would need to increase 10 times or more.

Nuts and seeds: Largely under-consumed in throughout Europe with needed increases >10 times for all regions.

In general, European food consumption follows patterns of other parts of the Western world with a need to reduce red meat and sugar consumption, but with significant opportunities to increase consumption, and thus also production of fruits, nuts, vegetables seeds, and whole grains.

a.2 Distance of 'Business as Usual' situation from SDG and Planet boundaries

The above section describes the distance to dietary health targets. Business as usual for Europe is relatively stable compared to Asia and Africa where anticipated movements to Western diets are of concern. In France for example, red meat consumption has fallen by 12% over the past decade, though it remains above recommended consumption levels.

Worrisome are growing trends of childhood obesity due to both over-consumption of junk foods high in sugar, salt, and fat, and increasing sedentary lifestyles.

There does however appears to be a growing response to such trends including public and private media campaigns to encourage consumption of fresh produce. For example Intermarche's ad, or the Les Fruits et Legumes Frais campaign (figure x) which was plastered across France during the summer of 2019. There are also signs that food environments in city centers and public spaces are responding to the public health challenge both in response to, and in advance of shifting consumer trends. This is most visible in urban centers, public transportation hubs (airports, train stations), and also visible in slowly shifting offer by major food companies and retailers.

Figure X: **the Fruits and Legumes Frais ad campaigns hit France in the summers of 2018 and 2019 encouraging consumers to spend time cooking, and to consume fresh produce while emphasizing that fresh produce are not high cost. Indirectly, the campaign emphasizes the need to increase consumption of dietary diversity, which calls into question how the agricultural sector will respond to growing demand for a diversity of produce. There is no mention of how these foods are produced in the ads.**

a.3 Environmental, health, economic, social and ethical emerging issues and controversies

Choice or fears of limited food choice drive deep critiques of health diets have argued that we cannot dictate what people eat and that dietary guidelines limit choice. This fails to recognize that dietary guidelines are very flexible. While significant attention is given to reducing meat consumption, particularly of ruminant meat, less attention is paid to the thousands of edible plant species, fish, and poultry whose consumption can increase. Taxing of unhealthy foods is highly controversial, including of sugar despite its being largely over consumed and with little to no health benefits. Taxing of meat has been approached/discussed in the UK, though remains highly controversial since meat consumption can have positive health benefits when consumed within dietary limits.

Access and affordability of foods are also highly controversial with several studies flagging that healthy foods can be more expensive than junk foods, and also noting that healthy foods can be more difficult to access in lower income neighborhoods. The so-called food deserts. While some studies have made the case that healthy foods are more expensive than unhealthy ones, there are at least two confounding factors. First, there are infinite combinations of foods that falling within healthy consumption ranges, which begs the question which combinations are more or less costly than which combination of unhealthy foods?

Convenience is also argued to be an important factor in dietary shifts with some making the case that in increasingly urban, and busy households, there is limited time for food preparation. Parents of families are increasingly over-committed, with both spouses engaging in full time jobs if not multiple jobs. The case has been argued that healthy food takes too much time to prepare driving parents to opt for prepackaged and pre-prepared foods. There are at least two important questions here: (1) what are the social consequences of this trend, (2) what options exist to make healthy and sustainably produced foods a convenient and desirable choice.

The EAT-Lancet Commission[5] (Willett et al. 2019) has proposed five environmental limits within which food systems should operate in order to reduce the risk of irreversible environmental change. The Planetary Boundaries should not be confused with targets – which policies and actions often aim to achieve as boundaries are not aimed for, but should be stayed within. Risk of irreversible change increases as society approaches, and surpasses the boundary limits described. Thus boundaries offer the best estimate of the upper limits of human appropriation of environmental processes. Efforts to move food system to within these boundaries should be supported by integrated policies and actions. Planetary boundaries recognize that in the Anthropocene, humans have become the dominant environmental force with impacts that are measured on a planetary scale on key planetary processes; notably the significant alteration of the stocks and flows of major biogeochemical processes. The six processes that the EAT-Lancet has elevated are (i) green-house gas emissions, (ii) land allocations, (iii) freshwater utilization, (iv) nitrogen loss, (v) phosphorus loss, and (vi) loss of biodiversity. The global boundaries for food are listed in table 1.

Table 1.

Earth System	Control Variable	Boundary	Interpretation
Carbon Cycle	GHG Emissions	5 Gt CO2 e yr $^{-1}$ (4.7- 5.4 Gt CO2 er yr^{-1})	No new emission from Agriculture
Land System	Cropland Use	13 km^2 (11-15 M km^3)	Zero land expansion
Water Cycle	Water Use	2500 km^3 yr^{-1} (1000-4000 km^3 yr^{-1})	>30% environmental flows in basins
Nitrogen	Nitrogen Use	90 Tg N yr^{-1}	<1-2.5 mg N L^{-1}

Cycle		**(65-90 Tg N yr^{-1})** **(90-130 Tg N yr^{-1})**	
Phosphorus Cycle	**Phosphorus Use**	**8 Tg P yr^{-1}** **(6-12 Tg P yr^{-1})** **(8-16 Tg P yr^{-1})**	**<50-100 mg P m^3**
Biosphere	**Biodiversity Loss**	**10 E/MSY** **(1-80 E/MSY)**	**50% land intact by ecoregion + 10% land intact in agriculture at the 1 km^2 scale**

a.1 Main facts, figures and trends

See companion paper and section below on biodiversity. It is also important to flag here multiple efforts to downscale planetary boundaries for the European region. Notable is the FABLE effort (Food Agriculture Biodiversity, Land and Energy) which is a collaboration of 20 countries plus the EU to develop globally coherent national pathways to healthy and sustainable food and land use systems.

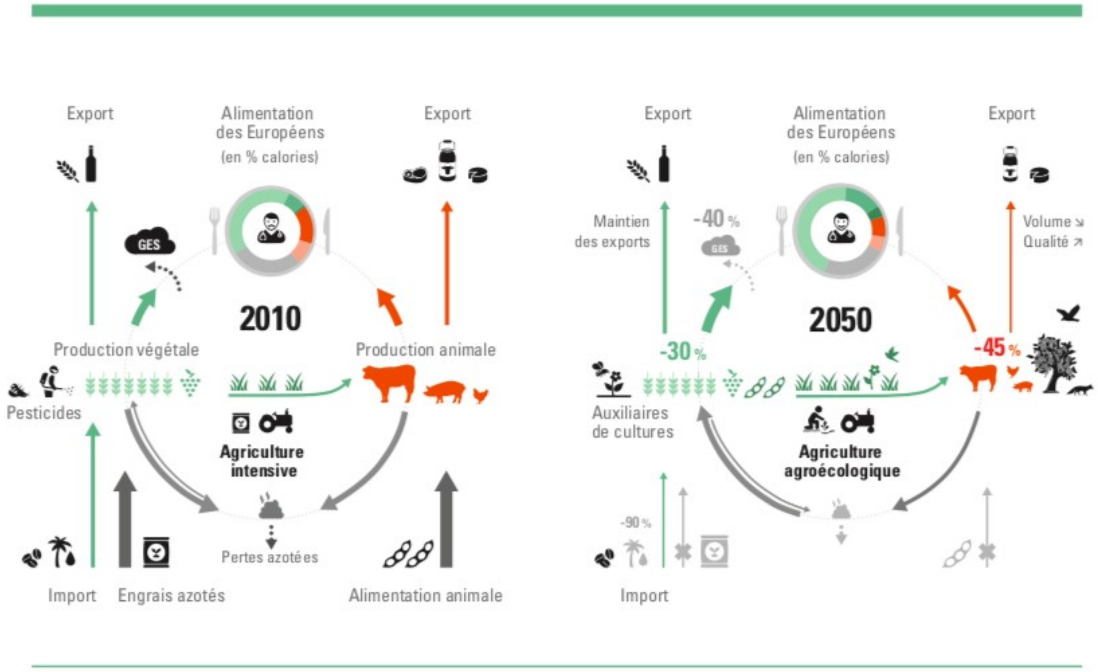
a.2 Distance of 'Business as Usual' situation from SDG and Planet boundaries

See companion paper, and section below on biodiversity.

a.3 Environmental, health, economic, social and ethical emerging issues and controversies

Possibly one of the best articulations of an agricultural transition pathway to health and sustainability is the one described by IDDRI's report on "Towards an Agroecological Europe in 2050" (Citation) which speaks to changes both in what is produced (healthier foods), and how those foods are produced. In addition this report begins to tease out what the trade implications are for Europe with suggestions of a transition to greater quality rather than quantity of produce, greater use of biodiversity in agriculture (see below), significant reductions in animal production but with a much greater integration of plant and animal production systems moving thus to more circular production systems. This articulation is increasingly compatible with food strategies of major urban centers (Paris, Copenhagen, Ghent, Lyon and others) whom are emphasizing a desire for greater consumption of foods from within the municipal watershed as a means of increasing socio-ecological resilience (e.g. more municipal say in environmental quality spilling over from rural into the urban space, greater municipal contribution to rural employment and economic security). Several of these cities have signed important declarations such as the Milan Urban Food Policy Pact, or the C40 Good Food Cities Declaration. Many of these cities have developed detailed food strategies which are notable for their focus on integrated metrics around food, health, social welfare, poverty, climate and other dimensions of environmental sustainability (e.g. Copenhagen, Paris, Lyon, Gent).

Figure x: **Diagramic representation of a transition towards and agroecolocial Europe as published in the IDDRI report. While whether agroecological is the preferred transition is an area of important social debate, what is notable about this schemata is how well is depicts multiple intersecting objectives and impacts on both human health and the planetary boundaries. Any proposed pathway should follow this model in terms of testing impacts on multiple outcomes.**



Environmental controversies

Significant debate on the downscaling of planetary boundaries to the European context, including whether meat production in Europe can/should exceed volumes that are anticipated under a healthy consumption scenario with Europe exporting this excess to countries with less suitable ecologies for meat production (e.g. the tropics). This assumes that European meat production is not dependent on grain imports from countries with high conversion rates from high value ecosystems. Part of this controversy is a generalizable failure by European agriculture to quantify and understand the environmental impacts it imports (e.g. impacts that are produced outside EU borders).

Health

At least two important controversies emerging:

First whether meat consumption values that are recommended by the EAT-Lancet are too low and emphasizing the contribution of meat and dairy to healthy diets. We note however that meat consumption is Europe is 2-4 times that recommended, thus a generalizable reduction, even if less than that proposed by the EAT-Lancet is a generalizable trend. What is often poorly understood in this debate is that overconsumption of meat, within the 2500 calorie recommendation, typically implies an important underconsumption of protective foods, notably whole grains, fruits, vegetables, and legumes.

The second important controversy which is growing is whether dietary standards should integrate environmental concern or not. That is, should governments be prescribing reduced meat consumption, without compromising health, as a means of achieving climate targets. This has important social implications and possibly some ethical concerns.

Economic and social Controversies

Important controversies regarding the impacts of dietary shifts on rural livelihoods, notably on farmers whom may have to transition out of livestock production (e.g. as proposed in the Netherlands which aims to cut its dairy herd by 50%). Missing from this discussion is the recognition that demand for food can only increase in light of still growing global populations, and thus that the debate is not about fewer farmers, but about important compositional shifts in what foods those farmers are producing. This runs into debates regarding how to keep the cost of food low, while ensuring sufficient (enviable) economic return to farming communities.

Social Implication of Transition to Safe, Just, and Healthy Food Systems.

a.1 main facts, figures and trends

a.2 Distance of 'Business as Usual' situation from SDG and Planet boundaries

a.3 Environmental, health, economic, social and ethical emerging issues and controversies

2. Contribution of the theme to the three transitions

Transition 1: Healthy and sustainable food for all

- *What is the contribution of the theme to the transition?*

Clear targets or boundaries defining healthy and sustainable food systems allow for alignment across sectors while also calling out intentional decisions to ignore and surpass targets. From a socio-ecological system and resilience perspective it is understood that bringing food within the safe and just space reduces the risk of regime shifts into less desirable states (e.g. agriculture that contributes to poor health and environmental degradation). It also suggests a food system state that is better able to absorb internal and external stressors such as climate change, shifts in consumer preferences, or global market pressures.

- *What are the appropriate (quantified) targets - relevant to the domain – needed to perform the transition?*

The EAT-Lancet Commission would suggest that EAT-Lancet planetary health guidelines, WHO guidelines, or national dietary guidelines would be suitable as targets. The Planetary Health Guidelines are evidence based, and while providing a universal target in support of dietary health does not dictate uniform paths to healthy eating. Internal analysis conducted by EAT finds that there is a much greater degree of difference between consumption patterns and dietary recommendations than there are between national guidelines, international guidelines, or EAT-Lancet's Planetary Health guidelines. Transitions to healthy eating patterns would avert 11 million premature adult deaths per year[5].

The EAT-Lancet Commission would also recommend that environmental sustainability be defined by planetary boundaries, notably carbon and climate, water quality and contamination by nitrogen and phosphorus; maintaining at least 30% environmental flows in major European rivers and finally keeping at least 50% of land by ecoregion intact for biodiversity, with an additional 10% per km^2 for conservation in agricultural lands. Many of the planetary boundaries proposed for Europe need to be downscaled in support of decision making.

Planetary boundaries are biophysical in nature and do not address social measures. However they are completely anthropocentric in that they describe a safe space for humanity. There are no socio-ecological or social resilience values/metrics known at this time – though resilience can be measures as the capacity of the socio-ecological system (Europe) to weather changes. Raworth has proposed

- *How to achieve the transition? What are the main barriers?*

- *Political lock-ins:* Deep and systemic lock-ins across domains including for example in the Common Agricultural Policy which while occupying 40% of the European Union budget still struggles to demonstrate impacts in either the provision of (i) healthy foods, (ii) production opportunities for farmers producing health foods, and (iii) reversing environmental trends.
- *Socio-cultural lock-ins:* Fear of backlash from society: increase food prices for consumer reduced production value for farmers; fear of the loss of direct subsidy interventions from Europe; aging rural population less resilient to change, lack of younger generation with resourcing, access, and or knowledge to engage.
- *Technological and market driven lock-ins:* Agriculture is increasingly specialized with large investments in often hyperspecialized technological infrastructure argued as necessary to increase efficiencies and to modernize. While these can create important efficiencies and increased production value per unit of environmental impact (climate, water, biodiversity) they driver hyper-specialization of the farming community which reduces resilience to change.
- These lock-ins are also a major concern in reducing the socio-ecological resilience of European agriculture which should be founded on securing the capacity of farmers to change with emerging markets, changes in consumer behaviour, and increasingly, changes in environmental condition.
- Farmers are increasingly being asked to produce more food, better food, and to produce environmental goods (carbon, biodiversity, water). However the same time, farmers are receiving increasingly smaller market shares of the crops they produce. Market and policy-based incentives must be re-oriented to pay for the true value of food. This includes the reorientation of public funds to pay for

public goods with reliable, and traceable metrics (e.g. a functional carbon and biodiversity market/payment system).

- *What are the main technological game changers that may contribute to the transition? What are the related risks?*

Technology is a useful slave, but a poor master. Technology is often articulated as a major game changer in progressing towards healthier and more sustainable production systems. Scanning at the future of agriculture three major trends are perceptible along an environmental continuum: (i) agroecology which aims to work with nature, (ii) conventional agriculture which adapts major crops to nature while reducing environmental change with field-based technologies such as irrigation, hybrid seeds and agrochemicals, and (iii) hypercontrolled production systems which aim to eliminate environmental variability completely with total control given to the farmer. Each of these typologies increases resilience but uses very different means of ensuring resilience. Agroecological approaches argue that resilience is achieved through diversification and improving environmental quality and that environmental variability is regulated though ecological interactions between species. Conventional production systems use inputs to regulate environmental variance, often at high environmental cost. Hypercontrolled production systems such as vertical farms, hothouses, cellular meat or high-tech aquaculture systems produce foods in highly controlled environment that completely eliminate environmental variability – literally by moving farming indoors. Each of these practices will articulate that they increase resilience, however using very different approaches, and by creating very different dependencies.

Game Changers

- Technology may significantly increase the production efficiency of cropping systems for example with precision agricultural systems, or the Dutch hothouse cultivation systems, or highly efficient dairy systems.
- Several technologies have also been suggest which will reduce the ‘drudgery’ of agricultural work including robotic harvesters fruit trees and berries; robotic weeders and precision sprayers of either fertilizers and biocides.
- Technology may also create producer consumer linkages that enable access to markets and increase capital gains by farming communities. These include efforts by cities to support farm to table systems, or can also include plans by companies such as Amazon to directly supply fresh produce to consumers at

home. These systems suggest capacities to increase revenue to farming communities while bridging the gap between consumer demand and production availability. Important questions remain regarding whether this approach will be useful in supporting greater consumption of protective or healthy foods.

Risks:

- Many of these technologies are extremely expensive, and hyperspecialized (Dutch dairy system). The require significant capital and infrastructure investment with little room for change. This is exemplified in the Netherlands at the moment where there are calls to reduce the Dutch dairy herd by 50% in order to achieve climate and environmental targets, but little discussion on how to transition highly specialized farmers to new crops.
- Some technologies promise to more tightly couple consumer demand to production capacities. For example Amazon expresses intent to become a major supplier of fresh produce delivered directly to the consumer's home. There are important questions how farmers, whom often are locked into a crop for a year or more (e.g. fruit trees) maintain productivity in the face of more rapidly shifting consumer demand. Some production systems and crops can be highly adapted (e.g. hothouse production with 5 crops per seasons and capacity to change volumes and proportions of crops produced interannually); but others, notably field based production systems have very little intra-annual flexibility.
- Greater distinction is needed between types of technologies, their information requirements and the dependencies they create:
    - Is the technology aimed at increasing the production efficiency of a single crop or variety (e.g. specialized harvester)?
    - Is the technology broadly applicable to a variety of crops facilitating farmer adaptability to shifting consumer demand or environmental change?
    - Does the technology create new dependencies between a producer and either an input supplier (e.g. precision farming systems) or does the technology give greater ownership of production decisions to the farmer?
    - Does the technology work to reduce environmental variability or does it enable to farmer to work with increasing environmental variability?
    - Does the technology empower the producer to adapt or become more resilient to change? Or does it transfer resilience onto a third party? What are the new dependencies the technology creates and what are the risks of this transfer to farming communities?

Transition 2: Full circularity of food systems

- What is the contribution of the theme to the transition?
- What are the appropriate (quantified) targets - relevant to the domain – needed to perform the transition?
- How to achieve the transition? What are the main barriers?

- What are the main technological game changers that may contribute to the transition? What are the related risks?

Transition 3: Substantial increase of biological, social, and economic diversity

What is the contribution of the theme to the transition?

Biodiversity targets can be quite complex and diverse following from the many different values that society places on nature including inspirational, cultural, and functional values for example. This can lead to complete stagnation in conservation effort drowning in the sheer number of indicators. As such, apex targets should aim for simple objectives that contain as many of the articulated values as possible, while facilitating policy action. Biodiversity underpins socio-ecological resilience with an emphasis on the functional contributions of biodiversity to human well-being.[1,12-17] Biodiversity's contribution to resilience however can be summarizes in two major points: (1) biodiversity provides critical services to society, including to food production such as carbon capture, pollination of crops with high nutritional value, pest control functions, soil nutrient cycling, and contributions to water cycle regulation and water quality amongst others; (2) high diversity allows nature to maintain these functions and services particularly in changing environments (e.g. climate change). The inverse is also true – reduced diversity limits response options in the face of change and can lead to important regime shifts.

What are the appropriate (quantified) targets - relevant to the domain – needed to perform the transition?

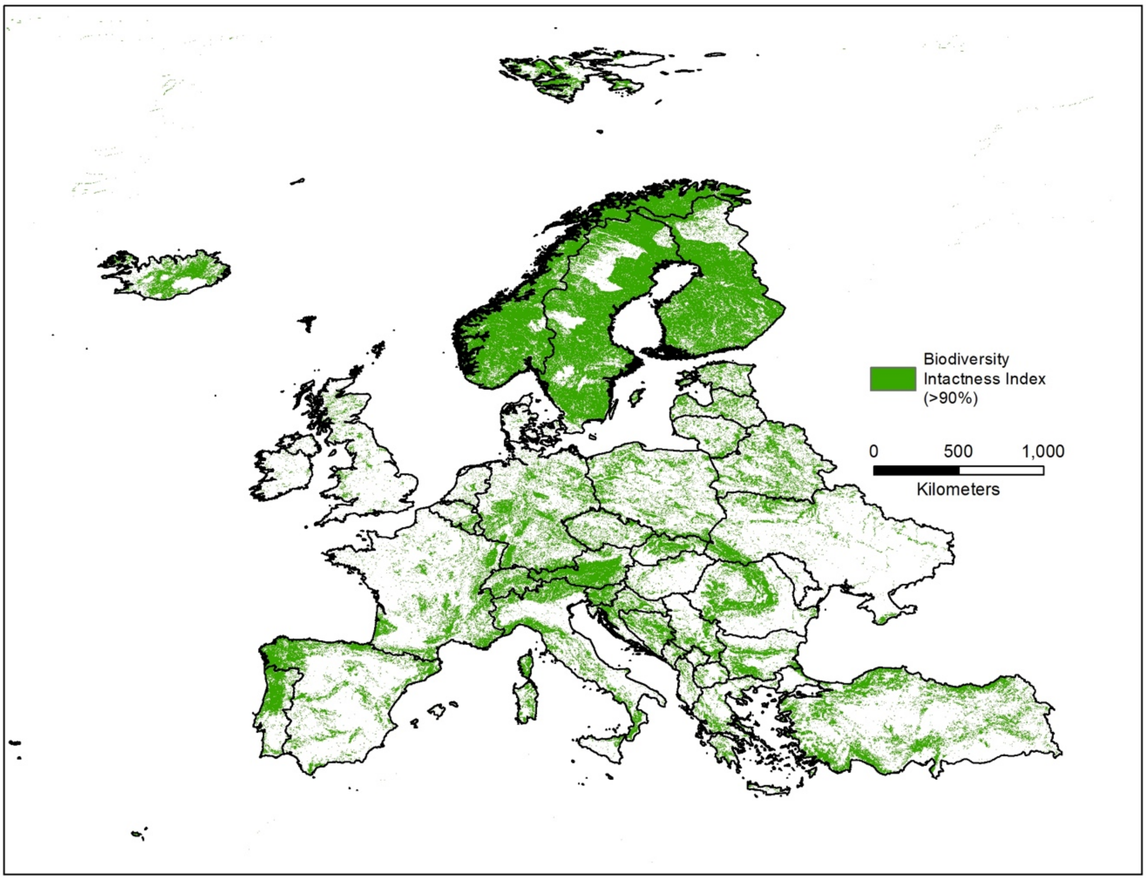
The EAT-Lancet has set as a specific biodiversity target that can be used as an area-based apex conservation target which secures both the need to protect nature for nature's sake, as well as to preserve the ecological functions of nature. This target calls for 50% of the area of each ecoregion in Europe with an "intact" status. Note that intactness is a biological rather than a political measure and is a measure of the remnant species conservation compared to pre-1950 levels in many cases. The biodiversity intactness index[18,19], while imperfect and in revision, provides a spatially explicit measure of intactness. An important caveat to this target is that it must be applied at the ecoregion level in order to be effective. Ecoregions are unique in their species composition and represent the finest scale global classification of ecosystems. Unlike carbon, biodiversity cannot be traded across ecoregions (e.g. this would be akin to trading the Iberian lynx for the American bobcat).

The second major element of the EAT-Lancet biodiversity target calls for maintaining at least 10% intact area within agricultural landscapes at the sub-kilometer scale. This recommendations recognizes that the ecosystem services that are provided to agriculture, including pollination, pest control, and sediment capture are all provided by nature but at fine scales (<100 m).[20-33] Conceptually, this target is very similar to the Ecological Focus areas recommended by the EU though we recognize that implementation is challenging, and that monitoring is also difficult. However, using existing remote sensed data, we can provide spatially explicit estimates of which regions meet the 10% target. We emphasize that this measure both is essential to securing the resilience of ecosystem services to agriculture provided by biodiversity, and also that it makes and invaluable contribution to wild biodiversity conservation when it secures connectivity across fragmented landscapes.

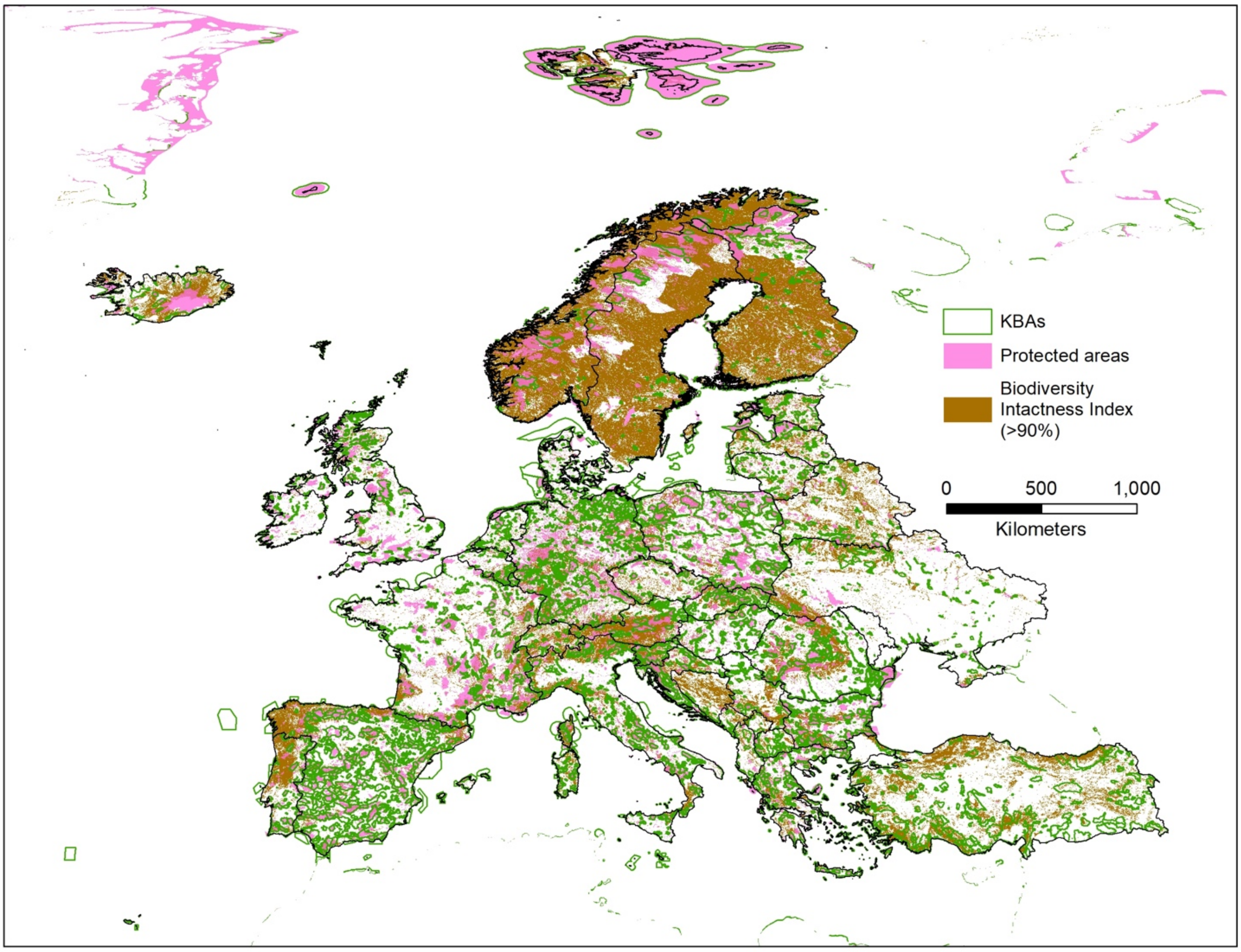
The final biodiversity target which merits consideration is production and dietary diversity and their impacts on health. Globally there is an important homogenization of diets which has important impact on biodiversity loss and capacity to adapt to climate change, as well as important impacts on human health and nutrition. While the EAT-Lancet[5] provides a universal dietary recommendation, this dietary recommendation does not set a diversity target in part because it recognizes the important freedom of choice. A baseline diversity target has been adopted by the FAO articulating that individuals should consume at least 5 out of 8 major food groups daily (verify). The biggest nutritional gains are found when a diversity of plant-based products are consumed (eat your colors!), though inclusion of animal protein is also an important contributor to health when consumed at recommended quantities.

We covered dietary shift above, here we focus on the intactness and embeddedness measure for Europe.

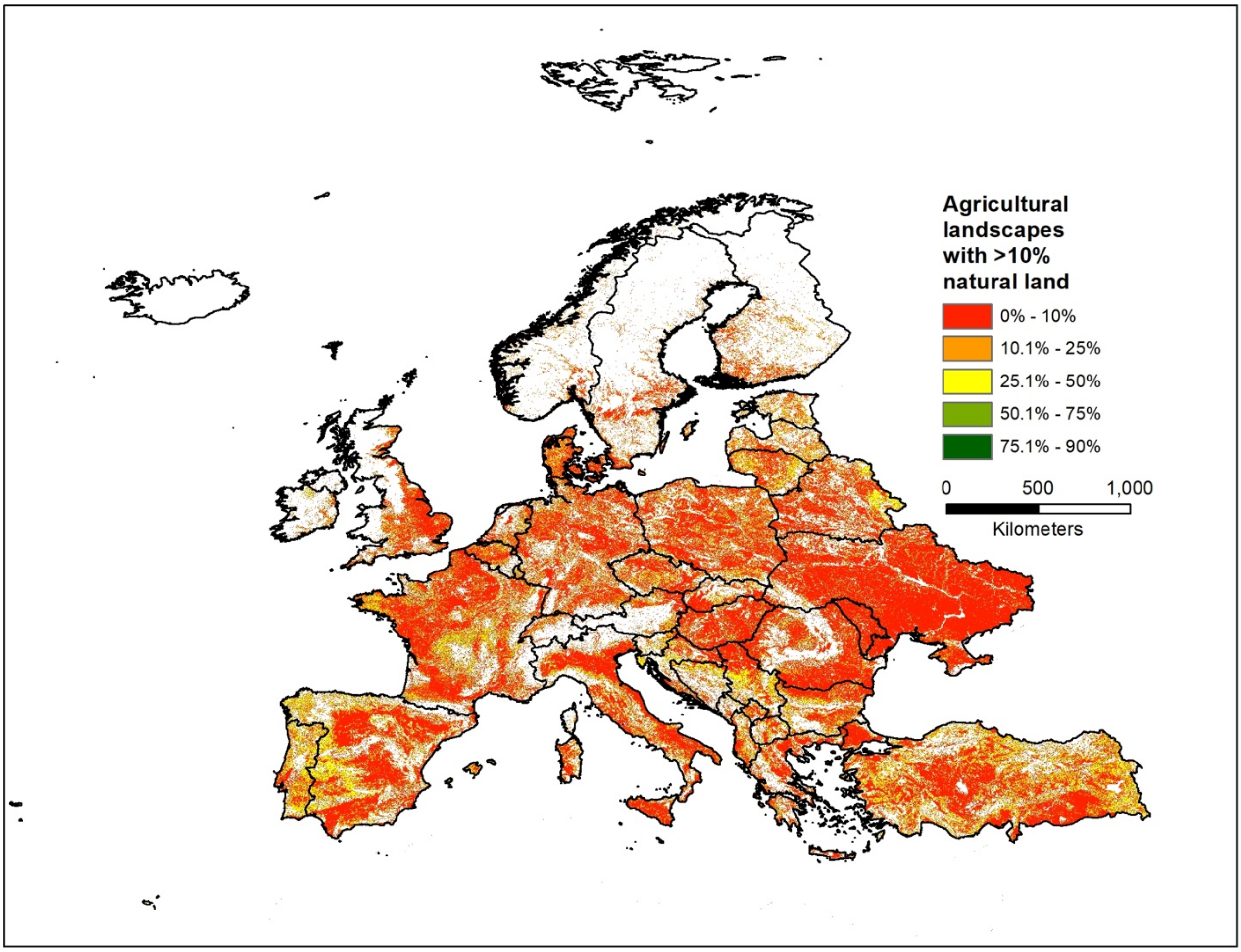
Map 1: **Areas in Europe where biodiversity intactness is estimated to be >90%. These are region where agricultural, or urban expansion should be avoided. Estimates of which European ecoregions have less than 50% of the ecoregion intact are found in table x. (maps are in revision and can be revised for final report).**



Map 2: **Key Biodiversity Areas (Green outline), protected areas (pink) and biodiversity intactness (brown) for Europe. Note that KBA's and Protected areas denote a social value (KBA's) or political designation (protected areas) where as intactness denotes as biological measure. It is likely that the Convention on biological diversity will adopt a 30% protected target in 2020, where as biologists signal that 50% intact is required to avert species loss by ecoregion. Values by country and by ecoregion can be found in table x (to be developed).**



Map 3: **The amount of biodiversity maintained within agricultural areas at the 1 km scale. The resilience of agricultural services is dependent on maintaining biodiversity in agricultural areas. The target would be to have 90% of agricultural areas in Europe with at least 10% intactness at the 1 kilometer scale. Currently we estimate that ##% of agricultural areas in Europe meet this target. Note that there are still some methodological challenges with this measure, and that the very fine resolution of the 1 kilometer target in the map below underemphasizes the significant areas that have met this target (consider using the inverse map).**



How to achieve the transition? What are the main barriers?

- Repurpose agricultural subsidies with a focus on: (a) greater recognition of the benefits that farmers receive from biodiversity, and (b) rewarding farmers for the production of public goods on agricultural lands (carbon capture, water regulation, quality improvement, sediment capture etc…).
- Encourage private sector sourcing from producer adopting regenerative agricultural practices.
- Diversification of supply chains.
- Dietary shifts for health benefits towards greater diversity of foods notably of plant-based foods.
- Halt expansion of agriculture and urban regions into intact regions.
- Support the development of agricultural/forestry practices that are compatible with maintaining intact biological communities (e.g. native timber management, extensive rangeland system, shellfish cultivation/aquaculture).

What are the main technological game changers that may contribute to the transition? What are the related risks?

3. Policy conditions for the achievement of the targets

- Review of Green Deal for Europe
- Review of new CBD Biodiversity Targets
    - Note the zero net loss by 2030 target: "No net loss by 2030 in the area and integrity of freshwater, marine and terrestrial ecosystems, and increases of at least [20%] by 2050, ensuring ecosystem resilience";
    - Note the inclusion of dietary diversity and health as a target: *"Improvements in nutrition for at least [X million] people by 2030 and [Y million] by 2050"* and *"Enhance the sustainable use of wild species providing, by 2030, benefits, including enhanced nutrition, food security and livelihoods for at least [X million] people, especially for the most vulnerable, and reduce human-wildlife conflict by [X%]."*
    - Note the specific reference to agricultural systems: *"Conserve and enhance the sustainable use of biodiversity in agricultural and other managed ecosystems to support the productivity, sustainability and resilience of such systems, reducing by 2030 related productivity gaps by at least [50%]*."

- Review of EU Country Dietary Guidelines. JPL has provided a homogenized analysis and access to data here and analysis of school based interventions here.
    - Note that this analysis also finds that 72% of EU countries consider broad mentions to sustainability (local, fresh, seasonal) and that 25% make specific references to sustainability including: varied diverse diet, plant-based less meat, sustainable sourced fish, reductions in food waste. Note that those that mention sustainability all date to post 2014.
- Consider the work of the IPES Common Food Policy recommendations and seek alignment between sectors:
    - Note that while many think Agriculture has most to offer and most to gain in terms of securing health and sustainability, there is also the perception that agriculture is most entrenched and resistant to change.
    - How to change the narrative and the political economy to enable agriculture to react and contribute while addressing concerns of loss of competitiveness to non-EU markets and producers?

References

1. Naeem S, Duffy JE, Zavaleta E. The Functions of Biological Diversity in an Age of Extinction. *Science* 2012; **336**(6087): 1401-6.
2. Rockström J, Williams J, Daily G, et al. Sustainable intensification of agriculture for human prosperity and global sustainability. *Ambio* 2017; **46**(1): 4-17.
3. Walter Willett, Johan Rockström, Brent Loken, et al. Our Food in the Anthropocene: The EAT-Lancet Commission on Healthy Diets from Sustainable Food Systems. . *The Lancet* 2019.
4. Caron P, y de Loma-Osorio GF, Nabarro D, et al. Food systems for sustainable development: proposals for a profound four-part transformation. *Agronomy for Sustainable Development* 2018; **38**(4): 41.
5. Willett W, Rockström J, Loken B, et al. Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. *The Lancet* 2019; **393**(10170): 447-92.
6. Springmann M, Clark M, Mason-D'Croz D, et al. Options for keeping the food system within environmental limits. *Nature* 2018; **562**(7728): 519.
7. IPES-Food. Unravelling the Food-Health Nexus: Addressing Practices, Political Economy, and Power Relations to Build Healthier Food Systems: International Panel of Experts on Food (IPES-Food) & the Global Alliance for Future of Food, 2017.
8. Afshin A, Sur PJ, Fay KA, et al. Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *The Lancet* 2019.
9. Food I. Towards a Common Food Policy for the European Union. *The Policy Reform and Realignment That Is Required to Build Sustainable Food Systems in Europe* 2018.
10. Biggs R, Schluter M, Biggs D, et al. Toward Principles for Enhancing the Resilience of Ecosystem Services. In: Gadgil A, Liverman DM, eds. Annual Review of Environment and Resources, Vol 37; 2012: 421-+.
11. DeClerck F, Jones S, Attwood S, et al. Agricultural ecosystems and their services: the vanguard of sustainability? *Current opinion in environmental sustainability* 2016; **23**: 92-9.
12. Naeem S. Ecosystem consequences of biodiversity loss: The evolution of a paradigm. *Ecology* 2002; **83**(6): 1537-52.
13. Naeem S, Bunker DE, Hector A, Loreau M, Perrings C. Biodiversity, ecosystem functioning, and human well-being: an ecological and economic perspective. Oxford: Oxford Biology; 2009.

14. Naeem S, Li SB. Biodiversity enhances ecosystem reliability. *Nature* 1997; **390**(6659): 507-9.
15. Naeem S, Thompson LJ, Lawler SP, Lawton JH, Woodfin RM. Declining Biodiversity Can Alter the Performance of Ecosystems. *Nature* 1994; **368**(6473): 734-7.
16. Diaz S, Demissew S, Carabias J, et al. The IPBES Conceptual Framework - connecting nature and people. *Current Opinion in Environmental Sustainability* 2015; **14**: 1-16.
17. Diaz S, Settele J, Brondízio E, et al. Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. 2019.
18. Scholes RJ, Biggs R. A biodiversity intactness index. *Nature* 2005; **434**(7029): 45-9.
19. Newbold T, Hudson LN, Arnell AP, et al. Has land use pushed terrestrial biodiversity beyond the planetary boundary? A global assessment. *Science* 2016; **353**(6296): 288-91.
20. Avelino J, Romero-Gurdian A, Cruz-Cuellar HF, Declerck FAJ. Landscape context and scale differentially impact coffee leaf rust, coffee berry borer, and coffee root-knot nematodes. *Ecological Applications* 2012; **22**(2): 584-96.
21. Martínez-Salinas A, DeClerck F, Vierling K, et al. Bird functional diversity supports pest control services in a Costa Rican coffee farm. *Agriculture, Ecosystems & Environment* 2016; **235**: 277-88.
22. Klein AM, Steffan-Dewenter I, Tscharntke T. Foraging trip duration and density of megachilid bees, eumenid wasps and pompilid wasps in tropical agroforestry systems. *J Anim Ecol* 2004; **73**(3): 517-25.
23. Krauss J, Steffan-Dewenter I, Tscharntke T. How does landscape context contribute to effects of habitat fragmentation on diversity and population density of butterflies? *J Biogeogr* 2003; **30**(6): 889-900.
24. Krauss J, Steffan-Dewenter I, Tscharntke T. Landscape occupancy and local population size depends on host plant distribution in the butterfly Cupido minimus. *Biological Conservation* 2004; **120**(3): 355-61.
25. Kruess A, Tscharntke T. Habitat Fragmentation, Species Loss, and Biological-Control. *Science* 1994; **264**(5165): 1581-4.
26. Kruess A, Tscharntke T. Species richness and parasitism in a fragmented landscape: experiments and field studies with insects on Vicia sepium. *Oecologia* 2000; **122**(1): 129-37.
27. Steffan-Dewenter I, Munzenberg U, Burger C, Thies C, Tscharntke T. Scale-Dependent Effects of Landscape Context on Three Pollinator Guilds. *Ecology* 2002; **83**(5): 1142-432.
28. Steffan-Dewenter I, Munzenberg U, Tscharntke T. Pollination, seed set and seed predation on a landscape scale. *P Roy Soc Lond B Bio* 2001; **268**(1477): 1685-90.
29. Steffan-Dewenter I, Tscharntke T. Effects of habitat isolation on pollinator communities and seed set. *Oecologia* 1999; **121**(3): 432-40.
30. Thies C, Roschewitz I, Tscharntke T. The landscape context of cereal aphid-parasitoid interactions. *P Roy Soc B-Biol Sci* 2005; **272**(1559): 203-10.
31. Thies C, Steffan-Dewenter I, Tscharntke T. Effects of landscape context on herbivory and parasitism at different spatial scales. *Oikos* 2003; **101**(1): 18-25.
32. Tscharntke T, Steffan-Dewenter I, Kruess A, Thies C. Characteristics of insect populations on habitat fragments: A mini review. *Ecol Res* 2002; **17**(2): 229-39.
33. Tscharntke T, Tylianakis JM, Rand TA, et al. Landscape moderation of biodiversity patterns and processes - eight hypotheses. *Biological Reviews* 2012; **87**(3): 661-85.

SAFE AND JUST FOOD SYSTEMS IN AN URBANIZING WORLD: TRENDS AND TRANSITIONS

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Summary

- Systemic transitions towards sustainable food systems are urgently needed.
- Such transitions require good governance enabled by strong political will and leadership.
- Cities are emerging as leaders for these transitions and are positioned to expand this leadership role. There is a growing body of evidence and examples that urban food policies can support the three SCAR V-Foresight transition pathways towards: Healthy and sustainable food for all; safe and just circularity of food systems; and, increasing diversity (see appendix 1).
- Specific conditions are required to support sustainable food system transitions in an urbanizing world. This report focusses specifically on:
    - Policy integration
    - Stakeholder engagement
    - A city-region approach
    - Reflexive governance
- There are also a number of barriers to overcome when planning for food system transitions. This report highlights:
    - Increasing de-politicization
    - Competing interpretations
    - Policy silos
    - Managing trade-offs when governing in a food system
- The governance of transitions to safe and just food systems in an urbanizing world need to be supported by a robust, multi-disciplinary and interdisciplinary research agenda

1. Socio-political change in public policies for safe and just food systems: Cities as transition leaders

‘Our struggle for sustainability will be won or lost in cities.’

UN Secretary General, Ban Ki Moon [1, p. 1]

‘The urban planet is here to stay, and the decisions we make today about

how we build and live in cities will affect generations to come.’[2]

The global demographic shift towards **urbanization is one of the major challenges** of the twenty-first century [3]. The world's urban population is expected to increase from 55% in 2018 to 68% by 2050. In Europe, urbanization is expected to increase from 74% to over 80% by 2050 [4]. These demographic shifts are fundamentally changing our food systems and our relationships with food [2]. In turn, understanding and anticipating trends in urbanization is fundamental to a transition towards sustainable food systems.

A sustainable food system for the EU is one that provides and promotes safe, nutritious, and healthy foods with limited environmental impacts for all citizens, current and future, in a way that also protects and restores ecosystems. It is robust and resilient, economically dynamic, just and fair, socially acceptable and inclusive. Further, it does not compromise the availability of healthy and culturally appropriate foods for others outside the EU, nor does it impair natural environments [5].

Establishing such a food system remains a pressing issue, particularly in European cities, where an estimated 34 million people are at risk of poverty or social exclusion [6, p. 14]. The increase of urban malnutrition, mainly expressed through the rising incidence of obesity and diabetes, and often linked to poor diets, is a serious public health issue, with notable social-economic effects [2]. At the same time, cities[111] are **key drivers of environmental change** across multiple scales. Occupying only about 2.2% of

[111] It is recognised that while ‘city’ and ‘urban’ are two concepts readily understood by the general public, a clear definition remains elusive. Consider that the UN publishes data on cities, urban areas and rural areas, relying primarily on national definitions [69]. The OECD has defined the city as having a link to the political level, at least 50% of city the population lives in an urban centre, and at least 75% of the population of the urban centre lives in a city [70]. In this report, the concepts are used interchangeably, but cities refer more explicitly to urban municipalities (i.e. politically defined spaces).

terrestrial area globally, cities use up to 60% of water resources, generate over 50% of waste and produce 60-80% of global greenhouse gas emissions [7], [8]. Consider that the ecological footprint needed to provide city residents with food, energy, and materials is often 200 times greater than the area of a city itself[2].

While cities contribute to many problems, they also have the **potential to foster positive change with global impacts**. Cities generate more than 80% of the global gross domestic product (GDP) [9]. The economic activity of EU-28 is concentrated in predominantly urban regions, with these regions generating more than half of all GDP [6, p. 36]. Cities have also been signaled as 'the optimal space for food policy innovation'[10], 'laboratories for further improvements' and as 'learning machines'[11] with the potential of operating as key change agents. The relative size of cities and territories, compared to nations, can offer comparative advantage for systems integration, adaptability, and impact [12, p. 4].

Given this, and considering the range of socio-political changes in public policies required to transition towards safe and just food systems, this report presents a brief overview of governing for sustainable food system transitions in an urbanizing world. Key insights from the emergence of cities as sustainability leaders are presented, with a focus on the rise of urban food policy initiatives. Specific conditions to support sustainable food system transitions in an urbanizing world are presented, specifically: Policy integration; Stakeholder engagement; A city-region approach; and, Reflexive governance. In relation to these conditions, a number of barriers to planning for food system transitions are consider: Increasing de-politicization; Competing interpretations; Policy silos; and, Managing trade-offs when governing in a food system. The report concludes by identifying specific research needs associated with these conditions and barriers. While the focus of this report is on cities, the issues addressed herein are transversal and set to inform food systems governance in the years to come.

2. Governing of food system transitions: The changing role of cities

'We're the level of government closest to the majority of the world's people.

While nations talk, but too often drag their heels—cities act. '

Former New York City Mayor Michael Bloomberg, 2012

In recent years, cities have become increasingly visible in the sustainability and food policy landscape, taking important measures to address global challenges. The UN's New Urban Agenda (UN Habitat 2016) calls for ambitious global goals for sustainability considering urban areas and changes to urban planning and development pathways, while SDG 11 aims to 'make cities and human settlements inclusive, safe, resilient and sustainable'. Municipal governments around the globe are embracing food as a policy priority to confront the impacts of climate change, redesign waste flows, and address food poverty, malnutrition, as well as rural-urban migration [13]. Cities are acting alone (i.e. urban food policies) and collectively (i.e. networks and pacts). Emergent governance arrangements at the local, regional and international level present a challenge the traditional role of the state and position cities (e.g. municipalities and other stakeholders) as central actors in global sustainability processes. Key examples include the coalition of Climate Mayors (USA) committed to advancing the Paris Climate Agreement, and the over 200 cities that have signed onto the Milan Urban Food Policy Pact since 2015. This mirrors a trend in EU initiatives connecting cities (see box 1). Looking ahead, we can anticipate a greater role for cities, and city-regions, in food policy and beyond.

At the intersection of the emergence of new governance arrangements and a rapidly urbanizing world, we see the rise of **urban food policies**, particularly in industrialized counties. An urban food policy is defined as a" concerted action on the part of city government to address food-related challenges [14, p. 9]. Urban food policies often emerge by way of engagement and pressure by civil society and other actors. These policies reflect different concerns and contexts. Their organizational structures and foci differ, but they tend to share similar goals of supporting sustainable and just food systems, with some working to support policy development for improving healthy food, increase availability and access to sustainable food, reduce waste, change land use or influence land use planning, enhance local markets, and/or strengthen local food economies. Moreover, urban food policies are often developed to address democratic deficits at the national and global level, with a focus on participatory processes and greater citizenship engagement, linking diverse stakeholders and policy domains, and prioritizing sustainable, inclusive planning and health.

BOX 1: Examples of European Union initiatives concerning cities

CIVITAS aims to support cities in their efforts to develop urban transport policies that promote more sustainable urban mobility and currently more than 200 cities across 31 different European countries participate. It is co-funded by the EU's framework programme for research. With respect to food, the platform shares relevant cases (e.g. sustainable logistics for the food industry). www.civitas-initiative.eu/

The Covenant of Mayors initiative was launched by the European Commission in 2008 with the objective of bringing together local and regional authorities voluntarily promising to implement EU climate and energy objectives in their territory. In 2015, the Covenant of Mayors for climate and energy was launched. Through their platform good practices related to food and agriculture are shared. www.covenantofmayors.eu/en/

EUROCITIES brings together local governments of 139 of Europe's largest cities and 40 partner cities to dialogue with European institutions. They also provide a platform for their members to share knowledge and ideas, exchange experiences, analyse common problems and develop innovative solutions. For example, they post information related to food policy, and host webinars on topics such as food waste, and food supply an distribution. www.eurocities.eu

Across Europe, urban food policies have contributed to food system transitions. Box 2 provides short case studies to illustrate how urban food policies have supported the three transition themes of the SCAR-V Foresight Exercise. Appendix 1 provides insights into how urban food policies advance the SCAR-V Foresight Exercise targets. Improving the effectiveness of urban and territorial food policies has potential for a range of benefits concerning regional economic development and improved governance and health [15]. Evidence, while still limited, points to benefits for food and nutrition security and the management of the environment, as well as wider community benefits including: increased Net Value Added in the regional economy, more employment in the urban and/or the regional food economy, preservation of the city's rural hinterland, reduction of food miles and CO_2 emission, enhanced trust/faith in the food system, and increased bridging social capital. However, as Caron et al. (2019) note, 'transformation will not occur spontaneously: it must be planned, designed, implemented, and monitored by those who will be locally involved in implementation working within agreed parameters for sustainable development at national and global levels' [16].

Attributing change to specific policies is not without challenges. In turn, presenting facts and figures on how public policies contribute to sustainable food system transitions must be approached cautiously. Another challenge is that reducing practices and impacts to 'hard numbers' can fail to capture context and result in outcomes that are overly prescriptive. The heterogeneity of urban food systems, and the diverse contexts that shape them, implies that context-specific pathways for transformation are necessary. Designing and implementing these pathways should be the responsibility of political bodies and associated institutions that can establish legitimate relevant objectives, assessment metrics, and indicators for food system transformation, in consultation with stakeholders (see below) [16].

Flexible monitoring and evaluation frameworks have been developed and tested, though they remain underutilized. These include but are not limited to:

- SDG indicator framework (notably SDG2 and 11)
- Milan Urban Food Policy Pact Monitoring Framework Indicators
- City-Region Food System Indicator Framework
- UK Sustainable Food Cities: Toolbox for Action

It must be stated that urban food policies are but one aspect of broader-scale food systems change [17]. Many problems associated with the food system rely on issues that expand beyond the jurisdiction of cities including: trade, economic, agriculture and public health. These are policy areas that usually cannot be fully addressed at the city level and point to the need for policy integration (see below). That does not however take away from the transformative potential of cities and of municipal policy and the emerging role cities are playing in these processes. Consider research in Ontario, Canada which showed how health and local economies can be improved by substituting 10% of imported fruit with local production. Impacts were estimated to be 130 million CAD in GDP, an additional 1,837 FTE jobs, and an extra 37.8 million CAD in total taxes' [18].

Box 2: Urban food policies for sustainability transition

Example 1: Healthy food in public canteens

Malmö, Sweden (pop. 317,000)

Link to Transition 1: Healthy and sustainable food for all

In 2001, the city council of Malmö established ambitious environmental targets around public (especially school) food, including ensuring that 100% of public food is organic by 2020 and that the GHG emissions associated with public procurement are reduced by 40% compared to 2002 levels. The strategy also aimed to increase healthy eating and set an example in terms of food safety. Malmö has seen an increase in plant-based meals, which has been linked to a 20% reduction of greenhouse gas emissions relating to food procured and consumed in public kitchens.

Example 2: Shorter food chains and less food waste

Ghent, Belgium (pop. 250,000)

Link to Transition 2: Full circularity of food systems

The 'Gent en gard' food strategy was launched 2013 with the following goals: a shorter, more visible food chain; more sustainable food production and consumption; the creation of more social added value for food initiatives; reduce food waste; and, optimum reuse of food waste as raw materials. Ghent en Garde tackles different challenges through tailor-made responses. Through new farmers' markets and a new logistics platform for professional buyers, 1.000 tons of food waste have been redistributed to 57,000 people over a two-year period. Since 2014 over 42 school gardens have received coaching with 240 parents, teachers and directors participating in workshops. Through their sustainable school meals 4500 students have access to 775,883 meals annually.

Example 3: Resilient and sustainable food system

Bristol, UK (pop. 435,000)

Link to transition 3: Increase in biological, social and economic diversity

A multi-actor Food Policy Council was established to advise city authorities and to develop A Good Food Plan (2013). The plan is concerned with making the city's food system more 'resilient' and sustainable. The Food Policy Council holds only advisory functions, but it has been effective in highlighting and integrating food issues in the Good Food Plan across multiple public departments, including culture and waste.

3. Conditions for sustainable food system transitions in the era of urbanization: a focus on policy

The role of municipalities in food system transitions need to be considered in relation to the emerging trends and barriers. Further, we must be cautious when focusing on municipal governance and policies as these cannot be understood separately from broader political and economic processes that cities, and city-regions, are embedded in, nor from national and global geo-politics. That said, key conditions to support sustainable food system transitions in an era or urbanization include a focus on participatory processes, policy integration, a regional approach, and a reflexivity in policy processes. Such conditions support a multi-level perspective approach to sustainability transition by acknowledging the dynamic and fluid nature of levels and actors.

Policy integration

A key condition for achieving sustainable food systems transitions will be effective policy integration. Calls for a food policy for the European Union reinforce this point [19]. Policy integration refers to strategies that aim to coordinate coherent policy goals and consistent policy means across diverse but related sectors to produce policy outcomes capable of addressing complex problems. Integrating food policies thus involves aligning food system goals and policies horizontally (e.g., across municipal departments, themes, local stakeholders) and vertically (local, regional, national, supra-national). This applies not only to policy content, but also to policy processes. The integration of food into and across urban policy, or the integration of themes (i.e. health, infrastructure, waste, and education) can be a challenge for municipal governments. There are procedural, structural and cultural factors that affect the capacity of local governments to develop integrated policies; including a lack of inter-departmental staff teams and clearly articulated responsibilities, along with a lack of a formal policy mandate to deal with food issues at the municipal level [20]. While political actors employ different strategies to achieve policy integration, overall, it requires alignment of tasks and efforts of the public sector through functionals support structures that coordinate policies. More research is needed to build up the evidence base and best practices for creating and implementing integrated policies vertically and horizontally. Central to this will be the engagement of key stakeholders.

The future is participatory: stakeholder engagement

Cities are making use of participatory processes and greater citizen engagement to develop and implement food policies. Indeed, innovative modes of governance are being introduced that are 'fundamentally about participatory decision-making and information sharing' where '[k]ey stakeholders should be represented and decide what issues to focus on and what actions to take' [21]. Such approaches are also categorized as multi-actor, in which a broad mix of actors collaborate to address complex societal problems. This is in line with a broader participatory turn in governance [22].

There is broad agreement that stakeholder engagement is fundamental to the development of legitimate policies. This has been made visible in the proliferation of multi-stakeholder processes (MSPs) devoted to bringing diverse perspectives together to inform and improve food policy at the local, national, regional and international levels. The concept of 'stakeholders' emerged in the 1930s to counter-balance the growing importance of 'shareholders' and related concerns around the responsibility of corporations to the public at large [23]. The term came to be defined as 'any group or individual that can affect or is affected by the achievement of a corporation's purpose' [24, p. 46]. Today this includes civil society, the private sector, and even governments [21]. While form and function of MSPs vary widely, they all recognize stakeholder interests are diverse, stakes are high, and opportunities exist to impact policy [25]. We cannot forget however that the organization of multi-stakeholder processes is an exercise in power [26].

A common criterion for identifying stakeholders in MSPs builds on the 'all-affected' principle [27, p. 195]. This principle implies that 'only those who are affected by a decision should be entitled to have a say in it' [28, p. 31]. When it comes to food, this becomes challenging as everyone is affected by the organization of food systems. At the same time, there is growing acknowledgment of the need to account for power relations, resulting in insights aimed at levelling an unequal playing field [29]–[33]. The universalist approach of the all-affected principle leads to varying (but often hidden, or ignored) opportunities to participate [26], [27], [34] and fails to account for the different impacts of resulting policies. Thus **a second condition to ensure food system transitions includes greater attention and strategies to not only to ensure that all stakeholders are able to engage in governance processes that affect them, but also to ensure that power relations are understood and addressed in an equitable way through transparent mechanisms** (see for example, the governance structure of the Civil Society and Indigenous People's Mechanism to the Committee on World Food Security[1] [35], [36]).

It has also been shown that participation of relevant authorities from across governance levels is important to urban policy development [37], [38]. This suggests a slight diversion from mainstream transition thinking that has tended to advance heroic formulations of change agents. Instead, a stakeholder approach emphasizes the role of collective actors in transition [39]. Furthermore, it challenges the tendency of assigning actors to specific level of the MLP [40]. In practice, transition actors, and particularly change agents, operate across multiple levels. Consider that a civil society actor mobilizing around local food policy councils can be simultaneously supporting international efforts through the Milan Urban Food Policy Pact, lobbying for an EU food policy, all while working for a national Ministry of Agriculture.

Looking ahead, we can assume that the trend towards stakeholder engagement will continue and will lead to the formalization and professionalization of participation. Greater reflection on what this means for food governance is required. At present, much of the literature on MSPs highlights the positive contributions to be gained from an opening-up of traditionally state-led processes [30], [33], [41], [42]. Yet, in there is also a convincing critique emerging to show that, in many instances, MSPs have de-politicizing effects [27], [43]–[45] (see below).

Beyond the city: a city-region approach

While a focus on the city has been central to the development of urban food policies for the last few decades, cities are, and will continue to be, dependent on food produced outside of the city. It is anticipated that transitions towards sustainable food systems will intersect with the demands of a majority urban global population resulting in reconfigurations of rural-urban linkages. As such, **a third condition for food system transitions in an urbanized world involves a focus beyond the boundaries of the city to address urban-rural synergies through a city-region approach.**

By way of illustration, consider that a transition to more sustainable forms of food production and consumption is likely to involve the reorganization of food production closer to urban markets. We already see the peri-urban emerging as a key site for sustainable agriculture initiatives, not only because of the proximity to urban consumers, but also because of other structural conditions that create space for experiments with alternative food systems [46]. However, an over-emphasis on peri-urban areas must not come at the expense of what happens to rural regions farther from the cities. These rural regions can still be linked to sustainable urban food networks, but there is more research and analysis needed to understand how to most appropriately move beyond (re)localization.

These new territorial governance arrangements are being supported by actors like the FAO who are promoting a city-region approach that aims to foster the development of resilient and sustainable food systems within urban centers, peri-urban and rural areas surrounding cities by strengthening rural-urban linkages. Such an approach requires city-regions to assess their food (inter)dependencies, identify weaknesses and potential pressure points, and where possible, develop targeted strategies to improve their food systems in such a way to include all actors, processes and relationships that are involved in food production, processing, distribution and consumption in a given city region [47].

Reflexive governance: learning-focused policy approaches

The fourth condition for the governance of sustainable food systems relates to reflexivity [48, p. 31]**.** Reflexive governance arrangements are characterized by the building up of capacities for social learning and iterative participatory goal formulation [49], [50] and are predicated on ongoing diagnoses [51]. As such, reflexive policies are better able to reacting to contingencies and change, in part through flexible strategies and monitoring [52]. Importantly, reflexive approaches to policy making that govern activities are connected to wider societal feedback loops and partly shaped by their own governing dynamics [53]. This is compatible with a systems approach. At least five strategies that promote the development of reflexive public policies for sustainability transition [49] can be identified:

1. integrated (transdisciplinary) knowledge production;
2. adaptivity of strategies and institutions;
3. anticipation of the long-term systematic effects of action strategies;
4. iterative participatory goal formulation; and,
5. interactive strategy development.

Action-based research and capacity training that supports decision-makers and stakeholders develop the necessary competencies, as well as spaces (i.e. living labs) where such approaches can be safety trialed, are fundamental to building up the reflexivity required to move towards integrated sustainable urban food policies.

4. Barriers to governing for food system transitions

Broadly, key barriers to implementing governance arrangements and policies in support of sustainability transition include: failure to deal with cross sector dynamics; inability to address issues related to persistent inequalities in food rights and entitlements (rise of food poverty in EU); increasing geopolitical and sectorial interdependencies; power imbalances and low institutional capacities; and conflicting values and interpretations [54]. More specifically, key challenges for policy integration include: constructing a resonating policy frame; the formulation of policy goals; involvement of relevant sectors and levels; clarification of the boundaries of optimal policy integration; and designing a consistent mix of policy instruments [55]. Capacity (e.g. skills and time), as well as budget to develop and implement, represents other key barriers faced by public authorities. There are also key structural issues that underpin food-related challenges that tend to be overlooked across urban food policies, including: poverty, labour; dietary transition; unsustainable diets; racism, gender relations; trade and distribution. Furthermore, engagement with the private sector remains rather limited and such policy processes have been critiqued for have a culturally elite bias, and for de-politicizing the policy process [56]. In what follows four broad barriers to sustainable food system transitions in an era of urbanization are considered: competing interpretations, policy silos, increasing de-politicization, and trade-offs.

Increasing de-politicization

A first barrier to advancing good governance for sustainable food system transitions means addressing the trend of depoliticization. Concerns around processes of de-politicization have been raised in social science circles, and with relation to food more specifically [57], [58], as part of a critique of globalization, neoliberalism and the maintenance of the status quo. De-politicization refers to processes whereby complex and normative policy processes are minimized, or structured to avoid or conceal the relations of power and conflictual dimensions inherent to them [59, pp. 262–63]. De-politicizing tendencies across MSPs and across broader political processes, are not to be equated with a lack engagement. Rather, such trends are reflected in, and reified by, broader moves towards, for example, so-called ‘post-truth’ and ‘post-fact’ politics, the rise of populism and a decrease in mainstream/ formal political participation (e.g. voter decline)[60].

Insofar as the de-politicization of public policy leads to a lock-in of status quo practices and values [36], often at the expense of alternatives, transitioning to sustainable and just food systems requires alternatives that can only be made visible through politicized policy processes: through processes that acknowledge conflicts, passions and diverse perspectives. The politicization of food governance is therefore fundamental to re-building food systems so as to ensure new possibilities are made visible, while re-invigorating policy processes through diverse, meaningful participation, engagement, and debate around contentious issues. Indeed, all future food policy discussions necessitate grappling with contentious issues, many of which have no win-win solutions, and in turn, for which important trade-offs must be made (see below).

Towards this end, a deeper understanding of the trend of de-politicization as well as the implications it has on democratic processes, particularly in relation to sustainable food systems, is required. This barrier can be addressed in part by implementing the condition of stakeholder engagement in ways that address power relations and access to resources while ensuring diversity [36], and embedding reflexivity in governance processes. Embracing a politicized policy environment means also establishing processes for acknowledging and addressing competing visions and understanding of current and future food systems.

Competing interpretations of complex concepts

Designing policies for sustainable food systems requires a common understanding of key concepts: how we define the problem informs the policies that are advanced. Yet, the concept of sustainability is not only understood in different ways, it is also applied in different ways, usually based on a relatively narrow interpretation [61]. This has implications for the governance of sustainable food systems. Further, while there is broad consensus that sustainability needs to encompass social, economic and ecological considerations, the focus tends to be on the latter. Social dimensions of sustainability, including issues of equitable and appropriate access, inclusion, and participation must be embedded, in a transversal way, in thinking around public policies for sustainable food systems transition. They must also be concretely embedded in the framework of planetary boundaries [62]. Raworth's [63] efforts to introduce so-called doughnut economics, are a step in the right direction in terms of framework for social-ecological thinking. Like the concept of sustainability, food systems are dynamic and conceptualized in different ways on the basis of contested knowledge and changing contexts [50]. What is understood as a food system in public policy spans from configurations of supply chains and distribution networks, to the integration of social-ecological system frameworks.

Competing definitions and interpretations point to distinct entry points, disciplines, narratives and values. This diversity presents challenges and barriers, but is also key to the future of food systems, particularly from a social-political perspective. Thus, while efforts to come to common definitions are valuable; there is also value in understanding competing definitions, including points of divergence and convergence therein. In practice, sustainable food systems represents a policy problem for which there is no neutral diagnosis or solution: a so-called 'wicked' problem that transgresses traditional policy boundaries and calls for policy-making processes that reflect, orient, and include diverse experiences, knowledge and values [64], [65]. This barrier can be addressed in part by implementing the condition of reflexive governance which provides a framework to acknowledge multiple perspectives, expectations, power dynamics, and strategies, while rejecting a single framing of the problem, a single prognosis of consequences, and a single way forward [66] (see section 3).

Policy Silos

The silo metaphor is often used to critique the dominant approach to organizing policy domains, but it seems particularly fitting when talking about food: silos store and protect grain, and are thus fundamental to food security. Yet, policy silos refer to the separation of ideas, practices, implications and impacts. To continue to develop public policies within silos is to ignore the complex dynamics of how people grow, access, eat and dispose of food. When health, agriculture, trade, and natural resources remain distinct departments, solutions rarely surface that adequately and appropriately embrace complexity [67]. Understanding this, scholars have highlighted the fragmented disciplinary engagements with environmental and nutritional outcomes of food systems at national and international level [68], although this is slowly changing with increased focus on nutrition and sustainable diets. Silos are a key barrier to policy integration, and thus overcoming siloed thinking is key to achieving policy integration (discussed above in future trends). When it comes to urban food policies, there are opportunities insofar as municipal-level challenges often lie with eco-social issues where silos are less pronounces when compared to national and international levels [56]. Recognizing the complexity of interactions across the food system means that changes to one part of the system with impact other subsystems (e.g. changes to biofuel policy can impact food availability and prices). Policy silos are incompatible, and indeed detrimental, to systems approaches. This barrier can be overcome by implementing the condition of policy integration (see section 3), but if further challenged by the need to address difficult trade-offs.

Trade-offs

A fourth barrier to the governance of sustainable food systems transitions relates to the need to address tradeoffs between different dimensions of food system sustainability. Such transitions will require situational decisions that involve reducing a quality or quantity aspect of one subsystem in return for gains in another subsystem. There are limited win-win situations ahead and greater attention is needed to identify possible policy pathways, related impacts, and related tradeoffs. This requires political will. This is indeed one of the key lessons to come out of the COVID-19 crisis: governments had to choose between flattening the curve with lockdowns and physical distancing at the expense of economic activity. Tradeoffs, but also synergies, must be anticipated, assessed and addressed in a transparent manner. Such a process could counter the trend towards de-politicization as it actively refutes the possibility of neutral decision-making. As a report of the Group of Chief Scientific Advisors [48, p. 19] notes, primary goals against which trade-offs and synergies are currently weighed include food security, food safety and economic considerations, but when sustainability becomes an overarching goal and priority, the tradeoffs will need to be adjusted accordingly. Indeed, there will be difficult decisions to be made and it is anticipated that the sooner they are made, the less drastic the negative impacts will be. More research is needed not only to identify policy pathways, impacts and tradeoffs, but also to understand how decision-makers deal with such tradeoffs.

Addressing inequality through the prioritization of the social dimensions of sustainability, addressing competing interpretations, overcoming policy silos and addressing trade-offs are key factors to support a socio-political shift in public policies for sustainable food systems transition. At the same time, it must be acknowledged that a good policy is not enough: what matters is how it is adopted and implemented.

5. Challenges for research

Supporting socio-political change in public policies for safe and just food systems needs to be backed by a rigorous, multi and interdisciplinary research agenda that reflects and a diversity of experiences and realities. Based on what has been presented above, specific research needs have been identified in Table 5.1.

Table 5.1: Future research needs

Topic addressed	Research Needs
	Conditions to govern sustainable food systems transitions in an era of urbanization
Policy integration	More research is needed to build up the evidence base and best practices for creating and implementing integrated policies, vertically and horizontally. Attention to how food policy is integrated (i.e. through the Green Deal and the Farm-to-Fork plan) is also needed.
	Improved methods for measuring policy impacts on food system transitions are urgently needed to allow for improved evidence-based policy making. Supporting policy-learning processes through living labs for example, can support this.
Stakeholder engagement	Better understanding of trends and implications around stakeholder engagement in policy processes, particularly impacts of formalization and professionalization, is needed.
	Research is needed into how to best organize stakeholder participation, recognizing the need to create spaces where competing values and related tradeoffs can be addressed and relations of power managed in equitable ways.
City-region approach	More research and analysis is needed to understand how to most appropriately move beyond (re)localization and to strengthen rural-urban linkages with a view towards supporting sustainable food systems transitions.
Reflexive governance	Action-oriented research that contributes to capacity and skills training around reflexivity is needed. To adequately develop the reflexivity required, opportunities need to be created for learning, testing, experimenting and also failing in ethically and safely trialed ways. These require monitoring, evaluation and ongoing adaptation.
	There is a need for knowledge production to be transdisciplinary, integrated and fed into processes that balance complexity with accessibility. Further, scientific debates, contradictions and narratives should be made explicit. Expertise and knowledge production should expand beyond traditional knowledge brokers (i.e. universities and research institutes).
	Barriers to governing for food system transitions
De-politicization	More empirical research is needed to further understand the causes and implications of de-politicization for the governance of food system transitions, particularly in relation to rising mistrust of science and politics, post-truth, and populism (e.g. understanding relations between food localization and nationalism).
Competing interpretations	More effort is needed to integrate social and economic dimensions into research on food systems sustainability. Given the lack of consensus on definitions, more conceptual clarity is required when developing research agendas, recognizing that consensus may not be possible, in which case mutual understanding should be the ambition.
Policy silos	Overcoming policy silos is fundamental to achieving policy integration. As noted above, research is needed to build up the evidence base and best practices for creating and implementing integrated policies.
Tradeoffs	In-depth qualitative and quantitative research is needed to contribute to the identification of policy pathways, impacts and tradeoffs, as well as to improve understanding of how decision-makers deal with such tradeoffs. More understanding of how trade-offs are identified, assessed and addressed is required, particularly in relation to policy integration, and with a view towards Food2030, the New Green Deal and the Farm-to-Fork plan.

References

[1] UNESCAP, "Expert group meeting on sustainable urban development in Asia and the Pacific: towards a new urban agenda background paper," 2014.

[2] K. C. Seto and N. Ramankutty, "Hidden linkages between urbanization and food systems," *Science (80-.).*, vol. 352, no. 6288, pp. 943–945, May 2016.

[3] C. S. Khoo and D. Knorr, "Grand Challenges in Nutrition and Food Science Technology," *Front. Nutr.*, vol. 1, Apr. 2014.

[4] D. of E. and S. A. P. Dynamics, "World Urbanization Prospects 2018," New York, 2018.

[5] SAM, "Scoping paper: towards an EU sustainable food system," Brussels, 2019.

[6] Eurostat, "Urban Europe: Statistics on Cities, Towns and Suburbs," Luxembourg, 2016.

[7] B. Frank, D. Delano, and B. Schaefer Caniglia, "Urban systems: a socio–ecological system perspective," *Sociol. Int. J.*, vol. 1, no. 1, pp. 1–8, 2017.

[8] P. J. Marcotullio, A. Sarzynski, J. Albrecht, and N. Schulz, "A top-down regional assessment of urban greenhouse gas emissions in Europe," *Ambio*, vol. 43, no. 7, pp. 957–968, 2014.

[9] A. Grubler and D. Fisk, "Introduction and overview," in *Energizing sustainable cities, assessing urban energy*, Oxon: Routledge, 2012, pp. 1–14.

[10] R. Sonnino, C. L. S. Tegoni, and A. De Cunto, "The challenge of systemic food change: Insights from cities," *Cities*, vol. 85, pp. 110–116, Feb. 2019.

[11] C. McFarlane, "The city as a machine for learning," *Trans. Inst. Br. Geogr.*, vol. 36, no. 3, pp. 360–376, Jul. 2011.

[12] FAO, "The role of cities in the transformation of food systems: Sharing lessons from Milan Pact Cities," Rile, 2018.

[13] MUFPP, "Milan Urban Food Policy Pact," *Website*, 2020. [Online]. Available: http://www.milanurbanfoodpolicypact.org/. [Accessed: 24-Apr-2020].

[14] IPES Food, "What makes urban food policy happen? Insights from five case studies.," Brussels, 2017.

[15] J. S. C. Wiskerke, "On Places Lost and Places Regained: Reflections on the Alternative Food Geography and Sustainable Regional Development," *Int. Plan. Stud.*, vol. 14, no. 4, pp. 369–387, Nov. 2009.

[16] P. Caron *et al.*, "Food systems for sustainable development: proposals for a profound four-part transformation," *Agron. Sustain. Dev.*, vol. 38, no. 4, p. 41, Aug. 2018.

[17] D. Barling, T. Lang, and M. Caraher, "Joined-up Food Policy? The Trials of Governance, Public

Policy and the Food System," *Soc. Policy Adm.*, vol. 36, no. 6, pp. 556–574, Dec. 2002.

[18] M. Dubbeling, C. J., and K. Hochberg, "The role of private sector in city region food systems-synthesis report.," 2016.

[19] IPES, "Towards a common food policy for the European Union," Brussels, 2019.

[20] B. Mansfield and W. Mendes, "Municipal Food Strategies and Integrated Approaches to Urban Agriculture: Exploring Three Cases from the Global North," *Int. Plan. Stud.*, vol. 18, no. 1, pp. 37–60, Feb. 2013.

[21] FAO, "Facilitating Effective Multi-stakeholder Processes," *FAO Capacity Development*, 2016. [Online]. Available: http://www.fao.org/capacity-development/resources/practical-tools/multi-stakeholder-processes/en/. [Accessed: 02-Dec-2016].

[22] J. Duncan and D. Barling, "Renewal through Participation in Global Food Security Governance: Implementing the International Food Security and Nutrition Civil Society Mechanism to the Committee on World Food Security," *Int. J. Sociol. Agric. Food*, vol. 19, pp. 143–161, 2012.

[23] T. Clarke and C. Stewart, *Changing Paradigms: The transformation of management knowledge for the 21st century*. London: Harper Collins, 1998.

[24] R. E. Freeman, *Strategic management: a stakeholder approach*. Boston: Pitman, 1984.

[25] H. Brouwer, W. Hiemstra, S. van der Vugt, and H. Walters., "Analysing stakeholder power dynamics in multi-stakeholder processes: insights of practice from Africa and Asia.," *Knowl. Manag. Dev. J.*, vol. 9, no. 3, pp. 11–31, 2013.

[26] M. Boström and K. T. Hallström, "Global multi-stakeholder standard setters: How fragile are they?," *J. Glob. Ethics*, vol. 9, no. 1, pp. 93–110, 2013.

[27] M. Kuchler, "Stakeholding as sorting of actors into categories: implications for civil society participation in the CDM," *Int. Environ. Agreements Polit. Law Econ.*, vol. 17, no. 2, pp. 191–208, Apr. 2017.

[28] R. Marchetti, "Models of global democracy: In defence of cosmo-federalism.," in *Global Democracy: Normative and empirical perspectives*, K. Archibugi and R. Marchetti, Eds. Cambridge: Cambridge University Press, 2012, pp. 22–46.

[29] C. Barnaud and A. Van Paassen, "Equity, Power Games, and Legitimacy: Dilemmas of Participatory Natural Resource Management," *Ecol. Soc.*, vol. 18, no. 2, p. art21, 2013.

[30] J. F. Warner, "The beauty of the beast: Multi-stakeholder participation for integrated catchment management," *Multi-stakeholder platforms Integr. water Manag.*, pp. 1–19, 2007.

[31] G. Schouten, P. Leroy, and P. Glasbergen, "On the deliberative capacity of private multi-stakeholder governance: The Roundtables on Responsible Soy and Sustainable Palm Oil," *Ecol. Econ.*, vol. 83, pp. 42–50, Nov. 2012.

[32] L. Westberg and C. Waldenström, "How can we ever create participation when we are the ones who decide? On natural resource management practice and its readiness for change," *J. Environ.*

Policy Plan., pp. 1–14, Dec. 2016.

[33] M. S. Reed *et al.*, “Who’s in and why? A typology of stakeholder analysis methods for natural resource management,” *J. Environ. Manage.*, vol. 90, no. 5, pp. 1933–1949, Apr. 2009.

[34] M. Boström and K. T. Hallström, “The Fragile Authority of Multi-Stakeholder Standard Setting,” in *Re-Discovering International Organizations (9-11 September)*, 2010, vol. 2011.

[35] P. Claeys and J. Duncan, “Food sovereignty and convergence spaces,” *Polit. Geogr.*, vol. 75, p. 102045, Nov. 2019.

[36] J. Duncan and P. Claeys, “Politicizing food security governance through participation: opportunities and opposition,” *Food Secur.*, vol. 10, no. 6, pp. 1411–1424, 2018.

[37] S. Franceschini and G. Marletto, “Assessing the benefits and the shortcomings of participation – findings from a test in Bari (Italy),” *J. Transp. Geogr.*, vol. 44, pp. 33–42, Apr. 2015.

[38] J. van de Griend, J. Duncan, and J. S. C. Wiskerke, “How Civil Servants Frame Participation: Balancing Municipal Responsibility With Citizen Initiative in Ede’s Food Policy,” *Polit. Gov.*, vol. 7, no. 4, 2019.

[39] T. B. Lawrence, B. Leca, and T. B. Zilber, “Institutional Work: Current Research, New Directions and Overlooked Issues,” *Organ. Stud.*, vol. 34, no. 8, pp. 1023–1033, Aug. 2013.

[40] F. J. de Haan and J. Rotmans, “A proposed theoretical framework for actors in transformative change,” *Technol. Forecast. Soc. Change*, vol. 128, pp. 275–286, Mar. 2018.

[41] M. S. Reed, “Stakeholder participation for environmental management: A literature review,” *Biol. Conserv.*, vol. 141, no. 10, pp. 2417–2431, Oct. 2008.

[42] F. Fischer, *Citizens, Experts and the Environment: The Politics of local Knowledge*. Durhan, NC: Duke University Press, 2000.

[43] E. Swyngedouw, “Governance innovation and the citizen: The Janus face of governance-beyond-the-state,” *Urban Stud.*, vol. 42, no. 11, pp. 1991–2006, Oct. 2005.

[44] N. McKeon, “Are Equity and Sustainability a Likely Outcome When Foxes and Chickens Share the Same Coop? Critiquing the Concept of Multistakeholder Governance of Food Security,” *Globalizations*, vol. 14, no. 3, pp. 379–398, 2017.

[45] L. Westberg and C. Waldenström, “How can we ever create participation when we are the ones who decide? On natural resource management practice and its readiness for change,” *J. Environ. Policy Plan.*, vol. Online fir, pp. 1–14, 2016.

[46] M. Woods, “Urban-Rural Linkages,” in *The Handbook of Sustainable and Regenerative Food Systems*, J. Duncan, M. Carolan, and J. Wiskerke, Eds. Oxon: Routledge, 2020, pp. 363–75.

[47] FAO, “Need for sustainable and resilient City Region Food Systems,” *City Region Food Systems Programme*, 2019. [Online]. Available: http://www.fao.org/in-action/food-for-cities-programme/approach/need-for-sustainable-and-resilient-crfs-copy-1/en/. [Accessed: 25-Sep-2019].

[48] SAM, “Towads a systainable food system: Moving from food as a comminity to food as more of a common good,” Brussels, 2020.

[49] J.-P. Voss and R. Kemp, “Sustainability and reflexive governance: Introduction,” in *Reflexive governance for sustainable development*, J. P. Vol, D. Bauknecht, and R. Kemp, Eds. Cheltenham: Edward Elgar, 2006, pp. 3–28.

[50] J. Duncan, “‘Greening’ global food governance,” *Can. Food Stud.*, vol. 2, no. 2, pp. 335–344, Sep. 2015.

[51] A. Rip, *A co-evolutionary approach to reflexive governance - and its ironies*. Cheltenham: Edward Elgar, 2006.

[52] F. Wolff, “The transformation of agriculture: reflexive governance for agrobiodiversity,” in *Reflexive governance for sustainable development*, J.-P. Voss, D. Baukecht, and R. Kemp, Eds. Cheltenham: Edward Elgar, 2006, pp. 383–416.

[53] J.-P. Voss and R. Kemp, “Reflexive Governance for Sustainable Development – Incorporating feedback in social problem solving,” in *ESEE Conference: Special session on Transition Management*, 2005, pp. 1–31.

[54] A. Moragues-Faus, R. Sonnino, and T. Marsden, “Exploring European food system vulnerabilities: Towards integrated food security governance,” *Environ. Sci. Policy*, vol. 75, pp. 184–215, Sep. 2017.

[55] J. J. L. Candel and L. Pereira, “Towards integrated food policy: Main challenges and steps ahead,” *Environ. Sci. Policy*, vol. 73, no. September 2016, pp. 89–92, 2017.

[56] H. Coulson and R. Sonnino, “Re-scaling the politics of food: Place-based urban food governance in the UK,” *Geoforum*, vol. 98, pp. 170–179, Jan. 2019.

[57] J. Duncan, “Governing in a Post-Political Era: Civil Society Participation for Improved Food Security Governance,” in *Advances in Food Security and Sustainability, Volume 1*, D. Barling, Ed. Burlington: Academic Press, 2016, pp. 137–161.

[58] A. Moragues-Faus, “Emancipatory or Neoliberal Food Politics? Exploring the ‘Politics of Collectivity’ of Buying Groups in the Search for Egalitarian Food Democracies,” *Antipode*, vol. 49, no. 2, pp. 455–476, 2017.

[59] C. Mouffe, “Post-Marxism: Democracy and Identity,” *Environ. Plan. D Soc. Sp.*, vol. 13, no. 3, pp. 259–265, Jun. 1995.

[60] M. Flinders and M. Wood, “Depoliticisation , governance and the state,” vol. 42, no. 2, pp. 135–149, 2014.

[61] C. Béné *et al.*, “When food systems meet sustainability – Current narratives and implications for actions,” *World Dev.*, vol. 113, pp. 116–130, Jan. 2019.

[62] W. Steffen *et al.*, “Planetary boundaries: Guiding human development on a changing planet,” *Science (80-.).*, vol. 347, no. 6223, pp. 1259855–1259855, Feb. 2015.

[63] K. Raworth, “A safe and just space for humanity: Can we live within the doughnut?,” Oxford, 2012.

[64] H. W. J. Rittel and M. M. Webber, “Dilemas in a general theory of planning,” *Policy Sci.*, vol. 4, no. 155–69, 1974.

[65] C. J. A. M. Termeer, A. Dewulf, G. Breeman, and S. J. Stiller, “Governance Capabilities for Dealing Wisely With Wicked Problems,” *Adm. Soc.*, vol. 47, no. 6, pp. 680–710, Aug. 2015.

[66] J.-P. Voss and B. Bornemann, “The Politics of Reflexive Governance: Challenges for Designing Adaptive,” *Ecol. Soc.*, vol. 16, no. 2, 2011.

[67] J. Duncan and M. Bailey, “Caution: Road work ahead,” in *Sustainable food futures: Multidsciplinary solutions*, Oxon: Routledge, 2017, pp. 203–214.

[68] T. Lang and D. Barling, “Nutrition and sustainability: an emerging food policy discourse.,” *Proc. Nutr. Soc.*, vol. 72, no. March, pp. 1–12, Dec. 2013.

[69] L. Dijkstra and H. Poelman, “A harmonised definition of cities and rural areas: the new degree of urbanisation (WP 01/2014),” Brussels, 2014.

[70] L. Dijkstra and H. Poelman, “Cities in Europe: The new OECD-EC definition (RF 01/2012),” Brussels, 2012.

Appendix 1: Review of targets, interventions and impacts of urban food policies

Target	Intervention	Impact	City-level examples
		Transition 1: Healthy and sustainable food for all	
Healthy diets	**Public procurement**	**Increase consumption of organic food (fruit and vegetables)**	**Copenhagen's (Denmark) Organic Conversion Project reached a 90% organic food procurement target for all 900 municipal kitchens.**
Sustainable diets	**Public procurement**	**Increase consumption of organic food (fruit and vegetables) in schools, hospitals and municipal canteens**	**Vienna (Austria) has procured organic food for school and hospital canteens with measurable reduction of greenhouse gases.** **In Ghent (Belgium) Thursday Veggie Day was introduced. 28% of people who participated at least once claim they have vegetarian. Between 2012 and 16 they organized 110 workshops on Thursday Veggie Day in schools.**
		Transition 2: Full circularity of food systems	
Reduce food waste	**Working with public institutions**	**Reduced food waste**	**Ghent (Belgium) has a food policy council has identified a market for food surpluses and has provided residents tips for conscious purchases, optimal nutrition and processing. In 2 years, 1.000 tons of food waste was redistributed to 57,000 people in poverty.** **Bruges (Belgium) engaged healthcare professionals in city hospitals to develop innovative solutions to hospital food waste, leading to significant reductions in food waste in Bruges hospitals through for example: addressing portion size, ordering a-la-carte style, providing a set dish with predefined options, ensuring recipes are closely followed, and sharing any leftover meal to social grocery stores.**
Short supply	**Territorial approach**	**Local food production**	**Ljubjiana (Slovenia) has a "City Rural Development" plan to support more than 800 farms in the city limit. The plan focuses on short supply chains, preservation of**

chains			**farmland, financial support for farmers, training of suppliers, retailers, chefs and food service professionals.** **The City Green Belt or L'Horta surrounding Valencia (Spain) has been conserved with municipal support and significant civil society mobilization to provide food for the city.**
Reorganizing rural areas	**Territorial approach**	**Territorial markets and social equity**	**Bordeaux (France) brought together 28 different government bodies to collaborate on plan for a "territorial social food system" and are tracking outputs for social and economic equity, improved health and stronger territorial markets.**
Land use	**Zoning**	**Local food production**	**Ghent has committed 100 ha of city-owned agricultural land to be used for local food production and 50% of food consumption in the city will be local food by 2040.**
Reorganizing logistics for optimizing flows between firms	**Green energy for local vegetable production**	**Reduce GHG, increase local vegetables**	**Latvia (Riga) has a program (supported by the national government) to convert methane emissions from the country's largest landfill to the country's largest source of green energy to heat greenhouse production of fresh vegetables in winter, with significant reductions in greenhouse gas.**
New consumption patterns	**Urban and peri-urban markets**	**Access to food through solidarity economy**	**In Lyon (France) the Lyonnaise Council for Sustainable Food supports solidary grocery stores and participatory kitchens, urban agriculture and short supply chains to advance access to food and community-based economic development.**
	Transition 3: Substantial increase of biological, social and economic diversity		
Biological diversity	**Integrated governance**	**Zoning to enhance agricultural diversification**	**The Nantes Metropol (France) has adopted an integrated governance approach between city and territorial governments, chambers of commerce and farmers groups. They use zoning to revitalize open space for agricultural diversification.**
Social diversity and inclusion	**Marketing regulations**	**Less advertising unhealthy options, increase in community gardens.**	**In Birmingham (UK) unhealthy food and fast food advertising in low income neighborhoods has been targeted and municipal commitment to expand school and community gardens has increased.** **In Ghent (Belgium) the city has supported a website where citizens can post available food or demand for**

	Online platforms	Connecting people to share food.	foods. The online platform has reached 20,439 individuals and serves as an online meeting point on sustainable food.
		Subsidized school meals.	Ghent has also developed sustainable school meals, which serves 4500 students or 775,883 meals. annually. School meals are not for free but 10% of the children in the city have the right to buy their meal for 1 €, facilitating access to healthy, nutritious food.
	Healthy school meals	Awareness building	43 schools last year engaged with the educational campaign on sustainable food. Educational materials were distributed to 5667 children and 2572 teachers.
	Education campaigns	Access to food	Further, after 2 years in operation, the Foodsavers program provided 57,000 people in need products or food baskets. These were distributed through 106 local poverty organizations and social restaurants based in Ghent.
	Redistribution		
Economic diversity	Multistakeholder platforms	Supporting private sector innovation	Ede (The Netherlands) has an integrated food policy coordinated across city departments and in alignment with regional and national government. The municipality subsidizes a food enterprise incubator called the "FoodFloor" showcase innovation.

Source: interviews, [12]

FINANCE AND CORPORATE STRATEGIES IN AGRICULTURE

Henning Otte Hansen, 5th SCAR Foresight Exercise expert

Abstract
Politicians, economists and people in the food value chain often face a dilemma: A conflict between economic and financial goals, on the one hand, and sustainability and environmental goals, on the other, occurs. Structural development, which is often the result of economic and financial drivers, is rather predictable, follows global trends, and is not significantly influenced by environmental shocks. This implies that it is difficult to change structural development. Therefore, political attempts to limit or change structural development will have a negative effect on farmers' economic performance. A crucial question is whether structural development is a barrier or a tool - a problem or a solution - for sustainable farming.

Organic farming, which is considered a step towards more sustainable food production, seems to follow the same long-term trends as conventional agriculture regarding productivity pressure, real price decreases and large scale production.

The mainstream corporate strategy seems to be changing currently with less focus on shareholder value and increased stakeholder value, which leaves room for greater care of the environment and sustainability. However, it is assumed that globalization and the utilization of its comparative benefits will continue.

The globalization trend seems to be strong. The vertical integration has become more internationalized, and international trade and investments are increasing. However, also a "localization trend" also appearing, which will become increasingly important in the consumer market. It is assumed that local and global demand can coexist.

Several direct or indirect initiatives and regulations are driving corporate responsibility within sustainability. In the paper four such drivers are identified and discussed.

Based on trends in agricultural structural development, drivers, changes of corporate strategies, analyzes of transitions, and policy conditions a number of main research questions and topics are identified.

1. Interpretation of the theme

This article discusses trends in the field of finance and business strategies related to the primary sector. Issues such as the role of finance in the structure of the industry, the evolution and the implications of global value chain development, the evolution of corporate strategies, present and future corporate responsibilities, etc. are presented.

Corporate strategies include the goals and tools that a business defines. The goals are typically related to economic survival, and development and optimization, while the tools are related to parameters such as competitiveness, market adaptation, growth, efficiency, innovation and competence. These principles, which lie behind strategies, are broadly the same for all companies in the agricultural and food industry.

However, in recent years, strategies with a focus on sustainable development and production have become more common. This possible paradigm shift may be a driver of more sustainable development in agriculture.
Often, a conflict between economic and financial goals, on the one hand, and sustainability and environmental goals on the other hand occurs. In many cases, economic and financial goals will result in the increased utilization of economies of scale, thereby accelerating structural development, specialization, compliance with market demands, etc. Market demands will not completely reflect the need for greater consideration of sustainability and the environment.

Therefore, agriculture faces a dilemma: achieving economically optimal production will be necessary to survive commercially. Agricultural holdings – at least industrial and competitive agriculture – are commercial enterprises where strategies focus on being market compliant and economically viable. In this context, being market compliant means being able to meet the commercial demands that exist and arise on the market.

A transformation to more sustainable production will probably not be rewarded or honored on the market and through the demand, and farmers will not receive a sufficient additional price to offset the reduced efficiency or higher costs that more sustainable production implies.

At the same time, farmers operate under international competition, where more expensive and more sustainable production could be out-competed and replaced by less sustainable imports. Barriers to imports of cheaper, but less sustainable products are unlikely to be in line with international trade rules.

Thus, there is a conflict between the economic market conditions in terms of competitiveness and economic survival and the political demands and conditions in terms of sustainability.

However, the economic and market conditions - and the derived structural effects - are difficult to change and even harder to reverse.

These are often megatrends, which are difficult to influence without causing other negative consequences in an increasingly open economy. It is, thus, necessary to identify and describe the economic and structural trends.

The drivers behind these trends are also important to identify as it highlights opportunities for influencing development. In addition, it is important to identify the gap between continued development and desired development.

Last but not least, it is important to assess the extent to which a change or reverse of the current structural development is an effective tool for ensuring greater sustainability in EU agriculture.

2. Analysis of the main emerging issues

This section analyzes the main trends and the underlying drivers of structural development in the industry. As organic agriculture can be considered a more sustainable form of agricultural production, the structural and economic trends that characterize significant organic agricultural production are analyzed and compared.

Furthermore, the evolution in corporate strategies is analyzed. While economic and financial goals are increasingly being supplemented by sustainability goals, new ways of improving sustainability are emerging.

Finally, the evolution and the implications of internationalization and, especially, the development of the global value chains are investigated.

Definition of structural development

The structure of the industry (both primary agriculture and downstream industries) has been changing significantly in recent decades, albeit to varying extents in different countries. Structural development appears in several different ways and with different drivers. The structural development in agriculture is described using the following parameters:

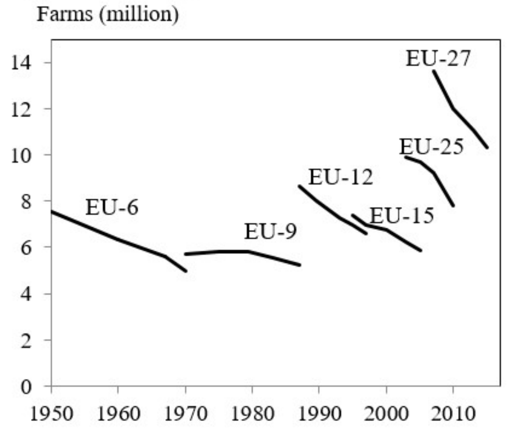
- Number of farms
- Size of farms
- Specialization (less diversification)
- Concentration
- Ownership
- Vertical integration
- Changed inputs

- More capital
    - More technology
    - Less labour
- Globalization
    - Global value chains
    - Foreign direct investments
    - Foreign labor/migration

Trends of structural development

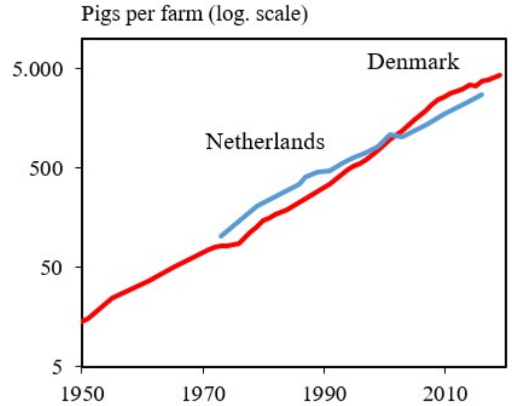
Figures 1-6 are examples of this structural development in European countries. The figures either cover the whole of the EU or are taken from specific countries, representing major trends in the whole of the EU. In general, the structural development is rather predictable and not significantly influenced by environmental shocks. It indicates that it is difficult to change structural development if desired.

Figure 1. Number of farms in the EU



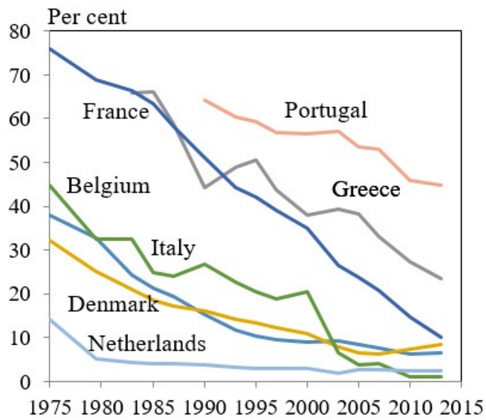
Sources: Eurostat (several issues)

Figure 2. Average size of pig farms



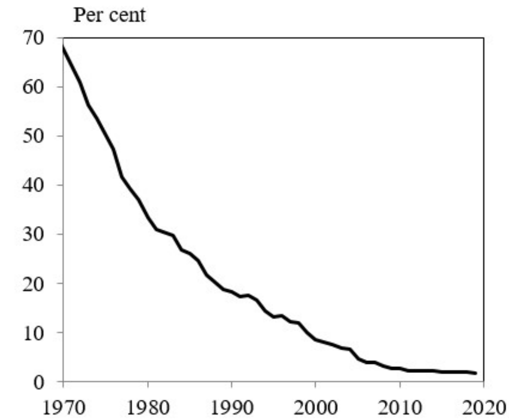
Sources: Statistics Denmark (several issues), European Commission (2015 + several issues)

Figure 3. Specialization. Share of farms with laying hens



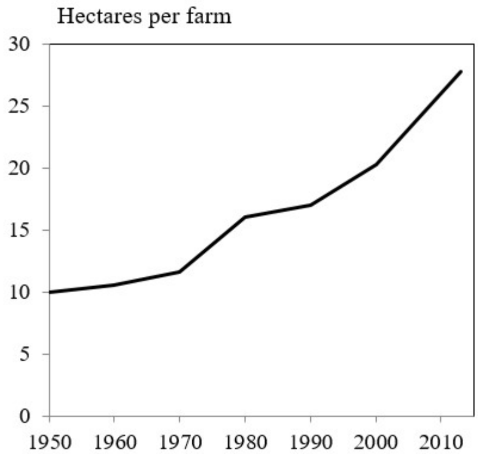
Sources: Eurostat (several issues)

Figure 5. Share of farms with both cattle and pigs in Denmark



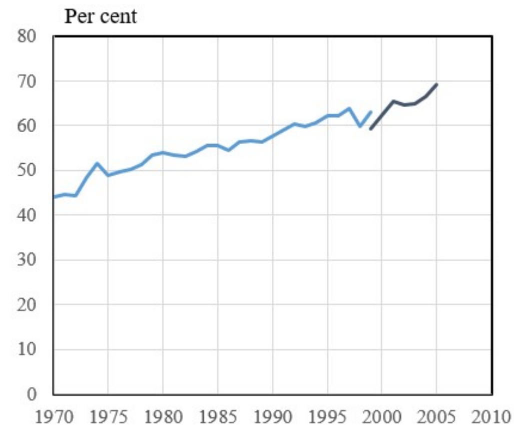
Source: Statistics Denmark (several issues c)

Figure 4. Average size of farms in Europe



Source: FAO (2013 + 2016)

Figure 6. 20 per cent biggest farms' share of total farm revenue in Denmark



Sources: Statistics Denmark (2010 + several issues b)

Diversity in its various forms (structural, biological, social and economic) is under pressure in European agriculture. Diversity (heterogeneity) and its development can be identified in several different areas:

- Number of farms

- Size of farms
- More specialized /less mixed farms
- Less rotation and more monocultures
- Economies of scale – larger fields
- Reduction in (harmful) insects, weeds, etc.
- Bigger and more efficient fields (fewer windbreaks, etc.)
- Increasing concentration (less even distribution of farms)
- Geographical concentration (sugar beets in fewer countries etc.)
- Livestock in more concentrated areas
- Migration away from rural areas by non-farmers ("farmer-ghettos")
- More land in rotation – less "natural and untouched" land

Some of these trends are also shown in Figure 1-6.

Drivers of structural development The structure of the industry in both primary agriculture and in downstream industries is heavily influenced by economic and financial drivers. Economies of scale – driven by technological development – and the economic performance of agriculture activities vs. non-agricultural activities have been major drivers of structural development in the form of fewer, bigger and more specialized farms. However, a number of different drivers has influenced the structural development:

Technology can replace labor and increase migration away from agriculture, resulting in fewer farms. Technology means that the economically optimal size of farms is increasing, resulting in bigger and more specialized farms, and the concentration will increase. Technology can also strengthen vertical integration in the value chain through increased traceability.

Economies of scale will result in fewer and larger farms.

Improved economic and financial conditions in agriculture will limit migration away from agriculture and encourage new (young) people to enter the agricultural business. The incentive to invest and grow will also increase the size of farms, and the need for risk diversification will be reduced, so specialization may increase. The improved economic and financial conditions may be the result of better market conditions, increased support, etc.

The macro-economic conditions and the general development in wages in the economy are also drivers. Attractive economic opportunities in non-agricultural sectors will pull labor away from agriculture and limit the supply of new labor to the sector.

Access to capital, markets, education, training, advisory services, etc. can strengthen specialization and large-scale agricultural production.

Also, infrastructure will be improved, which may lead to better vertical integration and division of labor between agriculture and the food industry.

Another common aim of agricultural legislation is to regulate structural development in agriculture. From a national perspective, structural development can be affected by legislation regarding maximum farm sizes, special requirements for buyers of agricultural farms, special support schemes for small farms, etc. From an EU perspective, structural development may be affected by differential support depending on farm size.

Although some non-economic and economically irrational drivers may exist (growth as a goal in itself), structural development is primarily a result of economic and financial drivers. The economic conditions for farmers in Europe are rather unique and common, as the terms of trade (output-input price ratio) are decreasing and productivity is increasing. This combined with changed and reduced support, more liberal trade and increased globalization have increased international competition and put even more pressure on the international competitiveness of European agriculture.

Political attempts to limit or change the structural development will, therefore, have a negative effect on farmers' economic performance.

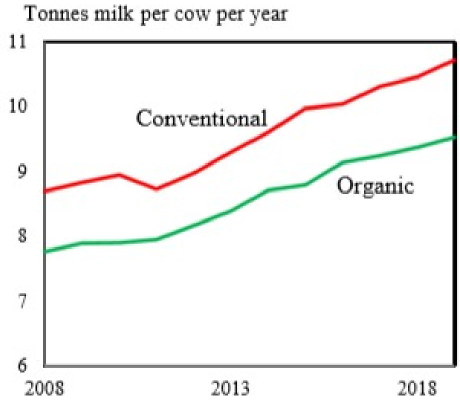
Organic farming and sustainable agriculture Organic farming can be considered a step towards more sustainable food production - regardless of the debate about organic farming's contribution, or otherwise, to ensuring more sustainable global food production. The question is, therefore, whether conditions such as economies of scale, structural development, pressure to increase on productivity, a decline in real prices and the agricultural treadmill (Cochrane, W. W., 1958), which is a characteristic of conventional agriculture, are significantly different in organic agriculture.

From a theoretical point of view, differentiated products such as organic products can only reduce or delay the conditions under which agriculture operates. This is mainly due to two factors: First, agriculture mainly produces raw materials that are difficult to differentiate and turn into unique products. Processing and marketing primarily create added value, while the agricultural products are still standard commodities that can be mass-produced.

It is difficult to create a "Blue Ocean" (a market with high growth and earnings and innovation, with limited competition, etc.) for agricultural products. The reason is that competition is too fierce, the possibility to copy is obvious and the potential to add unique features is too small.

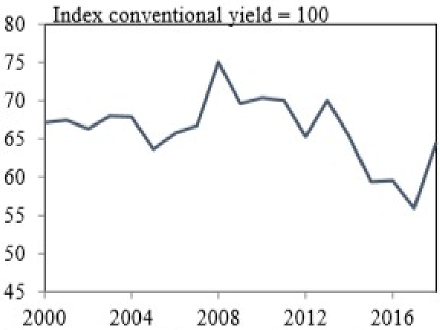
Second, even organic production in agriculture will quickly face price and productivity pressures, just like conventional production. Examples from Danish agriculture, which has significant organic agricultural production, show that in recent years, the development in prices, structure and productivity of organic products has largely followed the same development as conventional products (see Figures 7-11).

Figure 7. Yield of dairy cows in Denmark, full-time farms, 2008-19



Source: Statistics Denmark (2020)

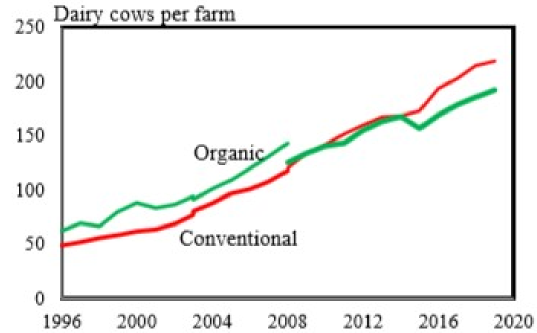
Figure 8. Organic yields as a per cent of conventional yields in crop production (full-time) in Denmark, 1995-2018



Note: Average of 11 crops, weighted with economic significance of organic and conventional farming

Source: Statistics Denmark (several issues)

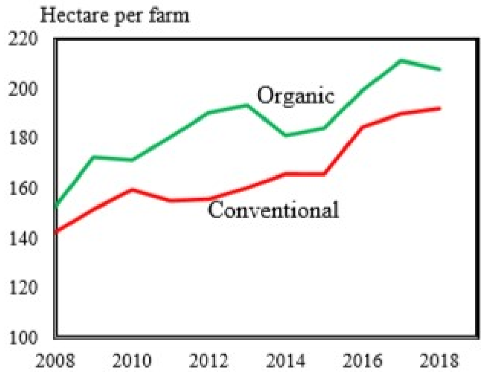
Figure 9. Average size (dairy cows per farm) of dairy farms in Denmark, 1996-2019



Note:
2008-2019: Full-time farms
1996-2008: Organic farms: All organic farms.
Conventional farms: All full-time farms with cattle

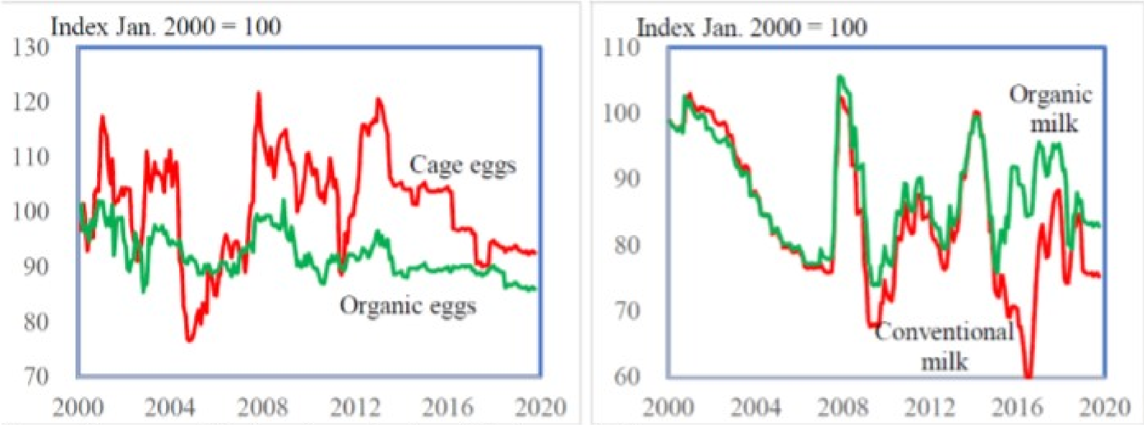
Source: Statistics Denmark (several issues)

Figure 10. Average size (hectare per farm) of full-time farms in Denmark, 2008-2018



Source: Statistics Denmark (2020)

Figure 11. Farmer sales prices of eggs and milk in Denmark 2000-2019



Source: Own presentation based on prices from industry organizations

Figure 7 shows that milk yield in organic and conventional agriculture has followed almost parallel developments in recent years. With regard to crop production, the yields in organic crop production have, on a weighted average, been approx. 70 per cent of the yields of conventional crop production (Figure 8). The long-term trend shows almost identical productivity growth in organic and conventional crop production.

The agricultural treadmill also affects structural development as technological development increases both productivity and economies of scale. This indicates that organic farming is not susceptible to structural pressure as, for example, organic dairy farms have followed the same trend as conventional dairy farms in recent years (cf. Figure 9).

Figure 10 shows that the average size of organic and conventional dairy herds is almost identical and follows the same development over time. Structural and productivity developments are almost identical in these organic and conventional agricultural industries.

The same conclusion can largely be drawn for price developments. As seen in Figure 11, the price trends for organic and conventional milk and eggs have been almost identical.

Change of corporate strategies In recent years, corporate strategies in the agricultural and food industry have changed. Financial goals are increasingly being supplemented by sustainability goals, which means that new ways of increasing sustainability are emerging.

Two different theories of corporate governance have been prevalent in recent decades and have set the framework for business development in a large number of cases. A shift in strategies seems to be emerging, so it is interesting to investigate the drivers of this shift, the content of the strategies and the specific impact on the agricultural industry. The two different theories of corporate governance are shareholder and stakeholder value (see box 1).

Box 1: Shareholder and stakeholder theory
Shareholder theory was originally proposed by Milton Friedman and it states that the sole responsibility of business is to increase profits. Shareholder value is the benefit delivered to the owners of a corporation as a result of management, leading to an increase in dividends and capital gains for the shareholders.

Stakeholder theory states that a company owes a responsibility to a wider group of stakeholders, and not just shareholders. Stakeholder value involves creating the optimum level of return for all stakeholders in an organization. This is a more broad-based concept than the more common shareholder value, which usually simply focuses on maximizing net profits or cash flows.

In the years 1940-1970, companies were designed to prioritize shareholders alongside national and employee interests. However, economic shocks during the 1970s (breakdown of Bretton Woods, oil crises, inflation, etc.) created an unstable environment, and the shareholder strategy gained increasing popularity.

Proponents of the shareholder model argue that the role of corporations is to maximize profit and serve the owners of the company. Any interest in social responsibility, such as environmental protection or increased workers' rights, should be pursued in executive's own time and not at the expense of the company, according to Friedman (1970), who is an outspoken supporter of the shareholder value model.

The 2008 financial crisis heightened the urgency for economic reforms. Corporations were accused of abusing their power, and a misalignment between corporate and societal goals created mistrust in the banking and financial sector (cf. Mukunda, 2014).

The financial crisis raised questions about the validity of shareholder capitalism as well as the legitimacy of the institutions that fostered the crisis.

The desire to think about more than just the shareholder is a trend that has been growing since the 2008 financial crises. It began with grassroots movements of US nonprofit organizations encouraging companies to think about their triple bottom line (Marquis, 2019), taking into account people and the planet along with their profits.

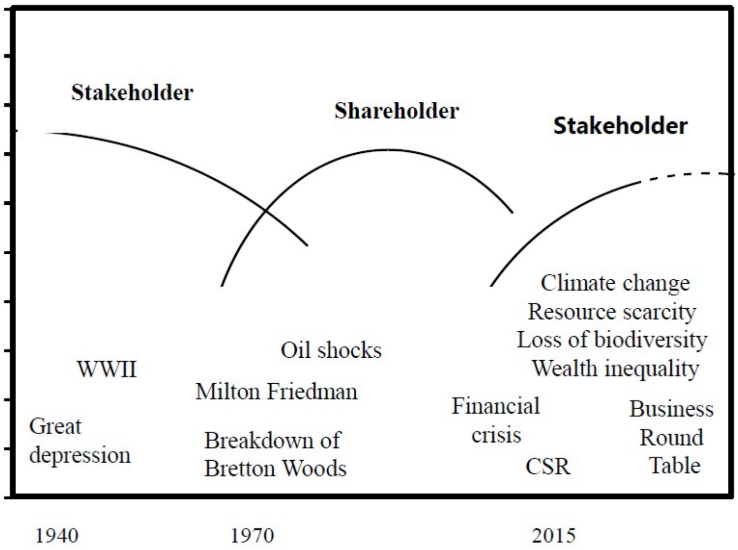
Today some companies are even certified as “B-corporations” and they allow an outside third party to confirm and certify that they are practicing business sustainably (Marquis, 2019).

An important and visible turning point towards the stakeholder strategy probably came in 2019, when the CEOs of nearly 200 companies announced that shareholder value was no longer their main objective. For the previous 20 years, the Business Roundtable, a non-profit organization consisting of the CEOs of U.S. companies, had held the view that maximizing shareholder value should be the principle goal of a corporation.

However, in August 2019, the Business Roundtable updated its statement to reflect the belief that there was a “fundamental commitment to all of our stakeholders” (customers, employees, suppliers, communities, and shareholders) (see WSJ, 2019).

Figure 12 illustrates the development and drivers in terms of shareholder and stakeholder strategies.

Figure 12. Schematic representation of shareholder and stakeholder strategy: Development and drivers



Note: The importance and timing of shareholder and stakeholder strategies cannot be accurately determined. Differences between countries and regions exist, and there will also be some temporal overlap between the two strategies. Therefore, the figure is only a schematic presentation.

Source: Own presentation based on Hansen (2014) and Mukunda (2014).

As previously mentioned, shareholder and stakeholder strategies are not unambiguous and their importance may vary between countries, industries and time periods. Therefore, the question is whether the agri-food industry is significantly different from other industries when it comes to shareholder and stakeholder values.

In general terms, agri-food companies are managed in the same way as other businesses. The conditions of competition are broadly the same. Jones and Nisbet (2011) analyze shareholder values versus stakeholder values in global food companies, and although the analysis is not entirely new and is based on case studies, it shows that the question of shareholder and stakeholder value is also relevant in global food companies.

Agri-food companies differ from other companies in that cooperatives are relatively common, (cf. Hansen, 2013). This may play a role to the extent that cooperatives in the agricultural and food sector base their regulations on the seven international cooperative principles, which were established by the International Cooperative Alliance (ICA). The 7th Principle is “Concern for Community”, which states that “Cooperatives work for the sustainable development of their communities through policies approved by their members”.

According to Allen and Albala (2007, p. 166) cooperatives and family firms are usually more stakeholder-oriented than firms that are controlled by financial investors (banks, insurance companies, institutional investors).

Value chains

An evolution in corporate strategies is also apparent in other areas: Value chains ("from fork-to-table") have changed, and vertical integration has taken on new dimensions and has become more internationalized (global value chains).

Vertical integration is an important element for several reasons. The up- and downstream business will influence the primary sector. With continuing structural development in these industries (consolidation, concentration, M&As, FDI, R&D-investments, etc.), the primary agricultural sector may be subjected to financial pressure. Farmer-owned cooperatives are important in several agricultural sectors in almost all European countries. As the number of cooperative members (farmers) is decreasing, the financial commitment per cooperative member is increasing simultaneously.

The necessity of increased vertical integration in the agri-food value chain (due to increased demand for traceability, food security, origin, labeling, product differentiation, waste reduction etc.) results in greater focus on vertical business models:

1) Farmer-owned and farmer-driven cooperatives are considered to be efficient ways of integrating the agri-food value chains. It leads to more balanced bargaining market power as the individual farmer often has a weak position in terms of both suppliers and customers in the value chain.

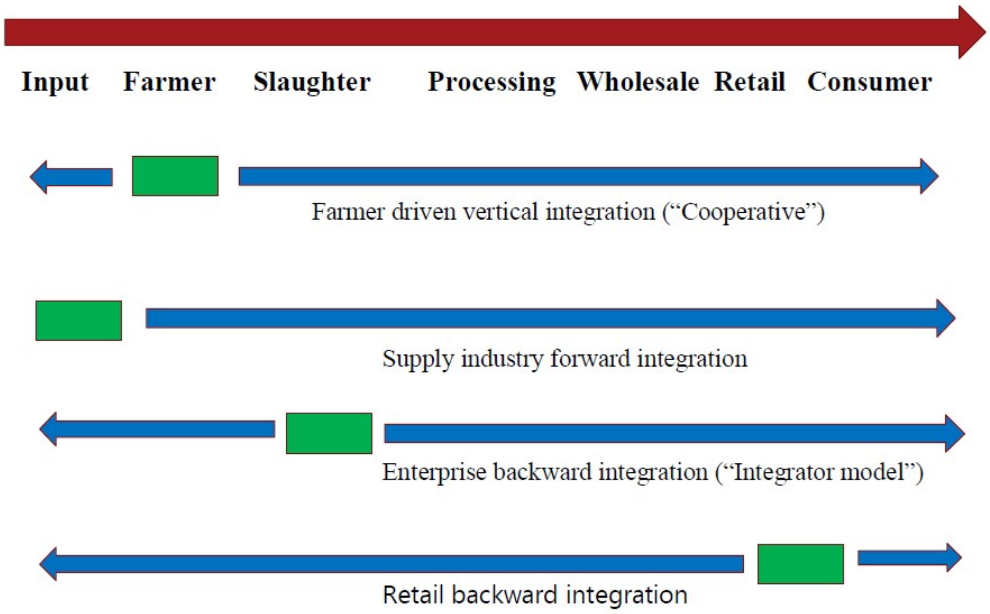
2) The processing companies (dairies, slaughterhouses, etc.) seek to secure access to supply (inputs) by backward vertical integration into the primary agricultural sector. This "integrator model" is becoming more popular in, e.g. the Spanish pig industry, and it seems to be economically successful. This may disrupt the existing agri-food value chain, which is driven by globalization, demand for investments, etc. The same trend is identified in the pig and poultry industry in the US.

3) The input industry is also moving downstream into the agricultural sector and even further downstream towards the consumer. A search for extra added value, better margins and options for product differentiation that is closer to the final customers are driving this business plan.

4) The retail industry also increases upstream integration. Access to unique supplies, lower transaction costs, labeling, etc. are drivers of this trend.

The four models are illustrated in figure 13.

Figure 13. Different business models in the agri-food value chain



Source: Own presentation

All four business models have the potential to increase vertical integration as well as improve efficiency, food safety, traceability, etc. in the value chain. Waste and transaction costs can be reduced, and the instruments to create a more sustainable agri-food production are present. However, the role of farmers, the farmers' economic position and the market power balance in the agri-food value chain is also affected.

When focusing on business models and strategies in primary agriculture, a number of elements and factors can be identified, which vary in degree from country to country and over time. To be competitive farmers, a number of instruments will appear; for example:

- Economies of scale (lower unit costs)
- Technology
- Efficiency
  - Yields
  - Precision farming
  - Labor input reduction
- Niche orientation (finding "Blue Oceans")
  - Local marketing
  - Own brands

An explicit goal of sustainable farming may also be a part of, and a driver of, farmers' business plans. Sustainable farming may be a goal as it is considered to be most profitable in the long term. However, the balance between economic/financial goals and sustainable goals is fine as, in general, farms with weak economic business plans will probably not succeed. Economic and financial drivers are, in general, expected to be superior to other drivers.

Global value chains

The significance of global value chains for European agriculture is, in general, increasing. Global value chains exist in different models and are interrelated to varying degrees:

- Import and export. Having a supplier of raw materials and/or customers in foreign countries.
- Outsourcing (off-shoring) of labor-intensive parts of the value chain to foreign countries.
- FDI (foreign direct investments) in primary agricultural production abroad.
- Global M&As (mergers and acquisitions), joint ventures, global strategic alliances.

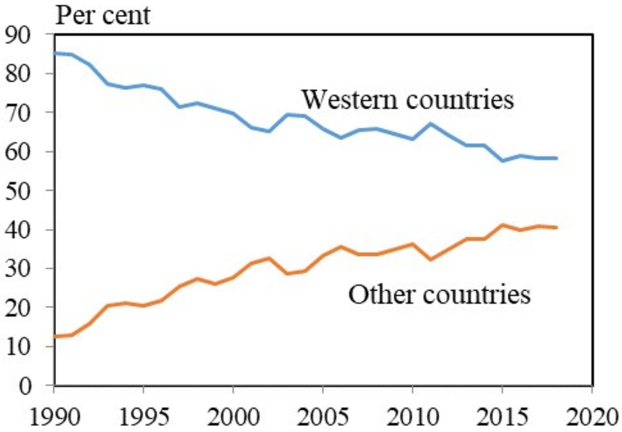
The increasing importance of global value chains has several implications (both positive and negative) for the sustainability of agricultural production:

- Production is moving to countries with better comparative advantages. The use of resources will probably be reduced.
- Transportation costs will increase.
- Monitoring and control of global value chains might be more difficult, resulting in less vertical integration.
- The risk of disease spread is likely to increase.
- Offshoring of, or FDI in, intensive horticultural and agricultural production may have negative environmental impacts in the host countries with less focus on environmental protection.
- Global value chains that are managed by transnational corporations in developed countries may lock the farmers in developing countries as commodity producers.
- Developing countries will benefit from increased demand for more agricultural products and processing by developed countries. This may increase economic welfare. However, the supply of agricultural products to the local markets in the developing countries will decrease, which will have a negative impact on food security.

A number of cases and statistical information can substantiate these trends.

The production of cut flowers has, to some extent, moved from Western countries to Africa and Latin America. The end-users and the majority of investors are still in Western countries, but the value chain has become far more global (cf. figure 14).

Figure 14. Export of cut flowers, 1990-2018



Source: Own calculations based on UN (2020)

Similar examples from fruit and vegetable production are also available.

Internationalization

Many food companies have the vision or strategy of becoming a global company. Therefore, globalization becomes an explicit strategic goal for the company's daily management. In addition, growth and globalization in shareholding companies is often driven by investor expectations.

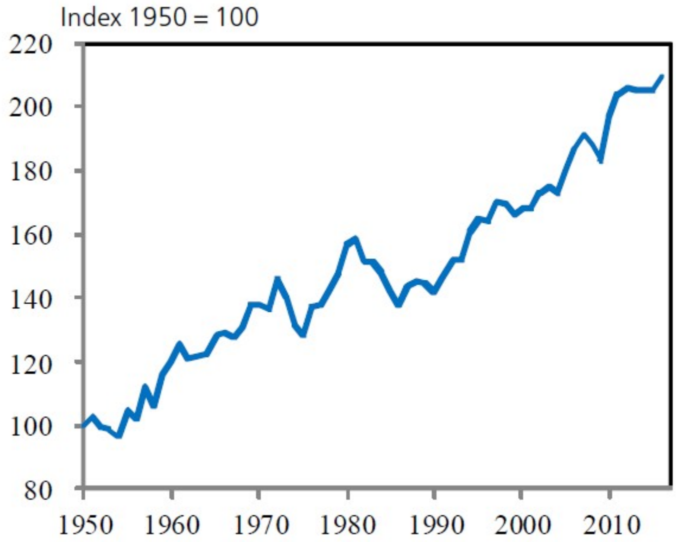
Cooperatives are not subject to the same external investor expectations. Globalization must, therefore, merely be an instrument for increasing earnings and not an explicit company goal. However, a review of the major Danish agricultural cooperatives' strategies show that most include direct globalization goals in the form of foreign activities, international market positioning, etc. (Hansen, 2018).

A review of other major international agri-food companies confirms that participation in - and the utilization of – globalization is an explicit goal of many companies. Although political and economic barriers still prevent strong internationalization of agricultural markets, international trade in agricultural products has been increasing.

Trends towards increasing internationalization in the form of imports, exports, foreign direct investments, global value chains, global M&As, global strategic alliances, etc. are quite clear.

International trade as a percentage of total production has, thus, increased significantly in recent decades, which means that international specialization is also increasing. This is illustrated in Figure 15, which shows the development in international trade and total production of agricultural products.

Figure 15. Development in international specialization for agricultural products



Note: International trade divided by total production

Source: Own calculations based on WTO (several issues)

As a consequence of the continuing decline in support or at least lower trade protectionism in the field of agriculture, the increase in international specialization is expected to continue. The globalization of the food industry is increasingly reflected in the form of direct investments abroad, cross border mergers, acquisitions and of foreign subsidiaries, etc.

Through investments and production abroad, comparative advantages and international specialization can be further exploited. Therefore, it is likely that trends with regard to greater investment abroad will continue in the future.

A "localization trend" is also appearing, which will become increasingly important in the consumer market. Consumers will demand local food driven by concern for the local environment, lower transport costs, traceability, etc. However, local and global demand can coexist, and the momentum of globalization is assumed to be so strong that it is not significantly weakened by a simultaneous and increasing demand for local food.

3. Contribution of the theme to the three transitions

In this section, the contribution of the theme - transformation to more sustainable production - to the following three transitions is assessed:

1. "Healthy and sustainable food for all".
2. "Full circularity of food systems".
3. "Substantial increase in biological, social, and economic diversity".

The content, barriers, drivers, etc. of these three transitions are, to some degree, identical. For example, the drivers behind any transition often involve political initiatives, new research and innovation, economic incentives, etc. Similarly, barriers to transition often consist of market, economic or political conditions.

For this reason, the analysis of transitions 2 and 3 will, to some extent, be similar to the analysis of transition 1.

3.1 Transition 1: Healthy and sustainable food for all

The availability of healthy food and ensuring food safety are considered to be a minor problem in Europe - both now and in the near future. The production of sustainable food, i.e. while maintaining an ecological balance, is a more significant problem in the short or long run.

Changing corporate strategies in the agricultural and food industry so that they have a greater focus on sustainability goals would improve sustainability. In recent years, corporate responsibility in relation to sustainability within the agri-food sector has increased significantly. The drivers have been:

- Pressure to change from a number of stakeholders, including NGOs, consumers, company owners, investors, pension funds, etc.
- Companies recognizing the business potential and competitive advantage of focusing on corporate social responsibility (CSR).
- The principles behind cooperatives include concern for the environment.

In this way, farmers are also directly involved in corporate social responsibilities. New technologies that increase sustainability and reduce the environmental and climate impact of agriculture are in many cases best utilized on larger farms. Precision farming technologies, robotics, etc. often require substantial investments in agriculture, making them profitable only if they can be applied to large areas. Therefore, economies of scale and large farms are a prerequisite for utilizing these technologies.

The question is whether structural development is a barrier - or a tool - for sustainable farming. The Danish example of organic production demonstrates that organic farming takes place on large farms, and that the conditions regarding economies of scale, productivity pressure and price pressure are quite similar to conventional farms.

Technology is one potential tool for increasing agricultural sustainability, while more extensive farming, organic farming, etc. are others.

The importance of technology is uncertain as it depends on future technological advances and breakthroughs. Technological game changers will be very crucial, but their occurrence, impact and potential side effects are unknown.

Producing more sustainable food is, in general, more expensive, and the negative impacts of unsustainable food production are not included in the price paid by consumers. Farmers' competitiveness will depend on the use of cheap readily available resources (land, fertilizer, water, seeds, labor, capital, etc.) regardless of the ecological sustainability of the production. From the economic and financial perspective of farmers' production, full sustainability will not be achieved without major economic, political or market interventions.

The evolution of organic agriculture in Europe is an example of the production of more sustainable food. Between 2012 and 2017, the total area under organic production increased by 25 per cent, and it is expected to continue to increase in the coming years. Up to 10 per cent of the agricultural land is now used for organic production in some EU-countries. The increase in the total area of organic production has been driven by both consumer demand and political intervention. Although organic production can not solve all sustainability challenges, and although organic production cannot be completely scaled up, lessons and methods from organic production can be useful.

It should be noted that organic food involves lower yields, which means that more land has to be utilized to produce the same amount of food. Organic production may reduce some problems regarding sustainability, but it may create problems regarding the climate as the increased demand for agricultural land may lead to a reduction in forest coverage, etc.

Furthermore, organic farming and organic production seem to follow the same structural development as conventional farming and production, i.e. increasing size and concentration.

Achieving the sustainability goals can be accomplished in several ways. Labelling through vertical integration, which is being increasingly used by food companies and the retail industry, is one significant way. Furthermore, governmental support for labeling is an increasing trend.

3.2 Full circularity of food systems

To a great extent, the full circularity of food systems, on the one hand, and structural development, finance and business strategies, etc., on the other, are independent trends:

Large and small farms, specialized and diversified farms, etc. can contribute to increasing the circularity of food systems. Increasing circularity can be achieved through a number of initiatives, including financial incentives, regulation, infrastructure, innovation, etc. However, a number of barriers also exist:

Increasing circularity, on the one hand, and economic and financial optimization on individual farms, on the other, may be contradictory. Financial support is often necessary to make circularity attractive to the farmers. Experience from other support schemes shows that farmers in the EU respond relatively effectively to financial support.

Increasing circularity can be achieved, to some extent, through investments in innovation. This applies, for example, to agricultural energy, where investments can reduce energy use or optimize the use of residual products from agriculture in the production of energy. Such investments may also be most attractive to larger farms.

3.3 Transition 3. Substantial increase in biological, social, and economic diversity

In general, economic and financial drivers in agriculture will lead to less diversity: Economies of scale and technological progress will make farms grow in size and become more specialized. Bigger machines, robots, etc. are most economically attractive when farms are large (measured in hectares, number of cows or pigs per , etc.). Therefore, in order to benefit from these technological advantages, farmers must increase the size of their farms, leave the business or become part-time farmers with income from other activities.

This is because farmers cannot usually establish a large and diversified farm at the same time. Furthermore, it is natural that farmers seek to exploit comparative advantages. As in many other industries, farmers focus on their core business and specialize, which leads to less diversification.

The market is not expected to solve the problem or to result in a substantial increase in biological, social, and economic diversity. Consumers in an increasingly globalized world with more processed food, more food service, etc. are not able – or willing – to pay a higher price for food that is produced under more diversified conditions. Even though labelling will allow consumers to choose more sustainable food products, a major share of the agricultural and food production will take place under strict price competition, where for example diversity parameters play a minor role. This is a major barrier.

Finally, with bigger and more industrialized farms, the demand for farmers to be highly professional with specific skills will increase. However, as farmers cannot be equally competent in all agricultural business areas, specialization will be necessary.

The correlation between sustainable food production, diversity and animal welfare, on the one hand, and economies of scale and specialization, on the other, is not obvious:

Large-scale farming may lead to less diversity, but also improved animal welfare and/or less use of resources.

Precision farming, another instrument for reducing the use of pesticides and fertilizers, will often be most useful on larger farms. In this case, larger farms will lead to more sustainable, but less diverse production.

4. Policy conditions for the achievement of the targets

Several direct or indirect initiatives and regulations are driving corporate responsibility within sustainability, food safety, animal welfare, etc., for example:

- <u>Public regulation and labeling</u>. Legislation, incentives, support schemes, public demand, etc.
- <u>Market demand</u>. Consumer demand can persuade the industry to change its production.
- <u>Retail labeling.</u>
- <u>Farmer and agri-food industry initiatives</u>. Agri-food companies/organizations have introduced their own regulation in addition to governmental regulation. These farmer-driven initiatives increase farmers' motivation.

All four drivers will be relevant in the future: We can not expect the market (consumers) to regulate sufficiently according to the overall political goals; free riders will exist. The retail industry does use own labeling as a competitive and marketing tool. Farmers also introduce standards and codes of practice in order to achieve a competitive advantage and differentiate their production.

As previously discussed, economic and financial drivers in agriculture will lead to less diversity and, in general, often lower sustainability. This means that political instruments are needed in order to substantially increase biological, social, and economic diversity, and to increase sustainability.

In general, the following policy considerations are important for the achievement of the targets:

- Adjustments to farms and agricultural holdings take time due to fixed and long-term investments.
- Instruments should not conflict with WTO agreements regarding support reduction and trade liberalization.
- Farmers are important stakeholders and their motivation for transition is important.

5. Challenges for research

Based on the previous sections, a number of main research questions and topic are outlined:

Goal-instrument analysis: Which economic, market and political instruments are most effective at increasing sustainability? Several instruments for increasing sustainability are available, but a cost-effectiveness analysis will improve the decision-making process. Some instruments or trends may both increase and decrease sustainability - as indicated in previous sections – which makes it even more difficult to choose the most efficient instruments.

Analyzes of possible negative side-effects are also important. Support schemes may conflict with free trade agreements and may, thus, result in trade disputes. Heavy restrictions on the agricultural industry may result in poorer competitiveness, which in turn will lead to declining production, declining employment and rising imports, which may conflict with other policy objectives.

Structural development of farms versus sustainable agriculture: A conflict?
The structural development of farms may be both a barrier and a tool regarding sustainable
agriculture. A closer scientific analysis of the connection between the two concepts will be useful.

Use of incentives vs. regulation/taxes to increase sustainability in agriculture.
Both types of instrument are relevant.

The role of the Common Agricultural Policy (CAP) in ensuring increasing sustainability.
Economic, political and financial ways of using the CAP as a driver.

Identification and ranking of sustainability goals in agriculture
Which sustainability measures are most important? (mixed farming? Less concentration?)

Economic vs. structural, biological and environmental sustainability
What are the costs involved in increasing each sustainability measure? What are the costs of economic diversity in the short and long run?

6. Literature

Allen, Gary and Albala, Ken (eds.) (2007): The Business of Food: Encyclopedia of the Food and

Drink Industries. 456 p. Greenwood

European Commission (several issues): EU agriculture - Statistical and economic information http://ec.europa.eu/agriculture/statistics/agricultural/

European Commission (2015): EU agriculture - Statistical and economic information - 2013 http://ec.europa.eu/agriculture/statistics/agricultural/2013/pdf/full-report_en.pdf

Eurostat (several issues): Agricultural holdings.

FAO (2013): 2000 World Census of Agriculture
Analysis and International Comparison of the Results (1996-2005). FAO STATISTICAL DEVELOPMENT SERIES 13.
http://www.fao.org/fileadmin/templates/ess/ess_test_folder/World_Census_Agriculture/Publications/WCA_2000/Census13.pdf

FAO (2018): FAOSTAT.
www.faostat.fao.org.

Friedman, Milton (1970): "The Social Responsibility of Business is to Increase its Profits", New
York Times, Magazine. September 2013, 1970

Hansen, Henning Otte (2013): Food Economics. Industry and Markets. Routledge. London and New York

Hansen, Henning Otte (2018): Andelsselskabers globalisering - Udvikling, barrierer og muligheder (Globalisation of cooperatives: Development, barriers and opportunities). In: Tidsskrift for Landøkonomi. No 1/2018. Vol. 204. pp. 69-93

Hansen, Henning Otte (2019): Megatrends i landbrug og fødevareindustri. (Megatrends in Agriculture and Food Industry) In: Tidsskrift for Landøkonomi, Bind 205, Nr. Særnummer, 2019, s. 150-167.

Hansen, Per H. (2014): "From Finance Capitalism to Financialization: A Cultural and Narrative
Perspective on 150 Years of Financial History", 2014, Advance Access Publication
doi:10.1093/es/khu047

Jones, Bryn Jones and Nisbet, Peter (2011): Shareholder value versus stakeholder values: CSR
and financialization in global food firms. In: Socio-Economic Review 9(2):287-314 · March 2011

Marquis, Christopher (2019): The Business Roundtable CEOs Have Spoken. Here's How They

Can Act. September 26, 2019
https://consciouscompanymedia.com/sustainable-business/the-business-roundtable-ceos-havespoken-heres-how-they-can-act/

Mukunda, Gautam (2014): "The Price of Wall Street's Power", Harward Business Review, June
2014 pp. 70-78

Statistics Denmark (2010): Extract of enterprise statistics (special demand)

Statistics Denmark (2019a): JORD2: Profit and loss accounts for full-time farms (average) by type of farm, annual work units, quartile group and items

Statistics Denmark (2019b): REGNOK1: Organic farms, financial results and balance by type of
farming and items (Discontinued)

Statistics Denmark (2019c): REGNLA2: Financial results and balance by type of farming and account items (Discontinued)

Statistics Denmark (several issues a): Regnskabsstatistik for jordbrug. Udvidede tabeller for jordbrug
https://www.dst.dk/da/Statistik/emner/erhvervslivets-sektorer/landbrug-gartneri-og-skovbrug/jordbrugets-regnskaber?tab=dok#

Statistics Denmark (several issues b): Momsstatistik (Value added statistics)

Statistics Denmark (several issues c): Agricultural statistics

UN (2019): UNCOMTRADE
https://comtrade.un.org/data/

WSJ (2019): The Editorial Board, "The 'Stakeholder' CEOs", Wall Street Journal (WSJ.com), August 19, 2019

WTO (several issues): World Trade Statistics
https://www.wto.org/english/res_e/statis_e/statis_e.htm

WILL COVID-19 MEAN A SETBACK FOR INTERNATIONAL TRADE IN AGRICULTURAL AND FOOD PRODUCTS?

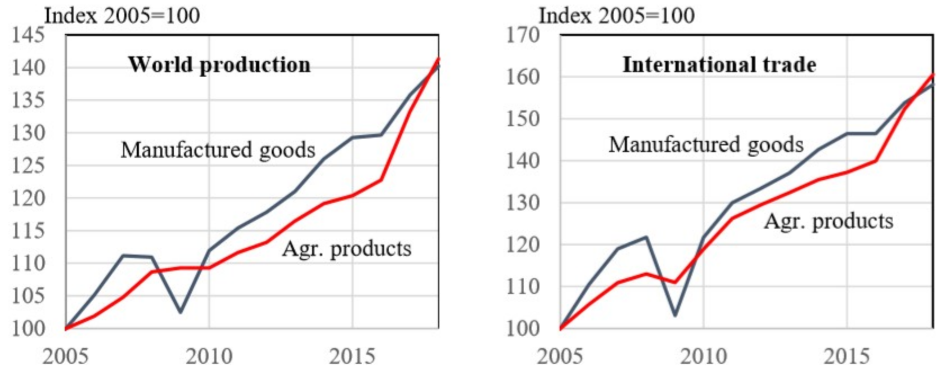
Henning Otte Hansen, 5th SCAR Foresight Exercise expert

Covid-19 is likely to lead to greater protectionism and less international trade in the agriculture and food industry. While the markets for agricultural and food products are relatively unaffected by crises, policy interventions will restrict trade without solving the Covid-19 problems - in fact, they will exacerbate them.

The importance of international trade International trade is important for agriculture in many parts of the world. In several countries, more than 50 percent of agricultural production is exported, so farmers are dependent on export. Consumers also benefit from international trade as it gives them access to cheaper food and a wider variety of food products. International trade also creates socio-economic benefits as trade provides opportunities for welfare economic optimization. Trade also means that agricultural production can become more geographically diversified, thereby reducing the amount of very intensive and potentially environmentally damaging agriculture. Finally, international trade also helps to strengthen interdependence between countries, which involves political benefits.

International trade and international crises International trade is often reduced during global crises. The financial crisis that started in 2008 led to a decline in world production and international trade. Global industrial production fell sharply in 2009, while total agricultural production remained almost constant. The same picture applies with regard to international trade: International trade in industrial products fell by 15 per cent, while international trade in agricultural goods fell by only 2 per cent - see figure 1.

Figur 1. Change in global production and international trade in agricultural products and manufactured goods, 2005-18 (volume)



Source: Own presentation based on WTO (2019)

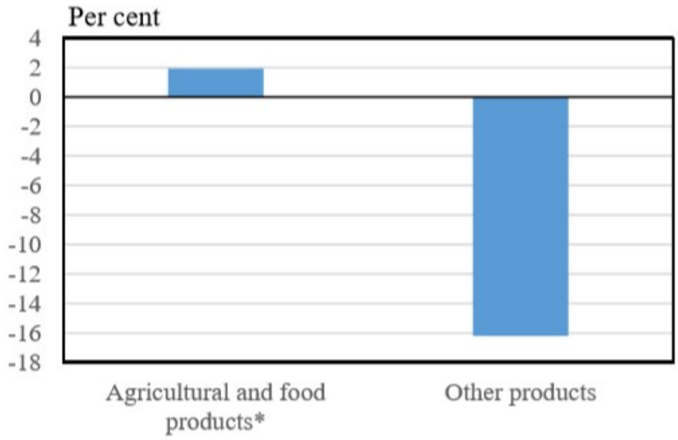
The figures underline the general assumption that agricultural production and trade are relatively unaffected by external shocks. Agriculture produces basic necessities, where neither supply nor demand is affected significantly by changes in the external environment.

Covid-19 and international trade in agricultural and food products Covid-19 has already caused major declines in world production: Many countries' industrial production has been significantly reduced, with particularly vulnerable industries such as tourism, air transport, restaurants, etc. experiencing a decline of up to 90 per cent. Covid-19 has also led to a reduction in exports, and a significant fall in international trade is expected.

However, the international trade of agricultural and food products is expected to be less affected than, for example, exports of manufactured products.

Denmark is a good example for illustrating the effect on international trade and sales: Denmark is a relatively open economy, and agriculture is extremely dependent on exports with an export share of around 65 per cent. In April 2020 - well into the Covid-19 crisis - Danish exports of agricultural and food were 2 per cent higher than in the same month in 2019. Other exports, on the other hand, had fallen by 16 per cent - see figure 2.

Figure 2. Change in Danish export from April 2019 to April 2020



* Agricultural and food products include the following SITC numbers: 0, 1,2, 4, 5, 6, 9, 41 & 42

Source: Own presentation based on Statistics Denmark (2020)

The figure emphasizes the fact that, when measured in exports, the agricultural and food industries have been relatively unaffected by the Covid-19 crisis.

The underlying market conditions, which are essential for production, sales and exports, are also relatively unaffected when it comes to Danish production of agricultural and food products. The terms of trade - the ratio between sales and purchase prices - were better in May 2020 than in May 2019 (cf. figure 3).

Figure 3. Change in sales and purchase prices and terms of trade in Danish agriculture, May 2019-May 2020.

Source: Own presentation based on L&F (2020)

The figure demonstrates that relatively positive development occurred during the period: Input prices fell, sales prices rose, and, therefore, the terms of trade improved significantly. This development is remarkable given the usual long-term decline in agricultural terms of trade. The sales price has been very unstable in recent years, which is primarily due to outbreaks of African swine fever, which in certain periods has benefited sales to China, in particular, where prices have been relatively high. In this case, factors other than Covid-19 have had a great influence.

Covid-19 and increasing protectionism? Although agricultural and food exports at first glance appear to be relatively unaffected by Covid-19, there are signs of increased protectionism and less international trade as a direct result of the pandemic. Unfortunately, crises - whether they be political, economic, environmental, structural or health-related - tend to be exploited for a protectionist agenda. More closed economies, less trade and more selfishness are used as solutions to crises. The connection between Covid-19, on the one hand, and protectionism and international trade, on the other, has been highlighted by many authors, e.g. OECD (2020), the Financial Times (2020), Askew (2020), Spring (2020) and Espitia, et al. (2020).

Covid-19 is used as evidence to back up the claim that globalization and international cooperation and interdependence have gone too far, and that we need to protect ourselves more and focus more on local areas. The more serious the crisis, the easier it is to gain acceptance of protectionism as a tool - whether it is a rational solution or not. A pattern is emerging whereby particularly weak and non-competitive countries and sectors are now using the Covid-19 crisis as an argument for protectionism: agricultural markets must be protected from the outside world, local markets must be protected and imports must be restricted. The fact that such measures are in conflict with WTO international trade rules and would considerably reduce overall economic welfare is apparently being ignored.

It is legitimate - but fundamentally economically irrational - to argue for less globalization, but restrictions on international trade and greater trade protectionism are not rational solutions when it comes to Covid-19. Less international trade in agricultural and food products will hardly have a significant impact on the consequences of the pandemic; on the contrary, it will result in a decline in economic welfare and will, in particular, harm the poorest.

Conclusion

The conclusion is that greater protectionism and restrictions on international trade in agriculture and food are likely to be the result of Covid-19. The reason is primarily political. Such measures will not solve the problems related to the pandemic; indeed, they will aggravate them. Covid-19 is being used as an excuse for protectionism, but there is often a hidden agenda - the protection of non-competitive industries. However, in a time of global challenges, global solutions are needed and, therefore, protectionism and trade restrictions are the wrong tools in the current situation.

Sources

Askew, Katy (2020): COVID-19 and protectionism in the food chain: An à-la-carte approach to EU rules? I: FoodNavigator. 16 april 2020 https://www.foodnavigator.com/Article/2020/04/15/Coronavirus-protectionism-and-food-security

Espitia, Alvaro and Rocha, Nadia and Ruta, Michele (2020): Covid-19 and Food Protectionism: The Impact of the Pandemic and Export Restrictions on World Food Markets (May 19, 2020). World Bank Policy Research Working Paper No. 9253

Financial Times (2020): Covid-19 is bringing out protectionist instincts. 19. april 2020 https://www.ft.com/content/ed78b09c-80a3-11ea-8fdb-7ec06edeef84

L&F (2020): Markedsblik uge 27, 2020 https://lf.dk/tal-og-analyser/markedsblik

OECD (2020): COVID-19 and international trade: Issues and actions http://www.oecd.org/coronavirus/policy-responses/covid-19-and-international-trade-issues-and-actions-494da2fa/

Spring, Jake (2020): Brazil fears agriculture protectionism amid pandemic: draft report. BUSINESS NEWS MAY 5, 2020. Reuters https://www.reuters.com/article/us-health-coronavirus-brazil-agriculture/brazil-fears-agriculture-protectionism-amidpandemic-draft-report-idUSKBN22G2WV

Statistics Denmark (2020): Statistikbanken. Værdi af import og eksport (1000 kr) efter SITChovedgrupperSITC2R4M

WTO (2019): World Trade Statistical Review 2019 https://www.wto.org/english/res_e/statis_e/wts2019_e/wts19_toc_e.htm

LIFE SCIENCES IN THE BIOECONOMY

Begoña Ruiz, 5th SCAR Foresight Exercise expert

Main messages:

- Life sciences in general and biotechnology in particular, can strongly support the agrofood sector, especially in the following fields: food production/security, food safety, healthy food and sustainability, as well as biodiversity.
- Regarding **food production and security**, life sciences and particularly biotech are contributing to food security and alternative protein sources such as insects, plant-based proteins, cultured meat or single cell proteins. Genetic engineering contributes to more efficient and sustainable crops. The substitution of conventional pesticides and fertilisers by others of biotechnological origin can be a contribution to the enhancement of organic food production, reduction of CO_2 emissions or even fight against diseases without known treatment.
- Life sciences are also contributing to **food safety**, by providing new biotech-based antimicrobials to fight food borne pathogens, such as enzymes, bacteriocins, antimicrobial peptides and bacteriophages or their endolysins. Those developments also contribute to fight against the antimicrobial resistances.
- A particularly interesting field in the area of **healthy food** is the one of bioactive ingredients and functional foods that have a positive impact on the health of specific population groups with special needs (elderly, children, sportspersons, pregnant women, climacteric women, hospital and/or oncology patients, etc.).
- **Sustainability and circularity** in food systems is also a field for life sciences. Biological treatment of food waste and wastewater, preceded by recovery of valuable compounds and energy contained in them, is fundamental to the waste-based biorefinery concept. Those valuable compounds include bio-based chemicals that can be further processed as biopolymers.

- Life sciences (and, in particular, biotechnology) can also contribute to **biodiversity** in several ways, for instance, providing tools to characterize, collect and store genetic diversity. Analysis of the genomic and transcriptomic data can also provide valuable information to manage adaptation and resilience to climate change. Biodiversity can also help agriculture by using consortia of microorganisms to make fertilisation mor effective and crops more resistant to drought. Finally, biotechnology can take inspiration from nature to design new materials – the bio-inspired materials – with novel and advanced properties.

- Challenges for research have been identified in the following fields: new protein sources, novel antimicrobials, bioactive ingredients, alternative (bio)pesticides, bioplastics, biorefineries, biological treatment of waste streams or fermented foods.

1. Analysis of the main technologies covered by the theme

A synthesis of the state of art in the field

Life sciences is an extremely broad concept, covering a large scientific and application area. It includes all sciences dealing with living organisms and life processes, such as biology, medicine, pharmacy, ecology, environmental science, biotechnology, etc.

Similarly, there are many definitions for bioeconomy, and therefore its meaning can be unclear. A recent publication has identified the shift from a "resource substitution perspective" of the bioeconomy to a "biotechnology innovation perspective" [1]. This publication defines bioeconomy as the use of biological knowledge for commercial and industrial purposes (other definitions add the economic sustainability aspect, such as the understanding of bioeconomy as a model of production based on using renewable biological materials in a sustainable way). This definition is very similar to the one generally accepted for biotechnology. However, the term bioeconomy has nuances of environmental sustainability, which is not the case for biotechnology, although the meaning of both terms is very close.

Thus, the link between life sciences and bioeconomy and biotechnology is intrinsic to their definitions. According to the previous paragraphs, it can be said that the bioeconomy is the use of life sciences for commercial and industrial purposes.

According to the scoping document of the 5th SCAR Foresight Exercise, the topic 'Life Sciences in the Bioeconomy' should be focused in biotechnologies such as 'omics', gene recombination and editing techniques, cell factories[112], system biology, microbiome, phenotyping and the impact of digitisation on it. All of it related to the scope of "natural resources and food systems: transitions towards a safe and just operating space". Those transitions have been defined as:

- Healthy and sustainable food for all
- Full circularity of food systems
- Substantial increase of biological, social and economic diversity

Thus, the technologies covered with the topic will be the ones related with food and diversity with a special focus in the last innovations brought by the biotechnology in the following fields:

- Food production
- Food safety
- Healthy food: bioactive ingredients and functional foods
- Sustainability and the whole cycle of food, including food packaging and energy supply

Regarding **food production**, life sciences are contributing to food security and alternative protein sources such as insects, plant-based proteins, cultured meat, or single cell proteins[113]. Insects have a very good potential to become a significant alternative protein source in sight of the protein scarcity in 2050 foreseen by FAO. Although cultural barriers are still present, the undeniable advantages in terms of protein quality and sustainability are strong drivers for the change [2]. Other possibility is based on plant-based proteins: development of new and more efficient crop varieties with higher yield and, at the same time, more resistant to pests and diseases and need less nutrients (fertilizer-frugal crops) and water. Genetic engineering is advancing fast, still co-existing with traditional and more laborious breeding techniques [3]. However, the recent advances in gene editing with CRISPR-Cas have revolutionized the biotechnology and will have a crucial role to face the challenges of the growing

[112] Cell factories are unicellular organisms (eukaryotic cells, bacteria, etc.) that can be used to produce valuable compounds, such as peptides or other type of molecules (in the framework of this report, especially bioactive molecules that can be used as food ingredients).

[113] Single cell proteins (SCP) are microorganisms with a high protein content, that can be used as food ingredient or food product.

population and climate change [4]. Also, plant production needs products to deal with biotic and abiotic stresses. The substitution of conventional pesticides and fertilisers by others of biological origin (biostimulants and biopesticides based on microorganisms and their metabolites, for instance), can be a contribution to the enhancement of organic food production, reduction of CO_2 emissions or even fight against diseases without known treatment.

Life sciences are also contributing to **food safety**, by providing new biotech-based antimicrobials to fight food borne pathogens. One of the main R&D areas in this field can be found in bacteriocins (toxins used by bacteria to attack other bacteria), antimicrobial peptides and bacteriophages (viruses attacking selectively a particular bacteria) including their endolysins [5]. Other biobased products use enzymes to destroy the biofilms where the pathogens grow and are protected against biocides. Those developments also contribute to fight against the antimicrobial resistances. An innovative application is active packaging, that reduce the microbial growth for instance with the help of bacteriophages or other biobased antimicrobials incorporated in the packaging material.

A particularly interesting field in the area of **healthy food** is the one of **bioactive ingredients and functional foods** that have a positive impact on the health of specific population groups with special needs (elderly, children, sportspersons, pregnant women, climacteric women, hospital and/or oncology patients, etc.). Plants, microorganisms, and eukaryotic cells can provide a broad spectrum of bioactive substances that can be produced in a sustainable way (both economic and environmentally, though attention has to be paid to fractionation and extraction methods in order to keep viability and sustainability).

Sustainability and circularity in food systems is also a field for life sciences. Biological treatment of food waste and wastewater, with previous recovery of valuable compounds and energy in them, is in the fundamentals of the waste-based biorefinery concept. While the environmental sustainability is the main benefit, work is still to be done to improve the economic sustainability of biorefinery processes applied to organic waste; in fact, it is one of the main objectives of the Strategic Innovation & Research Agenda of the Bio-Based Industries Joint Undertaking [6]. Another field that contributes to sustainability is in the area of food packaging, for instance with the substitution of conventional polymers by new and easily recyclable biopolymers or biodegradable materials and biocomposites. This field is growing rapidly; the market for bio-based polymers for plastics in EU is expected to grow by 4% per year in the coming 5 years [7]. Finally, sustainable energy supply for the whole food chain is also a topic that can be addressed by life sciences. Thus, bioenergy in the form of biogas, biomethane or biohydrogen can be produced from food and/or other organic waste by anaerobic digestion technologies. Bioethanol can be obtained by fermentation of substrates rich in carbohydrates. Although it might not cover the whole energy consumption of a food factory or farm producing the waste (raw material for the bioenergy production), it can help to reduce the fossil fuel consumption.

Biotechnology can also contribute to **biodiversity** in several ways: providing tools to characterize, collect and store genetic diversity [8]. Analysis of the genomic and transcriptomic data can also provide valuable information to manage adaptation and resilience to climate change [9].

Effects on biodiversity can also occur as a side-effect (not necessarily negative, but worth to be evaluated), such as potential modifications in the soil microbiome after applying a microbiological product or changes in the physiology of some insects after introducing a transgenic oilseed crop [10]. Finally, biotechnology can take inspiration from nature to design new materials – the bio-inspired materials – with novel and advanced properties [11].

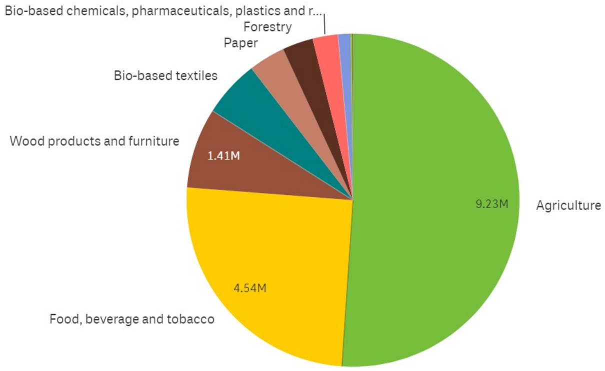
2. Analysis of the main emerging issues in the domain covered by the theme

Under this topic we would like to cover the environmental, health, economic, social and ethical implications of life sciences.

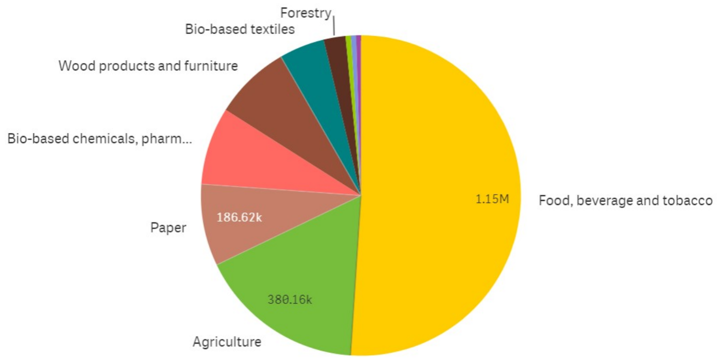
2.1 main facts, figures and trends

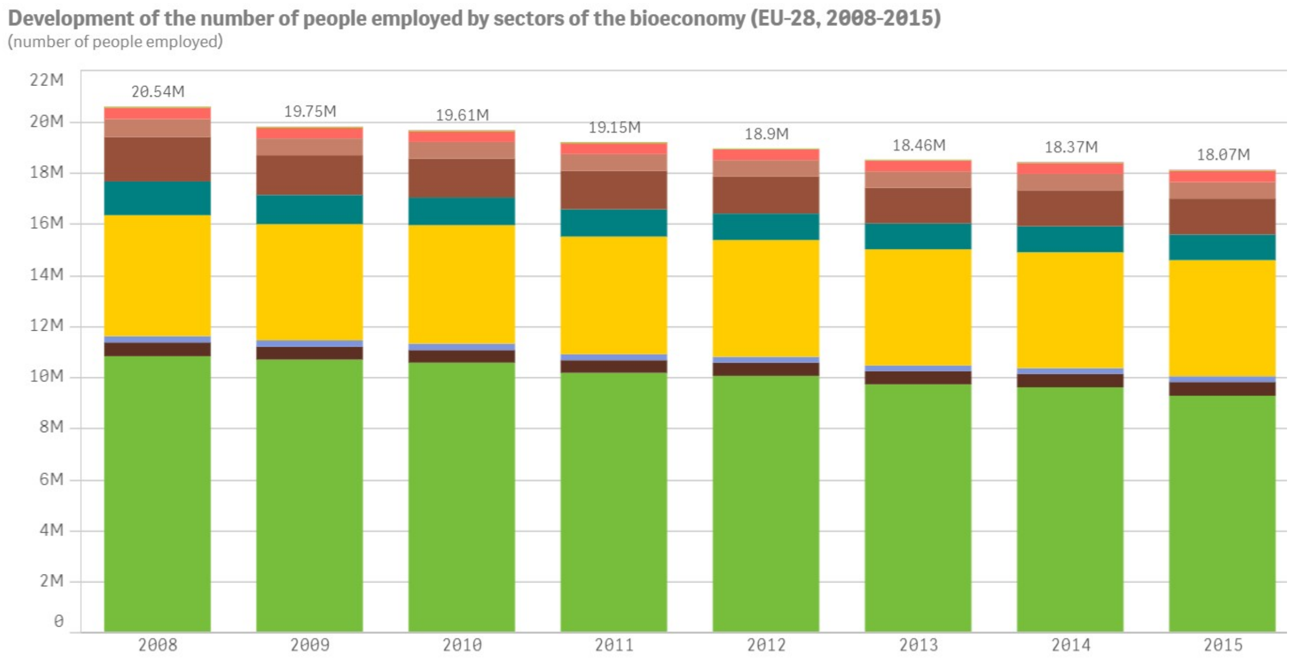
Due to the horizontal nature of the bioeconomy, it is rather difficult to find data at EU level about its links with agriculture, food and feed. One reliable source is the JRC in its publication Jobs and Wealth in the European Union Bioeconomy [12]. This publication values the share of people employed in the bioeconomy in 18.07M, and the turnover of the bioeconomy in 2,259 billion €, in 2015. More than two-thirds of both indicators correspond to the sectors of agriculture and food.

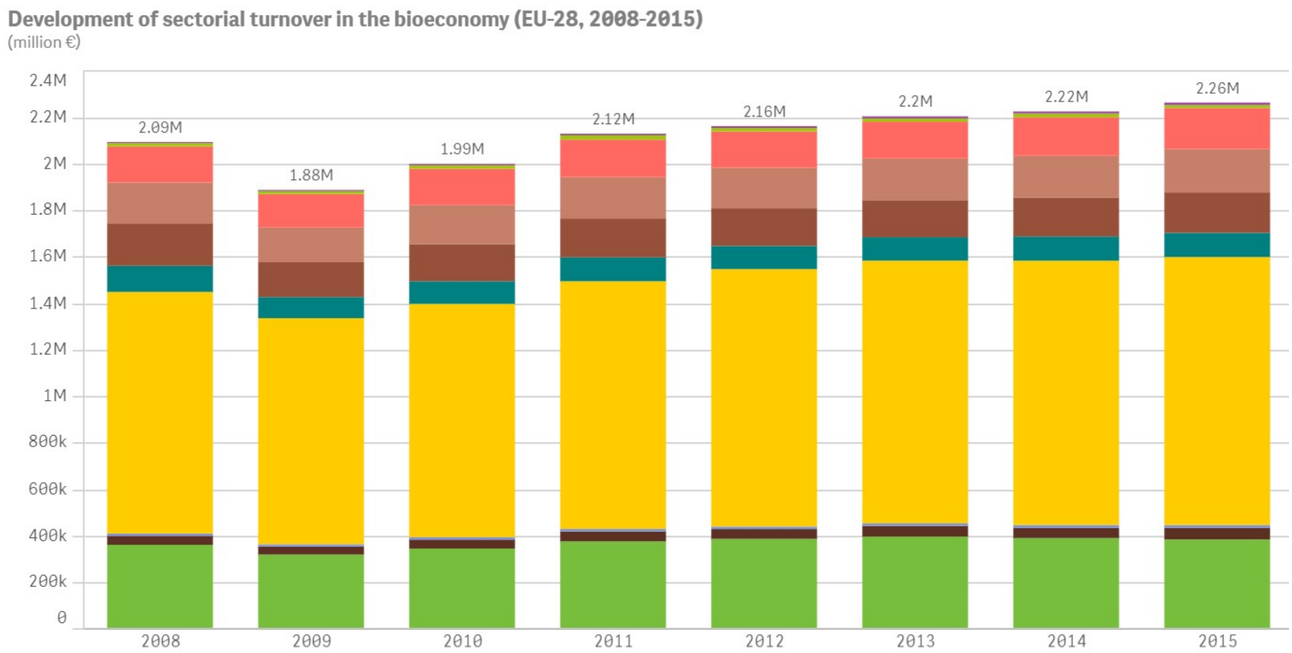
Employment in the bioeconomy by sectors in EU-28 (2015)
(number of people employed)



Turnover in the bioeconomy by sectors in EU-28 (2015)
(million €)







During the economic crisis, the number of people employed was reduced year after year. However, the turnover, although slightly, kept increasing since 2009. Bioeconomy is a very strong sector and can be considered a pillar for the EU economy.

Biotechnology is experiencing an accelerated development in the last years due to the recent improvements in genome characterization and editing. Technologies such as 'omics' and CRISPR speed up the research and allow to reach the market much faster than before. While those technologies are widely used in the pharmaceutical sector (health-related biotechnology or red biotechnology), their application to the agriculture, food and feed sectors is slower and mediated by the regulations and the public opinion.

2.2 Life sciences (biotechnology) in relationship with SDG and Planet boundaries

In the following table, several contributions of the biotechnology to sustainable development goals are summarised.

2 ZERO HUNGER	Biotechnology is bringing solutions to the resource scarcity and adding nutritional value and safety to food. Some examples: - Alternative protein sources (insects, cultured meat, single cell proteins…). - Bioactive ingredients for targeted population groups (elderly, young…). - Improvement of the yield, efficiency, resilience and quality of crops through genetic engineering. - New biobased antimicrobials to fight food borne pathogens. - New biotech-based techniques to detect food contaminants.
3 GOOD HEALTH AND WELL-BEING	Leaving apart the biopharma industry, biotechnology can also bring benefits to health through food and feed: - Alternatives to antibiotics / antimicrobials based on biotechnology (bacteriophages, bacteriocins). - Healthy and safe food and ingredients. - Active pharmaceutical ingredients (APIs) from biotechnology.
5 GENDER EQUALITY	The participation of women in the biotech sector is very important. Not only in the research field, but also in directive positions. To give an example, in Spain almost 60% of the total employees and 54% of the researchers in the field are women [13].

6 CLEAN WATER AND SANITATION	Biotechnology also contributes to sustainable water supply and wastewater treatment: - Biological treatment of wastewater to remove contaminants. - Development of production processes and crops that use less water.
7 AFFORDABLE AND CLEAN ENERGY 11 SUSTAINABLE CITIES AND COMMUNITIES 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Biotechnology brings solutions to obtain affordable, decentralised and clean energy from biomass. For instance, anaerobic digestion of biomass produces affordable and clean energy in the form of biogas, biomethane and biohydrogen. Biodiesel and bioethanol are other possibilities, that reduce the emissions of greenhouse gases in 60% and 70% respectively in comparison with fossil fuels [13]. In a related way, biotechnology contributes to the sustainability of cities and communities in several ways. Some of them are the biological treatment of solid organic waste, or the biorefineries from urban waste, in which all the valuable compounds are recovered and recycled prior to an energy valorisation or treatment. This concept is very well linked to the circular economy.
13 CLIMATE ACTION	Climate change is also addressed by the biotechnology, by substituting the fossil-based materials by biobased materials (fertilisers, pesticides, plastics, or other industrial products), thus reducing CO_2 emissions. Another CO_2 sink provided by biotechnology is the production of biofuels or even food ingredients by microalgae and cyanobacteria consuming CO_2. CO_2 emissions can be also reduced by substituting CO_2 producing processes by more carbon neutral processes (for instance, substitution of conventional fertilisers and pesticides by biological ones).
14 LIFE BELOW WATER	Contribution to the life below water can be considered through the wastewater treatment by biological processes.
15 LIFE ON LAND	Biotech-based crops have been proved to save 183 million ha of land (due to higher efficiency), reduce deforestation and reduce environmental impact by 18.4%. Data from ISAAA (International Service for the Acquisition of Agri-biotech Applications) between 1996 y 2016 [14].

In relation to the planetary boundaries, contribution of life sciences to several PBs can be identified:

- Climate change mitigation in many ways: reduction of CO_2 emissions by substitution of conventional products by bio-based ones (biopesticides, bioplastics, or other industrial products), biological treatment of waste and wastewater, bioenergy production from waste streams, biorefineries, new climate-resilient crop varieties, etc.
- Novel entities: in this case, the identified impact has to do with the biopolymers substituting conventional polymers, and the recyclability of polymers, mostly in relation with food packaging.
- Stratospheric ozone depletion: life sciences bring many technologies that can help to reduce the GHG emissions as stated in the first bullet point: bioenergy, substitution of chemicals by bioproducts, biorefineries, etc.
- Biogeochemical flows: the contribution to this PB would come, for instance, from wastewater and waste biological treatment, and biorefineries from organic waste.
- Land-system change: life sciences can provide alternative protein sources that reduce the use of land for food production (insects, highly efficient crops, cultured meat, single cell proteins, etc.).

2.3 Environmental, health, economic, social and ethical emerging issues and controversies

As previously stated, biotechnology can significantly contribute to an improvement in the **environment** through sustainable technologies for waste and wastewater treatment, biorefineries, bioenergy production, substitution of chemicals in land and industry by bio-based alternatives, etc. In addition, reduction of land, fertiliser and pesticides use can be achieved thanks to engineered crops. This last point brings many controversies due to the negative public opinion on this, raising **social and ethical** issues. However, there is scientific evidence and position papers signed by relevant institutions all over Europe supporting biotechnological crops [15],[16],[17].

Biotechnology has a very high impact on **health**, not only through the biological drugs and vaccines, but also through bioactive ingredients, probiotics, new and alternative protein sources and improvement of nutritional value/profile of foods (for instance fermented foods).

The **economic** impact of biotechnology (bioeconomy) has been treated before in this report, only emphasize the very high share of employment and turnover brought by the sectors of agriculture and food.

3. Contribution of the theme to the three transitions

Analysis should address the following questions:

- *What is the contribution of life science to the transition?*
- *What are the appropriate (quantified) targets - relevant to the domain – needed to perform the transition? How would be the target related to the transition?*
- *What are the main barriers to transition?*
- *What are the main technological game changers that may contribute to the transition? What are the related risks?*

3.1 Transition 1: Healthy and sustainable food for all

Contribution to the transition	Targets to perform the transition	Barriers to transition	Game changers	Risks
Food security	Alternative protein sources (insects, cultured meat, single cell proteins…)	Cultural barriers (insects). Technological barriers (cultured meat). Not vegan sources.	Social opinion. Regulations. Public policy. Technological developments.	Allergenicity issues.
Food safety	Develop and use novel antimicrobials from biological origin, to which no antimicrobial resistance is yet developed.	Rejection of the consumers – for instance, phages are viruses and bacteriocins are toxins and can be perceived as dangerous.	Social opinion and regulations. Technological developments.	New antimicrobial resistances
Healthy food	Bioactive ingredients, functional foods and diets tailored for specific needs of particular population groups (elderly, children,	Rejection of functional foods vs. “real” foods (“realfooding” trend). Regulation and	Education on healthy nutrition coming for professionals without particular interests that know	Accessibility to healthy food by low income population.

	pregnant women, climacteric stage women, sportspersons…). Specific focus on healthy microbiome.	approval process of novel foods and health claims.	well the food industry. Support industry to get through approval processes.	
Sustainable farming	Increase efficiency of crops in terms of land and water use. Shift to biological fertiliser and pesticides. Use of biostimulants.	Strong social rejection of GMO crops. Absence of regulation of biofertilisers in the past led to the commercialisation of low effectivity products that undermined the trust of the farmers on these products.	Extensive and knowledge-based information campaigns, providing scientific evidence of the reality of GMO crops and alternatives to conventional fertilisers and pesticides.	The opinion on these issues are strongly internalised and it will be difficult to change.

1.1.1. *3.2 Transition 2: Full circularity of food systems*

Contribution to the transition	Targets to perform the transition	Barriers to transition	Game changers	Risks
Sustainable packaging	Substitution of conventional plastics by fully recyclable bioplastics	Technological Economic Functionality of bioplastics	Achieve high efficiency in the bioplastic production to put their prices on the same level as conventional plastic.	High efficiency might go together with engineered strains (GMO rejection, regulation…).
Circularity	Sound waste valorisation, coupling resource recovery with energy valorisation and final waste treatment (biorefinery concept)	Economic feasibility.	Apply economic criteria, particularised to local conditions.	Waste producers are unlikely to transform to biorefinery managers (different technologies and economic cost). If biorefineries are not economically sustainable by themselves, they are unlikely to succeed as independent business.
Green energy supply	Bioenergy (biogas, biomethane, biohydrogen, biodiesel, bioethanol) can be	Technology can be a barrier for self-consumption (difficult to	Energy regulations. Policies to increase renewable energy	Bioenergy production facilities have to be well managed → centralised production → transport of

	produced from different food and agricultural waste.	manage for farmers or food industry).	production. Incorporate nutrient recycling to the equation.	waste → cost and CO_2 emissions.

1.1.2. 3.3 Transition 3: Substantial increase of biological, social, and economic diversity

Contribution to the transition	Targets to perform the transition	Barriers to transition	Game changers	Risks
Land use	Increased efficiency of crops, either by developing new varieties consuming less land and water, or by using products stimulating the nutrient uptake and resistance against pathogens.	Strong social rejection of GMO crops. Absence of regulation of biofertilisers in the past led to the commercialisation of low effectivity products that undermined the trust of the farmers on these products.	Extensive and knowledge-based information campaigns, providing scientific evidence of the reality of GMO crops and alternatives to conventional fertilisers and pesticides.	The opinion on these issues are strongly internalised and it will be difficult to change. Possible impact on species in contact with GMO crops [10].
Microbial proteins	Replacement of traditional protein sources (animal or vegetal), with the associated environmental benefits (less water and land use, less pesticide use, etc.)	Cultural barriers, legislation.	Technology for production of microbial proteins or single cell proteins in a more sustainable way (from syngas or biogas, for instance).	Energy balance is required. Possible impact on human livelihood [10].
Conservation of biodiversity	Novel tools to characterize and conserve biodiversity [9]**Error! Reference source not found.**.	Cost of the technology at the beginning, but it is decreasing rapidly.	Progress of technology in the area of genomics and other “omics” (proteomics, metabolomics…)	In the framework of Nagoya Protocol, access regulations or restrictions might be applied in the future to genetic sequences.
Increasing biodiversity	Recovery of old varieties and partly wild edible plants into food	Old varieties that were substituted by the current ones due to economic reasons (increased yield of	Breeding techniques that could compensate the yield	Not foreseen.

	system.	new varieties).	loss. Favourable opinion of consumers and willingness to pay.	

4. Policy conditions for the achievement of the targets

In this section policy conditions – relevant to the working group domain – necessary to the transition should be analysed

Policies on food, energy, agriculture, environment, etc. are relevant to the issues addressed in this report.

Policies encouraging education on healthy food are needed, that help citizens to make healthy choices according to their needs and based on scientific evidence. In the information era, it is difficult for the consumers to distinguish the quality information. This is breeding ground for disinformation, with consumer trusting "influencers" more than scientists about health-related issues.

Food industry is consumer oriented. If there is a strong demand of healthy food by consumers, the industry will try to fulfil it. Nevertheless, "health washing" should be avoided, both by surveillance on the industry and education of the consumers. Health claims on the packaging and advertisement are strongly regulated by EFSA. The achievement of a health claim that a company can use is extremely rare. Many companies don't dare to try due not only to the long and costly process, but also to the uncertainty of the result. A deeper knowledge of the process and the requirements to achieve a health claim with a smooth process would be desirable.

New and alternative protein sources, or novel bioactives, often have to go through the way of "novel food". This process can be difficult for small companies and should be facilitated through information and awareness campaigns, and openness of the relevant institutions.

Energy policies strongly affect the share of renewable energy production and consumption (including bioenergy). Too heavy public subsidies on renewable energy can lead to speculation, but the opposite situation can hinder the deployment of technologies that are still under development. Also, transport and mobility policies influence greatly the energy model – for instance the promotion of electric means of transport can reduce the possibilities of development for biomethane and biohydrogen.

Another “equilibrium” situation is the one regarding organic farming. A major shift to organic farming might be beneficial for environment in many ways, but it will increase the land use due to its lower efficiency. High efficiency crops are also needed to feed a growing population with increasing interest in plant-based proteins. Social opinion on GMO crops does not match the scientific opinion and evidence. Extensive awareness campaigns led by the relevant persons would be needed, accompanied by policies supporting the biotechnology. Awareness and support to biotechnology including gene editing or metabolic engineering should be extended also to the production platforms for particular molecules (bioactives, enzymes, active principles, etc.).

The substitution of conventional fertilisers and pesticides by biological products should be favoured by a clear regulation. Training of institutions’ staff is needed to apply the (sometimes) confusing regulations. Moreover, awareness of the farmers is needed on this kind of products, whose credibility has been undermined by some low-quality products aroused in the period with absence of regulation.

Policies on waste management and valorisation already exist both at EU-level and country-level. Their application, however, can be confusing even in different regions of the same country. Harmonisation criteria would be necessary to clarify what can be done and what should not (for instance with land application of some organic side-streams that are rich in nutrients and organic matter).

Extensive research has been carried out regarding waste biorefineries. This concept is fully in line with sustainability and circularity, since it means to extract every valuable compound from waste and valorise the remaining material until zero-waste. However, very few facilities have been created and even less are working using waste as feedstock (many more can be found with agricultural resources as feedstock) [18]. Since this activity would be carried out by waste managers (companies independent from the food producers), economic and local considerations should be considered to achieve economically feasible facilities.

5. Challenges for research

In this section main research questions and topics generated by the analysis of the transitions should be synthesized

Life sciences are always under development, and the food and agriculture fields are no exception. Immediate needs for research have been suggested already through the report and are summarized here.

- New protein sources: sustainable (economic and environmentally) and technically feasible processes, research on allergenicity potential.
- Novel antimicrobials: efficient production processes, increase efficacy and specificity through the use of biotechnology and technologies of further functionalization such as active microencapsulation.
- Bioactive ingredients: increase the knowledge on bioactivity of ingredients to help understanding the mechanisms of action, develop new bioactive ingredients and foods (also using engineered sources such as microorganisms of eukaryotic cells), increase bioactivity and bioavailability of ingredients by novel encapsulation techniques. Incorporate the use of omics in the development of functional foods. Specific focus on microbiome since it is linked with many health disorders.
- Alternative pesticides: new products based in biological active principles that can complement or substitute the conventional fertilisers or pesticides, or even provide treatment for pests and diseases without known treatment.
- Bioplastics: new materials that fulfil the technical requirements of packaging (transparency, barrier properties, durability, recyclability) with prices that can compete with the conventional ones.
- Biorefineries from waste: achieve full sustainability of the whole process, from an environmental and also economic point of view.
- Biological treatment of waste and wastewater: increase the efficiency of biological processes to remove organic matter, develop new bioprocesses able to remove other contaminants.
- New fermented foods: precision fermentation to achieve high quality and standardized fermentation processes leading to final products with improved properties in terms of organoleptic, technological and health properties.

References

[1] Birner R. (2018) Bioeconomy Concepts. In: Lewandowski I. (eds) Bioeconomy. Springer, Cham. DOI: https://doi.org/10.1007/978-3-319-68152-8_3
[2] Aiking H., De Boer J. Protein and sustainability – the potential of insects. *Journal of Insects as Food and Feed* 5, 3-7 (2019). https://doi.org/10.3920/JIFF2018.0011
[3] Gilbert N. The race to create super-crops. *Nature* 533, 308–310 (2016) doi:10.1038/533308a
[4] McClements D.J. (2019) Food Biotechnology: Sculpting Genes with Genetic Engineering. In: Future Foods. Copernicus, Cham. https://doi.org/10.1007/978-3-030-12995-8_9
[5] Quinto E.J., Caro I., Villalobos-Delgado L.H., Mateo J., De-Mateo-Silleras B., Redondo-Del-Rio M.P. (2019). Food Safety through natural antimicrobials. Antibiotics 8, 208. https://doi.org/10.3390/antibiotics8040208
[6] Bio-based Industries Consortium (2017). Strategic Innovation and Research Agenda (SIRA). https://www.bbi-europe.eu/sites/default/files/sira-2017.pdf
[7] Spekreijse J., Lammens T., Parisi C., Ronzon T., Vis M. (2019). Insights into the European market for bio-based chemicals. JRC Science Hub. Publications Office of the European Union. ISBN 978-92-79-98420-4. ISSN 1831-9424. doi:10.2760/549564.
[8] FAO. Haversting nature's diversity. http://www.fao.org/3/v1430e/V1430E00.htm
[9] Corlett RT (2017). A bigger toolbox: biotechnology in biodiversity conservation. Trends in Biotechnology 35, 55-65.
[10] Sutherland WJ, Broad S, Butchart SHM, Clarke SJ, Collins AM, Dicks LV, Doran H, Esmail N, Fleishman E, Frost N, Gaston KJ, Gibbons DW, Hughes AC, Jiang Z, Kelman R, LeAnstey B, le Roux X, Lickorish FA, Monk KA, Mortimer D, Pearce-Higgins JW, Peck LS, Pettorelli N, Pretty J, Seymour CL, Spalding MD, Wentworth J, Ockendon N (2019). A Horizon Scan of Emerging Issues for Global Conservation in 2019. Trends in Ecology and Evolution 34, 83-94.
[11] Wegst UGK, Bai H, Saiz E, Tomsia AP, Ritchie RO (2015). Bioinspired structural materials. Nature Materials 14, 23-36.
[12] JRC. Jobs and Wealth in the European Union Bioeconomy. https://datam.jrc.ec.europa.eu/datam/mashup/BIOECONOMICS/index.html
[13] ASEBIO. http://www.asebio.com
[14] ISAAA. http://www.isaaa.org
[15] Pellegrino E., Bedini S., Nuti M., Ercoli L (2018). Impact of genetically engineered maize on agronomic, environmental and toxicological traits: a meta-analysis of 21 years of field data. Nature Scientific Reports 8, Article Number 3113. doi:10.1038/s41598-018-21284-2.
[16] Open Statement for the use of genome editing for sustainable agriculture and food production in the EU (signed by 127 EU research institutions). http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=17663 http://www.efbiotechnology.org/Newsletter/img/open_s.pdf

[17] European Federation of Biotechnology (2019). European Federation of Biotechnology's view on benefits of gene editing. June 2019. https://www.efbiotechnology.org/images/uploads/gm_statement_2019.pdf
[18] Parisi, C. (2018). "Research Brief: Biorefineries distribution in the EU". European Commission - Joint Research Centre. doi:10.2760/126478

CHEMICALS IN THE BIOECONOMY

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a.1 Main facts, figures and trends

- fertilizers

Major nutrients provided in fertilisers and affecting crop yields are nitrogen, phosphorus and potassium. Ammonia is one of the most important chemicals produced globally with approximately 85% being used as fertiliser for food production (Brightling, 2018). It is produced through the extraction of atmospheric nitrogen gas, however the process requires substantial energy. The total energy consumption for ammonia production is equivalent to ± 2 % of world energy use. Phosphorus and potassium are produced from fossil resources. The EC have already placed phosphorus on the “critical raw material” list, since Europe depends heavily on import of phosphate rock for the production of mineral fertiliser. Estimates of phosphorus reserves are highly uncertain, but based on population growth and future demand for nutrients, it is expected that depletion will occur within 93 to 291 years (Meers, 2016).

Global use of the 3 major nutrients has increased between early 1960s and 2005/2007 from 34 to 166 million tons which was mainly related to the growth in developing countries. It has been projected to further increase to 263 million tons by 2050 (Alexandratos and Bruinsma, 2012).

Overall fertilizer consumption in Europe was rather stable over last decade, however the amounts applied have been high. In 2017, 11.6 million tonnes of nitrogen fertiliser was used in EU agriculture, an increase of 8 % since 2007 (10.7 million tonnes). In 2017, 1.3 million tonnes of phosphorus fertiliser was used in EU agriculture, a reduction of 9 % since 2007 (1.5 million tonnes) ((https://ec.europa.eu/eurostat/statisticsexplained - 20/05/2019).

The gross balance of nitrogen in EU has been reported to decrease in 1990 – 2014 period from above 100 to approximately 50 kg/ha UAA in 2015. The balance of phosphorus has also declined to below 10 kg/ha (fig. 1) (https://ec.europa.eu/agriculture/markets-and-prices/market-briefs_en). There are however, significant differences in both nitrogen application rates and gross nitrogen balance between European countries.

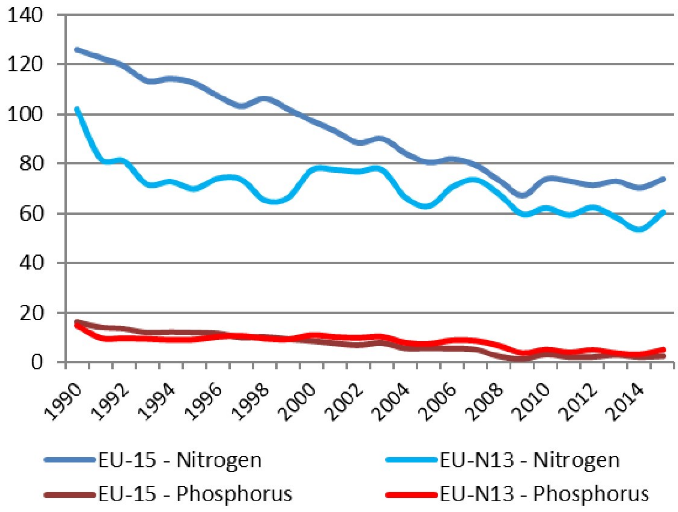

Fig. 1. Gross balance of nitrogen and phosphorus in soil in Europe within 1990 – 2014 period.

- pesticides

Chemical pesticide use worldwide have been intensively increasing since 1960s. They have been in general overused. There is a diversity in the in the awareness and rates applied in the agriculture. A government report in 2016 stated that pesticide use of Chinese farmers reached three times the global average. In 2013, Greenpeace reported that 70% of pesticide used in China was not absorbed by plants, but instead seeped into the soil and groundwater (Zhang, 2018). Asia is using pesticides most intensively when expressed a the amount per area – almost 4 kg/ha (Fig. 2). This amount have been doubled since 1990. The average rate in Europe is less than 2 kg/ha and it has been rather stable within last 3 decades.

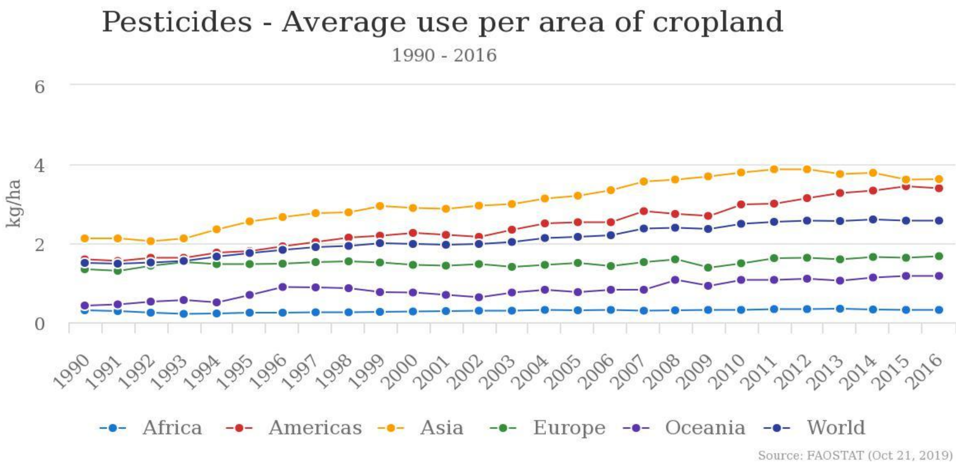

Fig. 2. Average use of pesticide per area of cropland based on FAOSTAT data (accessed 15.10.2019)

Pesticide production and use have been expanding fast (Fig. 3) (Agrios, 2005). Herbicides constituted the highest market among all pesticide groups, followed by insecticides and fungicides. Approximately 2.26 million tons of active ingredients were used in 2001.

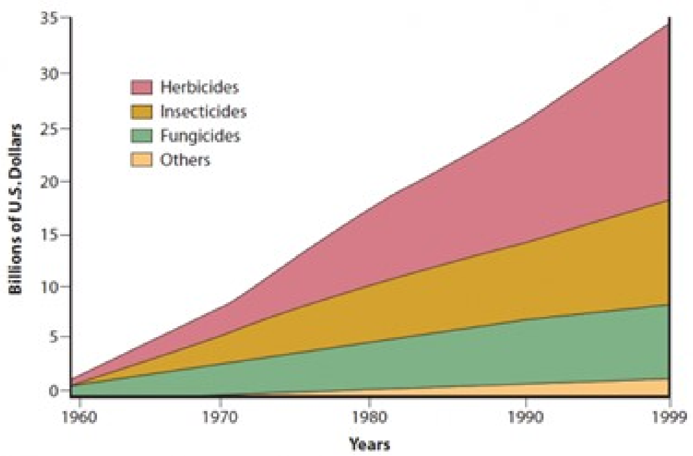

Fig. 3. Worldwide annual sales of pesticides in 1960-1999 period (*Agrios, 2005)*

- antibiotics

The global antibiotics market was evaluated at 42,654 million USD in 2018 with a projection to increase to 56,370 million in 2024. There are factors that drive the increase in antibiotics market and use. These are the emergence of anti-MRSA drugs (to combat methicyllin-resistant S. aureus infections), development of generic drugs and progressing vulnerability of aging population (www.mordorintelligence.com/industry-reports/antibiotics-market). Once a drug patent expires, the generic formulations become manufactured, causing much lower price of a drug. This improves the healthcare but also stimulates antibiotics overuse, resulting in spread of antibiotics and antibiotic resistance in the environment.

Of all antibiotics sold in the United States, approximately 80% are sold for use in animal agricultural production. Besides their clinical use, antibiotics have been administered to animals in feed to improve growth rates and to prevent infections. In 2006, the EU banned the use of antimicrobial growth promoters in animal feeding (Martin et al., 2015).

- plastics

The plastic production has revolutionized the human lifetime, but on the other hand dramatically affected waste generation structure and volume. Overall annual global production of plastics have exceeded 300 million tons (fig. 4). The production of synthetic polymers globally is dominated by the polyethylene and polypropylene. They degrade very slowly, which is why they survive in the environment from decades to centuries. Mainly physical processes cause the plastic to break down, which leads to the release of microplastics into the environment. The cumulative production has reached almost 8 billion tonnes of plastics.

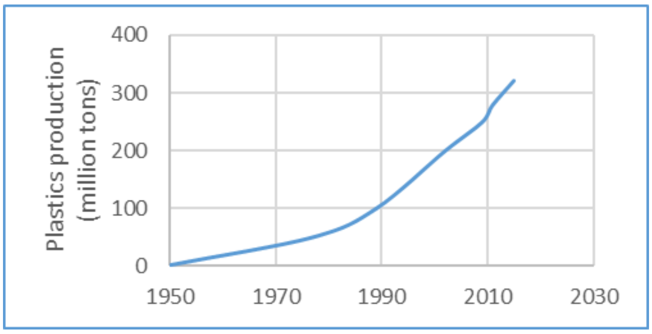

Fig. 4. Annual global production of plastics within 1950 – 2015 period. Source: *Based on Plastics Europe data.*

In general, packaging consumes 35 to 45 percent of the synthetic polymer produced in total. Geyer et al. 2017 analysed how long plastics are in use before they reach the end of their useful lifetimes and are discarded. They compared eight different industrial use sectors or product categories. The production of the packaging plastics with the lifetime less than 1 year, was 2-, 3-, 5-times greater than plastics used for textiles, consumer products or electronics, characterised by the lifetime from several to 10 years.

In 2015, an estimated 55 percent of global plastic waste was discarded, 25 percent was incinerated, and only 20 percent recycled (Geyer et al., 2017). As a result, the share of plastics in municipal solid waste (by mass) increased from less than 1% in 1960 to more than 10% by 2005 in middle- and high-income countries.

a.2 Distance of 'Business as Usual' situation from SDG and Planet boundaries

The table presents how intensive use and release of chemicals affects achievements of the most related SDGs and the distance from SDGs.

2 ZERO HUNGER	The release pf contaminants, especially pesticides, into the environment (soil and water) impedes achieving the target of ensuring access to safe food. Dioxins, released mainly during incineration processes, and potentially toxic trace elements (e.g. mercury) accumulate in fish and seafood. Transport of fertilisers to seas and oceans impacts water environment and availability and diversity of fish.
3 GOOD HEALTH AND WELL-BEING	The target is to reduce the number of deaths and illnesses from chemicals in air, soil and water. Widespread use of pesticides contribute to the risk – number of deaths due to pesticide pollution is not estimated. Not estimated but emerging risk from antibiotic resistance that are spread through waste, manure, treated municipal water and sludge disposal. Microplastics have been found in an urban air, being additional dangerous pollutant, along with PAHs, dioxins and the particulate matter.

6 CLEAN WATER AND SANITATION	The targets assume equitable access to clean water and eliminating release of pollutant into water. The increase (globally) or stable levels (Europe) in use of pesticides and chemical fertilisers prevent progress in reducing water pollution. Current technologies of wastewater treatment do not prevent dispersion of emerging pollutants to water.
11 SUSTAINABLE CITIES AND COMMUNITIES	The goals assume reduction of adverse impacts of cities on human, including improving air quality and waste management. Only single cities have strategies of urban land use planning taking role of green areas for living conditions into account. Not sufficient circularity of waste, including plastics, adds to air pollution through incineration and erosion processes. Five billion people still had not access to waste collection or controlled disposal (Progress report). 90% of urban citizens were exposed to air that did not meet the WHO guidelines in terms of PM2.5 (less than 2.5 microns). The exposure to microplastics, dioxins, PAHs, through the air is not being evaluated.
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Reduction of the plastic waste generation and its recycling/reuse is linked to the one of the SDG targets. So far plastics use is still increasing. The target is to manage chemicals and reduce their release and generation of hazardous waste. Despite conventions on controlling and recording transport of hazardous waste, only part of countries provide the data.
13 CLIMATE ACTION	Increasing production of plastics contributes to GHG emissions at both production and waste management, therefore the trend is still wrong. Chemical nitrogen fertilisers generate emissions at the production and the application stages but differ between the fertilisers forms.
14 LIFE BELOW WATER	The SDG aims at preventing and reducing marine pollution from land-based activities, including marine debris and nutrient pollution Global trends indicate further worsening the situation and deterioration of coastal waters due to eutrophication and pollution with plastics and persistent contaminants. Plastic debris has been found in all major ocean basins and 4 to 12 million tons entered the marine environment in 2010 alone (Geyer et al., 2017)
15 LIFE ON LAND	Overuse of pesticides and fertilisers induces loss of land and soil biodiversity that are key to combating climate change, land desertification and maintaining ecosystem services. Biodiversity is extremely important for resistance of ecosystems.

Planetary boundaries

There are no planetary boundaries set for novel entities and such contaminants antibiotics and micro-plastics, partly due to insufficient data on their abundance and impacts. It can be assumed that the planetary boundary for plastics in general have been already strongly exceeded, since the annual global production of plastics have exceeded 300 million tons and plastics with a short use predominate.

The boundary might be better represented and imagined by the is of pesticides. They constitute a risk for human health through incidental poisoning and their presence in soil and water but also hamper biodiversity, affecting crop performance (deficiency of bees and natural pest enemies). The use of pesticides was expanding fast with last 3 decades, even if it was relatively constant in Europe. There is still a risk of increasing their application amounts in currently developing countries. On the other hand, it can assumed that current application rates exceed what is really necessary to effective crop protection (Lechenet et al., 2017).

The planetary boundaries framework provides two sub-boundaries for biogeochemical flows, concerning the phosphorus and the nitrogen cycle. The major anthropogenic perturbation of the N and P cycles comes from agriculture. Global variable representing phosphorus cycle is: its flow from fresh water systems into the ocean. The planetary boundary is set at 11 Tg P yr–1 while its current value is evaluated at 22 Tg P yr^{-1} (Steffen et al., 2015). The exceedance of the boundary for phosphorus has two side negative implications – eutrophication of water and scarcity of phosphorus as a natural resource. The planetary boundaries for nitrogen are still discussed, since the original approach was based on the production of new reactive N by fixing N2 from the atmosphere by humans, was set at 35 Tg N yr^{-1} and did not cover all aspects of negative impacts.

It must be however emphasized that regional variability in anthropogenic nitrogen and phosphorus is very high, therefore addressing global thresholds does not cover the issue of risks related to current cycle of these nutrients.

a.3 Environmental, health, economic, social and ethical emerging issues and controversies

- fertilizers

General issues:

- Overuse of chemical fertilisers leads to eutrophication of ground- and surface water, deterioration of coastal waters and GHG emissions from croplands.

- Phosphorus is mis-managed - 1/5 of phosphorus mined for agricultural production ends in food
- Quality of and access to P rock difficult which is a main source of phosphorus in agriculture (Fig. 5).
- Geopolitical risks related to the fact that 88% of phosphorus reserves are controlled by 5 countries and 75% by one of them.

Food system issues:

- How to ensure food security when reducing fertilisation?
- Phosphorus is a fossil resource, non-renewable and there is no substitution for this nutrient in food production. Demand for phosphorus is increasing with its limited resources.
- How to ensure environmental safety when recovering nutrients from waste?
- Higher fertilisation driven yields cause dilution of micronutrients in crops and food
- Phosphorus scarcity and the related risk for food security.

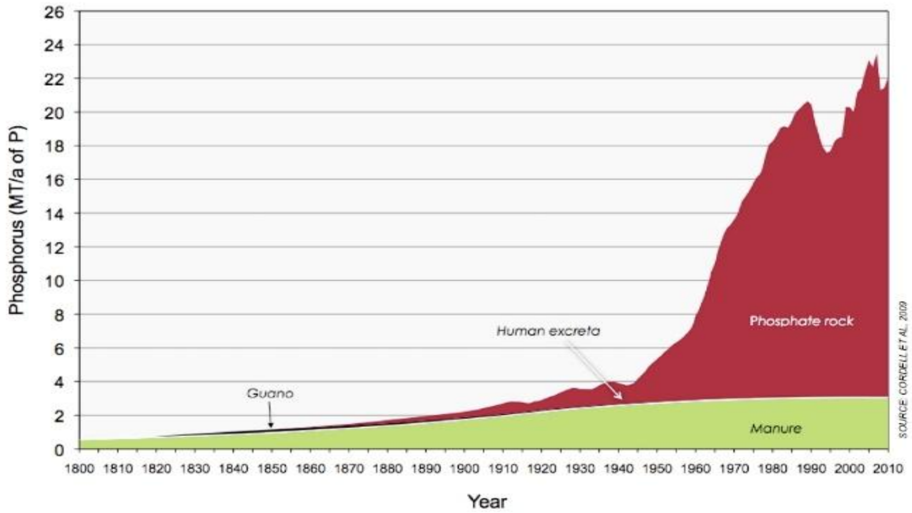

Fig. 5. Change of the historical sources of phosphorus fertilisers. Source: *Cordell et al The Story of Phosphorus.*

- pesticides

General issues:

- Their widespread use has caused health problems as a result of occupational exposure. The human population is exposed mainly through residues of pesticides in food and drinking-water.
- Global pesticide use may have resulted in biodiversity loss.
- Not recognized link between human disease and intensive agricultural production (e.g. fruit, flower production).

Food system issues:

- Bee populations have significantly declined in the past years due to pesticide over use. They pollinate more than 90% of the world's 107 major crops.
- Residues of highly hazardous pesticides can be found in food, especially in fish.

- antibiotics

General issues:

- Antibiotic consumption rate in low- and middle-income countries has been raising to levels typical for high-income countries.
- Potential decline of antibiotic effectiveness represents a major threat to human health.
- Pollution from antibiotic residues and antibiotic resistance genes (ARGs) can increase the likelihood of human pathogens acquiring resistance and unpredictable health problems at society level. The pollution comes from human and animal production antibiotics. The risk is accelerated by lack of widespread technologies removing antibiotics and ARGs from wastewater and manure.

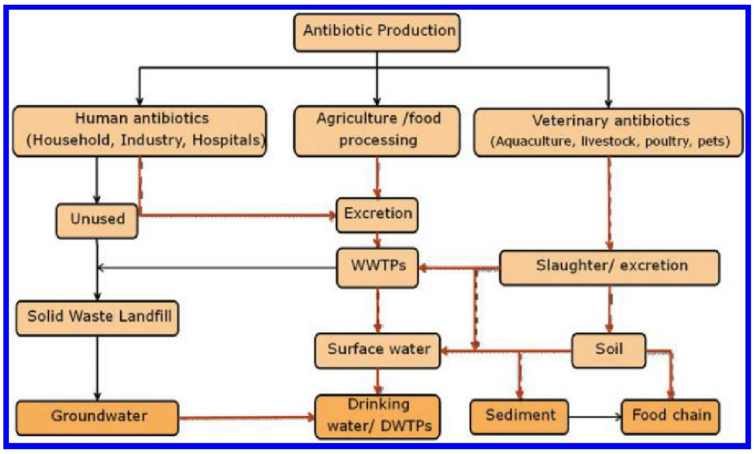

Fig. 6. Sources and pathways of antibiotics in the environment. *Source: Goel, 2015*.

Food system issues:

- Quality of manure and liquid manure for fertilisation.
- AR release when recovering nutrients from municipal waste and sewage sludge.

- plastics

General issues:

- The vast majority of monomers used to make plastics are derived from fossil resources.
- None of the commonly used plastics are fully biodegradable. Therefore they do not decompose but rather accumulate, in the natural environment or when landfilled.
- Macroplastics are converted to microplastics in the environment. Even if production of non-biodegradable plastics is banned, microplastics will persist for long.
- Plastic debris has been found in all major ocean basins.
- Contamination of aquatic and terrestrial habitats with synthetic fibers is also increasingly reported (Geyer et al., 2017).
- Plastic contributes to greenhouse gas emissions from the production stage to its management as a waste product.
- Trapping or choking marine animals by plastic waste.

- Very little evidence of the impact of microplastics in humans which affects the awareness.
- Risks to human: plastic particles themselves, the release of persistent organic pollutant adsorbed to the plastics (PCB, PAH, bisphenol) and leaching of plastic additives
- Plastics found in urban dust, 12,000 microplastic particles per litre in samples of Arctic sea ice

Food system issues:

- Chemicals present in plastics can potentially migrate from the plastic product to the human organism or the environment
- Persistence of food products without plastic – radical change of food system needed.
- Micro- and nanoplastics in have been already found in mussels and oysters, honey, beer and table salt
- Microplastics may enter drinking-water sources in a number of ways
- Microplastics released from food packaging, e.g. from nylon tea bags, directly to what human consume.

2. Contribution of the theme to the three transitions

Analysis should address the following questions:

• *What is the contribution of life science to the transition?*

• *What are the appropriate (quantified) targets - relevant to the domain – needed to perform the transition? How would be the target related to the transition?*

• *What are the main barriers to transition?*

• *What are the main technological game changers that may contribute to the transition? What are the related risks?*

Transition 1: Healthy and sustainable food for all

Targets/intervention to perform the transition	Contribution to the transition	Barriers	Game changers	Risks
Precise N and P management enabling the overall use reduction	Sustainable farming	Technological, knowledge transfer, economic	Research, modern advisory systems, technology providers, policy	No major risks
Appropriate soil management to limit nutrient loss and sufficient yield	Sustainable farming, food security	Insufficient awareness, knowledge transfer	Advisory systems	No major risks
Biological development – improved cultivars	Sustainable farming, food security	Technological	Research, advisory systems	No major risks
Develop highly efficient, low toxic and low residual pesticides, mainly bio-pesticides	Food security, sustainable farming	Existing market, technological	Policy makers, technology providers	Unknown residual effects of biopesticides
Stop the use of antibiotics in aquaculture	Food safety	Non-effective controlling, political	Policy makers, policy implementation	No major risks
Manure/liquid manure treatment technologies to use them widely instead of synthetic fertilisers and avoid emerging risks from manure	Food safety, sustainable farming	Technological	Research and technology providers	No major risks
Stop non-medical use of antibiotics in agriculture	Food safety, sustainable farming	Non-effective controlling, political	Policy makers, policy implementation	Animal health needs to be controlled
Restrict the intentional use of microplastics in any industrial	Healthy food	Regulatory	Policy makers, society	No major risks

sector (e.g. cosmetics,)			opinion	
Recapturing and removing plastics from offshore waters and shorelines	Healthy food	Financial	Policy makers, society opinion	Lack of funds and responsibility

Transition 2: Full circularity of food systems

Targets/intervention to perform the transition	Contribution to the transition	Barriers	Game changers	Risks
Recovery of phosphorus and nitrogen from waste	Waste circularity, sustainable farming	Technological	Technology providers, policy and strategy makers	Risk of transfer of emerging pollutants from waste if not connected with technology and research progress
Wastewater treatment technology upgraded to remove chemicals and antibiotics/ARGs	Waste circularity	Technological	Research, technology providers	Insufficient knowledge in the facilities
Ban synthetic plastics to use only fully recyclable bioplastics. Ban of mixing various polymers in one bag material	Sustainable packaging	Technological, economic	Policy makers, society opinion, retailers	Difficulty to control globally
Eliminating single-use materials; reducing the use of plastics where possible	Sustainable packaging	Lifestyle, functionality of plastics in food storage and preservation	Policy makers, society opinion retailers	Pressure from society lifestyle, need for food storage. Must be combined with local food systems
Limit the types of plastic to a single standard which is easy to recycle. New bioplastics introduced only when technology of their degradation simultaneously developed and implemented	Sustainable packaging, waste circularity	Technological, regulatory, market	Policy makers, society opinion, technology providers, research	No major risks

Transition 3: Substantial increase of biological, social, and economic diversity

Targets/intervention to perform the transition	Contribution to the transition	Barriers	Game changers	Risks
Reduce impact of pesticide producers/reduce rate	Increasing biological diversity	Market, knowledge transfer	Awareness building – advisory systems, policy makers	Farmers afraid of lower yield
Implement integrated pest management (IPM), protect natural enemies and biodiversity	Increasing biological diversity	Economic, knowledge transfer	Awareness building – advisory systems, policy makers	Farmers afraid of lower yield
Intelligent pest monitoring and pest management decision support systems	Increasing biological diversity, economic diversity through market development	Economic, knowledge transfer	Technology providers	Part of farmers below economic effectiveness will not implement
Spatial development of cities enabling inactivation/limiting transfer of pollutants to air and water	Landscape diversity improving living conditions	Awareness of decision makers, lack of tools	Technology providers, administration, citizen impact	Economic pressure on decision makers

3. Policy conditions for the achievement of the targets

In the domain of chemicals in the bioeconomy, the research stimulation and technology development will be especially important. The policy on further engagement of research and industry will be key for bringing effective technologies into practice.

A lot can be achieved through new technology development in the area of:

- waste/manure treatment to avoid emerging risks/pollutants (pesticide residues, antibiotics, hormones),
- nutrient recovery from waste,
- bioplastics development and their biodegradation,

- bio-pesticide development,
- intelligent systems of fertilisation and pest management, based on digital monitoring and ICT decision support systems
- Biological development – new cultivars efficient in nutrients and adopted to changing climate conditions.

A range of policies is relevant to the domain of chemicals: agricultural, environmental, fertiliser, waste management, energy, packaging, urban development.

Current and future agricultural policies shall make further shift into promoting more sustainable agricultural production, including supporting biodiversity, precise fertilisers and pesticide application, cooperation between farms for feed/manure and land sharing, promoting water retention to support sufficient yields under limited precipitation, protecting soil capacity to produce yield, not contaminating soil.

Education of farmers and transfer of knowledge must be a key component of agricultural policy. Some interventions are potentially relatively easy to implement and enable partial achievement of the goals, such as reducing chemical fertilizer and pesticide use. Knowledge on conditions of pesticide effectiveness and their hazardous effects would lead to reduction of the applied amounts. Farmers must be aware how to keep the soil quality that will enable achieving sufficient productivity without applying high rates of fertilisers. The important component of the agricultural policies would be supporting innovation at farm level, including digitisation – to more precisely manage the nutrients and pesticides.

The pesticide regulations will need a radical update to eliminate the use of persistent highly hazardous pesticides in order to avoid accidental poisonings, hidden effects on human health and severe impact on the environment and the biodiversity. Awareness on hazard and appropriate classification of hazards related to pesticides is needed to enable aware farmer decisions.

Controlling exposure

Long-term phosphorus scarcity shall be put on the priority agenda for global food security. Systemic approaches are required to stop mismanagement of phosphorus and enable its effective circularity.

Energy policies will be effective through stimulating the bioenergy production, especially biogas plants with enhanced technologies to safely treat manure, remove biological and decompose chemical contaminants and recover nutrients.

Urban development policies, involving aware spatial planning, are the necessary tools that might reduce exposure of human to contaminants in the air and temperature extremes. The appropriate green area density and selection of plant species enables adsorption and inactivation of contaminants such as dioxins, PAHs, metals, micro-plastics, etc. Spatial pattern of various land uses also enables the air movement and ventilation of the city centres, reducing the human exposure. Protection of soils with high water retention capacity has a cooling effect during summer heat islands.

Drastic policy change is needed concerning use of plastics, including limiting its use where possible, limiting single use plastics and using only bioplastics when necessary, improving recycling programmes and circular solutions. Awareness building is a key component of the transition regarding use of plastics and antibiotics. Eliminating single-use materials is possible but it would involve all citizens in the solution. A precautionary approach is needed in healthcare to limit the amounts used and spread of antibiotic residues and antibiotic resistance. Waste streams containing pathogenic infectious bacteria and antibiotics must be treated separately. A major technological progress is needed in the treatment of sewage sludge, waste water and manure to get rid of antibiotics and the antibiotic resistance risks. Use of antibiotics for non-medical purposes in animal production must be fully banned across the world.

4. Challenges for research

The challenges for research in the ‘Chemicals in the bioeconomy’ domain cover both technological and knowledge or data aspects.

Technological research challenges:

- Technologies of degradable plastics developed simultaneously with technologies of plastics effective decomposition.
- Technologies of biological decomposition of plastics existing in landfills and
- Effective recovery of phosphorus and nitrogen from waste and wastewater to produce bio-fertilisers with high nutrient efficiency
- Biological development to improved nutrient efficient, drought resistant, pest resistant cultivars of crop plants
- Develop highly efficient, low toxic and highly degradable pesticides, particularly bio-pesticides. Pesticide residuals are non-toxic.
- Manure/liquid manure and waste-water treatment technologies are upgraded to remove contaminants, antibiotics, micro-plastics, antibiotic resistance genes.
- Digitisation in use of fertilisers and crop protection and mitigation of climate change.
- Development of tools enabling improved urban spatial development aimed at creating health living conditions in cities.

Knowledge and data challenges:

- Analysis of the side effects of the circular economy, especially secondary release of contaminants.
- Tools and strategies of involvement of citizens and citizen science in food systems, waste management, plastics cycle, urban development.
- Quantitative data on the abundance of antibiotic resistance and microplastics and their effects on the environment and human health.

References

Agrios G., 2005. Plant pathology, 5th Edition. Academic Press, ISBN 978-0-12-044565-3, doi.org/10.1016/C2009-0-02037-6

Alexandratos N, J. Bruinsma. 2012. World agriculture towards 2030/2050. The 2012 Revision. ESA Working Paper No. 12-03

Brightling J. 2018. Ammonia and the Fertiliser Industry: The Development of Ammonia at Billingham. Johnson Matthey Technol. Rev., 62, (1), 32–47

Cordell D., J.O. Drangert, S. White. 2009. The story of phosphorus: Global food security and food for thought . Global Environmental Change 19, 292–305

Geyer R., J.R. Jambeck, K. Lavender Law. 2017. Production, use, and fate of all plastics ever made. Law Sci. Adv., 3: e1700782

Goel S., 2015. Antibiotics in the Environment: A Review. In the Emerging Micro-Pollutants in the Environment: Occurrence, Fate, and Distribution, Edition: 1st, DOI: 10.1021/bk-2015-1198.ch002

Lechenet M., F. Dessaint, G. Py, D. Makowski, N. Munier-Jolain. 2017. Reducing pesticide use while preserving crop productivity and profitability on arable farms. Nature Plants 3, 17008, doi.org/10.1038/nplants.2017.8

Martin M.J., S.E. Thottathil, T.B. Newman. 2015. Antibiotics Overuse in Animal Agriculture: A Call to Action for Health Care Providers. American Journal of Public Health, Vol 105, No. 12, 2409-2410

Meers E. 2016. EIP-AGRI Focus Group How to improve the agronomic use of recycled nutrients (N and P) from livestock manure and other organic sources. Technical report, https://www.researchgate.net/publication/314378572_EIP-AGRI_Focus_Group_on_Nutrient_Recyling_Starting_Paper_on_how_to_improve_the_agronomic_use_of_recycled_nutrients_N_and_P_from_livestock_manure_and_other_organic_sources

Steffen W., K. Richardson, J. Rockström, S.E. Cornell, I. Fetzer, E.M. Bennett, R. Biggs, S.R. Carpenter, W. de Vries, C.A. de Wit, C. Folke, D. Gerten, J. Heinke, G.M. Mace, L.M. Persson, V. Ramanathan1, B. Reyers, S. Sörlin. 2015. Planetary boundaries: Guiding human development on a changing planet. Science 13, 1259855, DOI: 10.1126/science.1259855

Zhang W.J. 2018. Global pesticide use: Profile, trend, cost / benefit and more. Proceedings of the International Academy of Ecology and Environmental Sciences, 2018, 8(1): 1-27

CHANGING POLICIES TO ENABLE TRANSITION : WHAT ARE THE RESEARCH NEEDS ?

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In this paper, we will analyse the role of policies in the transition pathways towards an EU food system that stays within planetary boundaries, with the particular intention to identify the type of research needs to support this role of policies. This means it is a lot about policy analysis and policy research, but many other types of research needs are identified here.

The paper draws from recent social science research on transition management and the governance of transitions, mainly from the field of science and technology studies (STS), but also from the field of policy analysis in political science. It also links with the three transition pathways discussed in the 5th Foresight Expert Group report, to identify policy instruments or policy areas that would be particularly crucial to trigger, fuel or orientate transitions.

1. <u>Policies for transition or policies as a factor of lock-in</u>

A particularly important lesson from the study of past transitions, for instance from horse driven carriages to automotive cars at the end of the 19th century or the extension of organic agriculture at the beginning of the 21st century (Geels and Schot, 2007), is that transition can be blocked by a self-reinforcing systemic regime (exactly called a "socio-technical regime") that prevents innovative solutions in technologies or organizations to become mainstream, because the technologies and solutions already in place have an incumbent's advantage : they are favored by existing norms and standards, existing technical organization modalities and contracts in supply chains, and they have a privileged access to financial resources or political capital.

The role of public policies in transitions should thus be considered not only as policy levers that can trigger or incentivize transitions, but also as blocking factors, for instance when they favour incumbents: public norms and standards, but also subsidies or fiscal policies, and even competition policies, that should normally prevent a dominant position, but might need to be questioned because it is unsure that they actually manage to reverse the asymmetries of resources that disadvantage new solutions.

A major type of policy solution for transitions is therefore to look at existing policies that might be blocking factors, and identify possibilities for changing these policies. This will be the object of a further section.

2. Dedicated transition policies

In order to unlock the existing innovation regime and enable innovative solutions to grow from a niche position to a larger scale, specific policies can be designed to support transitions (Alkemade et al. , 2011) :

- **Strategic niche management** (Van der Laak, et al, 2007; Rotmans et al., 2001)) - Acknowledging the asymmetries in access to resources for niche innovations, this type of policies puts the emphasis on strategically nurturing niche innovations, and in particular rebalancing the inequalities in access to strategic resources, like credit or technical advice. The European Innovation Partnership, and in particular its component dedicated to Agriculture and Food, can target these types of needs for niche innovations : groups of farmers or groups of stakeholders along a supply chain who have developed an innovative solution can apply for financial support, in particular in order to support their capacity to evaluate performance in terms of environmental and social sustainability as well as economic profitability.
    - **Research and innovation needs** :
        - *Dedicated research support for performance evaluation capacity in the specific context of a niche / local innovation*
        - *Organisation of the innovation system to support niche innovations (access to credit, incubators,…)*

- **Regional scale clusters** (Loorbach et al, 2008; Mathijs, 2012) - Local and regional scale authorities are ideally placed to organise an innovation system that supports transitions towards innovative solutions, for two reasons. First, past successes in innovation policies indicate that geographical proximity within an innovation cluster of a variety of actors (research, universities, larger companies,SMEs, civil society, public agencies, financial sector…) is critical to enable the emergence of innovative solutions and prepare their upscaling or outscaling, which is at the heart of European innovation policies favouring regional innovation clusters. Second, particularly concerning food system innovation, the three transitions discussed in the former chapter show that local and regional authorities, although they do not all have the legal mandates on the agricultural and food sector, have developed numerous innovations at different scales, as well as local policy solutions to trigger transitions. Subnational food policies for instance are dealing with public food procurement, land access and land use planning, local contracts of payments for ecosystem services, Community Supported Agriculture, social support and food banks, advertising regulations, education and awareness raising, governance (food policy councils, multistakeholder platforms, participation and inclusiveness, transparencyn, evaluation), clusters for food system organisation / Innovation clusters for regional bioeconomy…

There is thus a very large potential of innovation in local and regional authorities' strategies for food system transition, that could be supported to ensure experiments or innovations can be upscaled or mainstreamed.

- **Research and innovation needs** :
    - *Analysis of synergies (and potential trade offs) between regional / local food policies and regional / local innovation clusters and policies*
    - *Support to regional / local innovation clusters that gather the diversity of relevant food system actors (civil society, consumers, farmers, SMEs and large industries, cooperatives, food retailers, food aid and social aid…)*

- **Long term objectives, gradual change policies and foresight dialogues** (Berkhout et al, 2007) – Because it is difficult to identify already now which of the niche-scale solutions could be the future large scale solution for sustainability, a central recommendation from the field of transition management is to ensure ambitious long term objectives are properly set (like the European Green Deal sets them with climate neutrality, zero pollution, or the protection of biodiversity), in order not to prescribe radical immediate change but favour the gradual exploration of alternative solutions.

  The problem emerging from different experiences of long term oriented, gradual change policies, is that gradual change might be too slow, or not disruptive enough, to really reach radically improved environmental performance even over a longer period of time, as can be exemplified from the field of non point source nitrates pollution in intensive livestock producing regions in different European countries. Or even worse, that change does not happen because alternative solutions remain niche for the long period of time that was initially foreseen to make change more acceptable and to mainstream alternative solutions. The case of the pesticides use reduction policy in France, decided in 2008 with the objective to halve pesticide use by 2018, is illustrative of such a failure, because pesticide use actually continues to increase, which is of course linked to the systemic nature of the lock-in.

  Lessons from these past examples enable to identify key necessary (albeit not necessarily sufficient) conditions for such long term policies to have an impact the environmental outcome. Both types of conditions imply the mobilisation of research and expertise :

- **Research, innovation and expertise needs** :
  - *continuous, transparent, independent and inclusive monitoring and evaluation of the distance to target is necessary to ensure that failure to change and adopt alternative solutions is recognised early enough and that lessons can be drawn to adjust the policy (instead of reducing the ambition of the objective !)*
  - *organisation of a permanent and inclusive conversation about ex ante assessments, as well as future scenarios and pathways of change (a permanent foresight dialogue) to ensure aspirations and expectations of different actors are able to align, favouring innovative solutions and innovative coalitions of actors to emerge.*

3. Changing major policies that have shaped the existing food system and its lock-in

All the aforementioned policy solutions are important building blocks of a transition pathway, but it is also very important to recognize that the current European food system has been shaped by an important set of policies, that are at the core of the European Union institutions, and that still explain numerous critical trends in the ongoing evolution of farms, diets and food industries.

In particular, the modernization of the agricultural systems with the CAP and the establishment of the common market with specific market organisation measures for the agricultural sector, export subsidies and finally direct payments have radically transformed European farms over the last decades, enabling a considerable increase in agricultural output and in farm productivity, but also leading to environmental degradations, despite the amount of policy instruments both within Pillar 2 of the CAP and the Environmental directives (Water, Habitat, Nitrates…). The CAP continues to be a major driver of change in the EU farming sector.

But it is also important to name the competition policy of the EU, the implementation of which has been guided by a general interpretation of competition in which a downward trend in prices to the end consumer is the sign of a well functioning market. Along with the CAP, the EU competition policy has contributed to giving access to cheap (but not necessarily nutritionally well balanced) food for all EU consumers, and it has also contributed to the concentration in the agrifood industry and retailing industry, while supply chain agreements and producers organisations to gain more negotiation power for the upstream players have on the contrary been very precisely scrutinized.

The trade policy of the Union has also led to structural changes in farming systems, as can be exemplified by the Kennedy Round trade deal, which led, in order to maintain the CAP, to the commitment to import soybean and has installed the soybean feed imports dependency of the EU's livestock industry, which can be considered a major factor of lock-in, as can be illustrated by the numerous failures to implement effective policies and strategies for a European protein autonomy.

The EU's health and safety as well as environmental regulations have also played a critical role , leading to a food industry whose traceability, safety and quality standards are considered very high on global markets. Some of the key policies described hereabove are also major driving factors behind trends in the EU food system that are opposing in many cases the three transitions described in the former chapters : economies of scale, massification and specialisation of production regions and systems, economic concentration…

In such a context, it appears that the transition policies described in the former section would be unable to unlock transition pathways if these major EU policies are not better aligned with the objectives of the transition. The Green Deal (and its Farm to Fork strategy) offers a key moment of for a change in these policies, which is why it is critical to assess what needs to be changed in these policies : their objectives and instruments, as well as their processes and institutions.

Nevertheless, these policies having been consubstantial to the establishment of the European Union itself, reforming these policies is particularly challenging, as they are entrenched in the structure of EU institutions and EU negotiation processes between member states, as can be illustrated by the negotiations on the reform of the CAP, entangled with the negotiations on the overall EU budget.

- **Can the CAP be reformed** ? - A large subsidy programme like the first pillar of the CAP has been considered by economists as impossible to reform (Swinnen, 2015; Petit, 2019). Subsidies schemes install configurations that make it difficult to radically change the policy and the conditions of attribution of subsidies, particularly given the share of the income of farmers that is coming from these subsidies. This is not uncommon as a general discourse in economics : there are vested interests installed by subsidies policies, who are politically powerful and have no interest to reduce their allocation of public subsidies. The structure of the intergovernmental negotiation within the EU framework and the role of the Council reinforce this : each country in the end, particularly if discussing potential cuts in the EU Budget, will favour the solutions that maximises how much of the EU money returns to them. This is presented as one of the key explaining factors why more ambitious greening mechanisms could not be decided in 2013, leading to an incapacity of the so called greening of the 1st pillar to improve environmental performance of the policy, as stated by the EU Court of auditors.

The very scope of the policy might even be a problem, as the transitions discussed in this report are about the whole food system. A thorough reform of the CAP should thus be envisioned, but is not for the moment on the EU agenda even for the next 7 year period.

In such a context, the capacity to reform the policy and to assess its inconsistencies with other objectives of the Green Deal and with other policies will be particularly crucial.

- **Research and innovation needs** :
  - In the current projected reform of the CAP, member states are given back much more responsibility and autonomy to design National Strategic Plans to use CAP funds. *The capacity of the Commission to avoid a race to the bottom in terms of sustainability ambition of those plans will rely on an independent capacity to assess the adequacy of those plans given the overall sustainability objectives of the EU, as stated in the Green Deal (climate neutrality, zero pollution, biodiversity protection), their coherence with other strategies and directives (climate, biodiversity, water, habitat, avoided imported deforestation,…), as well as to evaluate the implementation of these plans.*
  - *Analysis of the risk that the CAP remains a statu quo factor, and what are the rooms for manoeuvre in the current institutional context to reform the CAP*

- **Can the competition policy be mobilised for the transition ?** - Competition policy is at the heart of the European project, given the centrality of the Common market. Ambitious European environmental standards have been developed initially through a creative and audacious interpretation of the need for a level playing field for economic players in the common market, in the framework of a European Economic Community that had no mandate over environmental policies. More recently, the interpretation of the competition policy by the European institutions has been considered a blocking factor for the transition, when it forbids to reclaim more negotiation power to primary producers, in order for them to better negotiate their share of the value on food products, and thus

having more room for manoeuvre to transition.
The Green Deal constitutes a very good political window of opportunity to discuss the way the competition policy can be used as a trigger for transition, rather than an impediment to the "industrial policy" or the "structural transformation policy" that the Green Deal is presented to be at the scale of the whole continent. There is an ongoing debate between member states and among economic actors, about how this could be implemented : favouring EU scale champions in different sectors, or on the contrary ensuring innovative SMEs can challenge incumbents, which is particularly acute in the food system that is particularly made of a very large number of SMEs, despite the concentration trends in specific segments of the supply chain. This has given rise to important debates about supply chain organisation and the share of value and negotiating power along the chain.

- **Research and innovation needs :**
    - *Defining the Green Deal roadmap for the Food industry*
    - *Analysis of how to introduce sustainability objectives into the competition policy*
    - *Organisation of a pluralistic policy debate, within member states and at European scale, among diverging recommendations for the competition policy and its mobilisation for the Green deal in the food system*

- **How to mobilise the EU's trade policies for the transition** ? - Existing sustainability arrangements at the World Trade Organisation or in bilateral trade agreements, like Sustainability Impact Assessments or Sustainable development chapters, have a very limited capacity to influence the negotiation of trade agreements, and thus their effects for more or less sustainability in the field. There is currently a politically very active debate in some member states like France on integrating sustainability in bilateral trade negotiations. Some of the political proposals ask for an exploration of how trade agreements could be used as a lever for transformation. But this option seems for the moment very difficult to be negotiated, as the most open economies among member states (Netherlands, Denmark, Sweden, Germany…) are very cautious that such suggestions are not leading to reducing the possibility of a successful negotiation with third parties.
  There has also been a recent opening of a European scale debate on changes in the EU's trade policies through the mention of carbon border tax adjustment in the Green Deal.

There is for the moment no consensus on the optimal solution to mobilise bilateral trade negotiations as a lever for transitions, nor on the most negotiable solution.

- **Research and innovation needs**
  - *Analysis and comparison of different legal, technical and political scenarios to integrate sustainability in trade policy*
  - *Analysis and comparisons of different strategies mobilising norms and standards, both public and private, to raise the level of sustainability both in exporting and importing countries*
  - *Organisation of a pluralistic policy debate, within member states and at European scale, among different options for trade policies*

Other major driving forces behind the transformation of the food system, as illustrated by the three transitions discussed in the former chapters, would also need to be analysed, and in particular **financial sector regulations**.

- **Research and innovation needs**
  - *Analysis of the effects of financial sector regulations on the transitions in the food system, identification of major necessary policy developments in financial regulations*

4. The cognitive dimension of policy change : new knowledge and new ideas to make changes happen in policies and institutions

As appears from the former section centred on three major policies at the heart of the European institutions, different types of knowledge on and for policymaking can play a key role to change the policy landscape, at different steps in the policy development cycle : agenda setting, problem formulation, formulation of alternative policy options, comparison of the performance of options, choice of policy instruments, policy implementation, policy evaluation…

In particular, given the systemic nature of the transitions explored in the former chapters, and given the long term nature of the objectives set to the transition, three main types of knowledge for the policy cycle can and will play a critical role : assessments of coherence between policies, pulbic policy evaluations, as well as new ideas and new frames.

- **Policy Coherence** : Policy coherence, and in particular policy incoherence, can be one of the major rational arguments to question existing policies and reform them, when they are not aligned with the long term objectives set by the Green Deal or with other policies (health, environment, etc.). Nevertheless, as the example of Sustainability impact assessments of Trade agreements shows, even

when revealed by a rigorous assessment, policy incoherence is often not leading to change in the final decision, because in fine political arbitrages can play in favour of the statu quo, particularly when. The higher relative political importance of a specific issue (Agriculture and the CAP) or of the institutions that voice such a concern, compared to other issues or institutions (Environment, Health and Consumers), can explain that initiatives like the Hearings on a Sustainable Food Policy launched under the initiative of Environment Commissioner Potocnik in 2012, have not led to substantial policy proposals. Given the systemic nature of the food system transitions that is analysed in this report, in convergence with the Farm to Fork Strategy of the Green Deal, ensuring the coherence of the variety of policies that impact the food system is going to play a key role in adjusting the policies and put them at the service of the intended transition pathways.
Furthermore, the overarching nature of Green Deal objectives, as presented by the European Commission, opens an important workstream on assessing the coherence between all EU and member states policies and these objectives. The policy coherence between sustainability objectives and sectoral policies could thus have a more important role to play in the next years, given the recent insistence on SDGs reporting for all the Commissioners, in the mandate letters that the the President of the Commission has sent to them.

- **Research and innovation needs :**
    - *Methodologies and data infrastructure for policy coherence assessments between Green deal objectives, SDGs, and all other policies at EU and Member state levels*
    - *Organisation of an open policy debate, based on independent and inclusive policy coherence assessment*

- ***Ex post, in itinere*** **and** ***ex post*** **evaluation of policies** – The former sections have already revealed the importance of assessing *ex ante* the adequacy of policies and programmes with respect to attaining long term sustainability objectives that imply a radical transformation of our economies and societies. This type of ex ante evaluation can be illustrated by the necessity to question the sufficient ambition of a short term decisions (for instance investments in methane production from agricultural biomass in the next five years) with respect to the objectives of the Nationally Determined Contribution in 2030 (reducing the EU's greenhouse gases emissions by 45 / 55%), as well as with the 2050 objective to reach climate neutrality. This poses important methodological challenges in terms of time scale as well as concerning jurisdictional levels, which thus implies to inform a debate about effort sharing between member states, or between regions or sectors within a specific member state. Furthermore, once such policy objectives are set, there is a need to accompany, monitor an assess the transition pathway. In this regard, it is important to acknowledge that public policy efforts to make agriculture and food systems more sustainable, both on the social and environmental dimensions, are not new : environmental policies, for instance, have been developed already since the 1970ies, and diagnoses of structural and systemic sustainability policy problems have already been made in the 1980ies, for instance on the structural excess in the nitrogen cycle of livestock intensive regions. Past successes, but also importantly past failures, are important to inform current policies. Public policy evaluation can thus play a key role in informing current policymaking, and can also be considered a lever to change existing policies. As has been illustrated by successive reforms of the CAP, public policy evaluation in all its interdisciplinary ambition, is a necessary condition for changing a policy, even if it is often not sufficient to change the policy. Independent institutions like the European Court of Auditors or its equivalent bodies at member state level are the major players in this field, but an open, pluralistic and inclusive dialogue on policies also necessitates the participation of other research institutions and civil society organisations. Collective expertise processes by key research institutions are often a major contribution to policy change.

- **Research and innovation needs**
    - *Methodologies to assess ex ante the adequacy between short to mid term policy and programming decisions, mid term (2030) transition objectives, and long term sustainability goals (2050)*
    - *Methodologies and dialogue processes to assess ex ante the adequacy of objectives set for specific sub-sectors or jurisdictions with respect to an overall transition objective (at EU or member state level)*
    - *Analysing the conditions at which the subsidiarization of EU policies can both be a chance for transition policies emerging from local initiatives, and maintain an overall ambitious objective in terms of sustainability*
    - *Continuous inclusive and transparent dialogue on state of progress on a transition pathway, informed by a permanent dialogue on a plurality of future long term scenarios*
    - *Public policy evaluation methodologies and processes, involving research institutions at different stages, and particularly collective expertise processes*

- **New ideas to reframe policy problems and innovate in policy solutions** – One of the most critical roles of knowledge production for policy making is to produce new concepts and narratives, identify new public problems or new ways to frame a public problem, at the stage of agenda setting. This is illustrated by the idea to reframe the existing common agricultural policy into a common food policy, or to propose the bioeconomy concept instead of looking at agrifood chains. Concepts emerging in the academic or expert forum have a capacity to set new issues on the agenda, to open room for a new formulation of the policy problem, or of the space of solutions. There is nevertheless a risk that the space of possible policy solutions or instruments is actually restricted to standardised and recurrent policy instruments, whatever the public problem is : there is a path dependency in the forum of policy expertise, advising policy makers, and it is not sure that a disruptive framing of the sustainability problem in the food system will be followed by innovative policy solutions, that might still stay the same.
  Beyond this path dependency, it is also important to recognise that the field of ideas to influence policy framing and policy instruments is a strategic and competitive field : new concepts will be opposed or contradicted, re-digested. Narratives, concepts, framings and policy solutions needs to be considered as a living ecosystem, where competition between paradigms also matters, as well as dominance and asymmetries in resources for these different paradigms. The concept of bioeconomy is in this perspective a very good example, because it can be related to a variety of significations, all supported by different schools of thought and different coalitions of private and public players.
  In the field of scenarios and foresights, as the various existing foresight exercises analysed for this report have shown, the dialogue between different visions of the future is as much about competition as about coordination : emerging alternative scenarios, counter-scenarios, often struggle to obtain as much political and media attention as mainstream visions.
  In such a context, a public research policy should intend to nurture pluralism in ideas, narratives, scenarios and concepts that can feed the policy debate, which can mean ensuring support for critical social science research, that intends to reveal underlying narratives and framings and point at implicit contradictions and the necessity to explore alternative narratives and visions. It also means ensuring that policy dialogues are inclusive and participatory not only in the sense of making sure that all major actors are represented, but that there is a pluralism of worldviews, narratives and scenarios, which necessiates a specific structure and organisation.
    - **Research and innovation needs** :

- *Support to critical viewpoints in all disciplines to reveal underlying narratives and framings*
- *Support to the emergence of new ideas, scenarios and framings in research*
- *Encourageing pluralism in ideas feeding the policy debate, organisation of a policy debate that ensures pluralism*

5. Conclusion – a policy mix to trigger the three transitions, aligning existing and developing new policies

Based on the former sections, the role of policies in transition pathways is therefore crucial, but there is not one specific transition policy, but rather a whole systemic policy mix that is needed to make change happen in all dimensions of the food system : this policy mix needs to be developed with a view on systemic coherence, as well as specifically targeting the need the not only develop new policies but also tackle the blocking effects of existing policies, that can drive the food system in the direction opposed to the intended transitions.

Currently, the main policies targeted when thinking about food system transitions are agricultural policies (taxes and subsidies, fiscal policies, access to resources like land or capital, labour regulations, public extension services, public research, environmental regulations..), consumer oriented policies (taxes on products, information to consumer and labels, education, awareness raising, advertising regulation, social aid and social cohesion, access to nutritious food and access to choice, collective catering and public procurement…), but also importantly food industry and retailing regulations and policies (taxes, information, transparency, traceability, norms and standards, contracts, competition regulation, responsible innovation…),. But it is also important to redefine the scope and boundaries between different policies, to include for instance innovation policy, health and environmental policies, financial regulations, as well as national, regional and local level policies.

It is beyond the scope of this report to develop the whole policy mix for the three transitions at all scales of governance, but the following grid could be useful for policymakers to identify the policy changes that are needed in their specific situation :

Policy Scope	**Transition 1 - Circularity**		**Transition 2 – Diversity**		**Transition 3 – Healthy diets**	
	Blocking policies that need to be	New policies to be	Blocking policies that need to be	New policies to be	Blocking policies that need to be	New policies to be

	realigned	developed	realigned	developed	realigned	developed
Food system policies						
Agricultural policies						
Consumer oriented policies						
Supply chain policies						
Innovation policies						
Other driving policies						
Competition policies						
Trade policies						
Financial regulations						
Other major policies ? (health, environment,…)						

To feed such a policy development process at different scales of governance, this chapter has identified **a list of reseach needs** dedicated to feeding inclusive and transparent policy dialogues, as well as a list of **science policy interfaces**, that will be necessary in order for an independent evaluation and assessment capacity to contribute to such policy dialogues.

Beyond the general notion of a mission oriented approach to research, this chapter also insists on the necessity to **acknowledge the competition and the asymmetries existing between different paradigms and solutions pathways**, that leads not only to **be very clear about the long term objectives** that are at the heart of the mission oriented approach, but also to **organise and actively support pluralism in the exploration of potential pathways** for transition.

References

Alkemade, F., Hekkert, M. P., Negro, S. O., (2011) Transition policy and innovation policy: Friends or foes?, Environmental Innovation and Societal Transitions, Volume 1, Issue 1, Pages 125-129, ISSN 2210-4224, http://dx.doi.org/10.1016/j.eist.2011.04.009.

Berkhout, F., Smith, A., Stirling, A., 2004. Socio-technological regimes and transition contexts. In: Elzen, B., Geels, F.W., Green, K. (Eds.), System Innovation and the Transition to Sustainability: Theory, Evidence and Policy. Edward Elgar, Cheltenham, pp. 48–75.

Geels, F. W., & Schot, J. (2007). Typology of sociotechnical transition pathways. Research policy, 36(3), 399-417.

Loorbach, D., Van Der Brugge, R., & Taanman, M. (2008). Governance in the energy transition: Practice of transition management in the Netherlands. International Journal of Environmental Technology and Management, 9(2), 294-315.

Mathijs E., (2012) : Transition to a sustanaible agrofood system in Flanders: a system analysis http://lv.vlaanderen.be/nlapps/docs/default.asp?id=3127

Petit, M., (2019) Another Reform of the Common Agricultural Policy: What to Expect, EuroChoices, Volume18, Issue1, April 2019, Pages 34-39, https://doi.org/10.1111/1746-692X.12221

Rotmans, J. René Kemp, R., Marjolein Van Asselt, M., (2001) "More evolution than revolution: transition management in public policy", foresight, Vol. 3 Iss: 1, pp.15 – 31

Swinnen, J., (2015). *The Political Economy of the 2014-2020 Common Agricultural Policy: An Imperfect Storm*, Rowman & Littlefield, 9781783484843. ⟨hal-01590525⟩

Van der Laak, W. W. M., Raven, R. P. J. M., & Verbong, G. P. J. (2007). Strategic niche management for biofuels: Analysing past experiments for developing new biofuel policies. Energy Policy, 35(6), 3213-3225.

FACTS AND FIGURES REPORT – SCAR COLLABORATIVE WORKING GROUP ON ANIMAL HEALTH AND WELFARE RESEARCH

1. Presentation of CWG Animal Health and Welfare Research

The SCAR Collaborative Working Group (CWG) on Animal Health and Welfare Research (AHW), a forum of research funders and programme owners/managers with the objective of improved collaboration on research prioritisation and procurement, creates the necessary critical mass and focus to propose, coordinate and deliver the animal health and welfare research needed by the European policy makers and livestock industry. Furthermore, the CWG AHW currently forms the European regional network of the International Research Consortium of research funders and programme owners, aiming to coordinate animal health research globally (STAR-IDAZ IRC). The CWG consists of 46 partners from 24 countries, not only EU member states but also associated countries and neighbouring third countries.

2. Domain covered by the working group

The actors within the CWG AHW are research funders, programme owners/managers, Commission services, risk managers, livestock industry, and pharmaceutical industry.

Its activities include:

- animal health and welfare research (emerging and major infectious diseases, production diseases, welfare of production animals and pets, research capacity and capability including infrastructural aspects, policy supporting research and research targeted at supporting food and veterinary authorities, fish and bees, zoonoses, and drug resistance, but excluding food safety issues relating to the handling of livestock products and diseases of wildlife, except where wildlife acts as a reservoir of infection for humans or production animals)
- supporting the inter-sector, one-health approach of outbreak preparedness and management
- information flow (meetings, correspondence, website, databases)
- strategic research agenda (SRA), regularly updated
- so far 3 ERA-NETs initiated (EMIDA, ANIHWA, ICRAD)
- so far 75 million EUR of jointly funded research, more to come

- rapid response to emerging crises thanks to the active network (funders, programme owners and managers, industry)
- global impact via STAR-IDAZ IRC
- any EU networking tools which help achieving our aims, including increased collaboration with other WGs
- reflection papers on new challenges.

3. Main facts, figures and trends regarding the domain covered by the working group

SDG 2 – Zero hunger (Food security)

SDG 3 – Good health and well-being (Food safety)

SDG9 – Industry, innovation and infrastructure

SDG 12 – Responsible consumption and production

SDG 15 – Life on land

SDG17 – Partnership for the Goals

The global human population is predicted to increase to 9.6 billion by 2050, and this population will be increasingly urbanised. In general, urban populations are wealthier than rural ones, and demand greater amounts of animal proteins compared to other food products. This increasing demand on global food systems and more specifically livestock food systems are being met by a shift toward intensive livestock production systems relying on diets of concentrated feed, indoor housing and use of highly specialised animal breeds. These are kept in high-density farms, clustered in areas with access to transport and processing systems. On the other hand, there is an increased consumer demand (in Europe and internationally) for animal products based on organic farming in full respect of agroecology or originating from animals kept with more respect of animal welfare. A proportion of these animals are housed indoors with lower stocking densities or in group housing systems and with more attention to the needs of the animals to express their natural behaviour (for instance access to investigation materials). Others are housed outdoors or with access to outdoor facilities or pastures for grazing

At the same time the disease threats to the livestock industry have increased steadily over the past decades due to globalisation and trade, increased farming intensification with changed husbandry and management structure, environmental changes/changes in the weather conditions and changes in wildlife management. These factors contribute to a higher risk of spread and evolution of pathogens to humans as well (zoonotic potential, need for a One Health approach) and pose additional threats to animal welfare.

The World Organisation of Animal Health (OIE) estimates that morbidity and mortality due to animal diseases cause the loss of at least 20% of livestock production globally. This represents at least 60 million tonnes of meat and 150 million tonnes of milk with an estimated value of approximately $300 billion per year. Some examples:

- African swine fever (ASF) has been spreading steadily in Eastern Europe since its introduction into Georgia in June 2007 and reached Belgium in 2018. More recently positive cases were also found in Serbia. China and a large part of South-East Asia are at this point affected (OIE and FAO). ASF has a serious economic impact on the livestock industry, having caused already the loss of millions of animals in Asia alone.
- A very severe outbreak of FMD occurred in the UK during 2001 costing in excess of £3 billion with 6.5 million animals slaughtered.
- Varroosis is a major factor in honeybee mortality, putting at risk insect pollinated crops which are estimated to provide approximately one third of human food, and in Europe about 80% of this pollination is provided by the European honeybee.

Zoonotic diseases are very common around the world, and scientists estimate that more than 60% of the known infectious diseases in people originate from animals, and 75% of new or emerging infectious diseases in people are spread from animals. Zoonotic spill over into human populations can occur by direct contact between people and pathogen-carrying animals or, for example, through the consumption of infected wildlife or livestock products, and through the environment.

- The poultry and pig industry for example have had to contend with numerous influenza outbreaks and, since 1900, there have been 5 influenza pandemics that have killed millions of people. Over the past decade, a range of (zoonotic) influenza virus outbreaks have been reported, with 1567 confirmed human cases and 615 deaths since February 2013 (FAO).
- BSE reached epidemic proportions in the 1990s, requiring more than four million cattle to be culled.
- Antimicrobial resistance (AMR), which may be transferred between animals, humans, and the environment, continues to be a major challenge.

For these reasons, an integrative and harmonized cross-sector interaction (One Health), including the environment (wildlife, arthropod vectors, environmental contamination etc.) is essential to propose efficient solutions.

4. Analysis of the main emerging issues in the domain covered by the working group

SDG 2 – Zero hunger (Food security)

SDG 3 – Good health and well-being (Food safety)

SDG9 – Industry, innovation and infrastructure

SDG 12 – Responsible consumption and production

SDG 15 – Life on land

SDG17 – Partnership for the Goals

The CWG AHW's activities have included work on emerging diseases since its inception in 2005. The EMIDA and ANIHWA ERA-NETs funded joint research *e.g.* on bovine tuberculosis, brucellosis, and vector-borne diseases (including bluetongue and Rift Valley fever). Emerging issues were also addressed in the fields of fish health (*e.g.* molecular tracing of viral pathogens in aquaculture and control of Flavobacteriaceae infections in European fish farms), AMR (*e.g.* prevalence and optimised detection of resistance to antibiotics for animal and human health and evaluation of alternative strategies for raising pigs with minimal antimicrobial usage). Specific CWG AHW's activities also targeted animal welfare, which was one of the topics covered by the ANIHWA ERA-NET, during which several projects were funded on critical animal welfare issues (*e.g.* tail docking in pigs and food pad dermatitis in poultry).

A SRA was drafted and kept updated, the most recent version at this point being the CASA report "EU Animal Health Strategic Research Agenda: 2017 update". This updated SRA allows the CWG AHW activities to specifically target the most urgent topics, all the while taking into account recent developments. Three fields of activity are addressed in the CASA report:

(a) structural and political aspects,

(b) technology, and

(c) animal health-specific topics.

The descriptions of the "very high priority" topics are shown below. For more detailed information we are referring to the CASA report (https://www.scar-cwg-ahw.org/wp-content/uploads/2018/05/Final-Report-CWG-AHW-CASA_updated-EU-AH-SRA.pdf).

Priority:	a) **Structural political topics**
Very high	• Partnerships/collaborations – global/regional research alliances – sharing information between countries • One health approach • Maintenance of capacity – research capacity; diagnostic capacity; surveillance, including field professionals • Knowledge/technology transfer – to end-users (vets, farmers, pharmaceutical industry); Public Private Partnerships • Integrated surveillance system/ centralised diagnostic testing – risk-based approach to surveillance - better surveillance of domestic and wild animals - use of farmers for frontline for disease detection – precision livestock farming

Priority:	**b) Technological**
Very high	• Easy to use field diagnostic technology • Vaccine development/new genetically engineered vaccines – immunology - predictive biology- reverse genetics – synthetic biology • Diagnostic tests - Express methods - routine deep sequencing methods - Real time PCR • Big data – bioinformatics • Surveillance - Syndromic surveillance - precision livestock farming (PLF)/automated disease surveillance; risk-based approach to surveillance

Priority	b) **AH specific topics**
Very high	• Antibiotic effectiveness and availability -better use of antibiotics; alternatives to antibiotics - Host resistance; vaccine development/ vaccinology, including HPI; biosecurity/management, antimicrobial peptides, immunomodulators • Improved understanding of the role of wildlife - epidemiological studies on wildlife - livestock interaction and disease spread • Disease introductions, including trans-boundary animal diseases -generic detection platforms, risk pathway identification, traceability of animals and their products, technology for inactivation of pathogens • Vector-borne diseases - emergency preparedness -alternative methods to control vectors – a) Integrated pest management, b) biological control and c) genetic modification

Since there is an increasingly wide gap between research and industry science as well as a lack of agreed Strategic Research Agendas in the field of animal welfare science, we perceived a need for an additional gap analysis, in order to be able to provide guidance to research funders for the identification of research priorities in animal welfare, and to better align priorities among the different public and private stakeholders, including industry. In 2017, the CWG AHW therefore implemented, a gap analysis on welfare research in livestock (https://www.scar-cwg-ahw.org/wp-content/uploads/2017/07/Gap-analysis-on-Animal-Welfare-research.pdf) and in 2018, in collaboration with SCAR Fish, on fish (https://scar-europe.org/images/FISH/Documents/Report_CWG-AHW_CASA_FISH-welfare.pdf).

5. Contribution of the working group to the three transitions

5.1 Target 1: Healthy and sustainable food for all

European livestock farming has an important role in European and global food and nutrition security (SDGs 2, 3, 9, 12, 15, 17). It contributes to securing the provision of protein-rich (including essential amino acids), safe and healthy food for European citizens while responding to diversifying demands and avoiding deficiencies in micro-nutrients. Managing animal health is the fundamental basis/prerequisite of safe food, as well as an important factor in securing animal welfare. The industry is key as provider of vaccines, drugs, and diagnostics, helping to safeguard animal health and welfare.

The animal health sector also plays an important role in controlling diseases in the human population due to the fact that more than 6 out of 10 known infectious diseases in people are inherently zoonotic. The One-Health approach has been appreciated in veterinary medicine for decades, but its applicability remains difficult. To overcome the difficulties of collaboration with the human medicine sector, a bottom-up approach would be preferable.

European production standards are high: the high-quality food markets are comprehensive of food safety, traceability, ethical and societal principles such as animal welfare, healthiness and the control on environmental impact. As such, increasing attention goes to animal welfare but also to good farming practices, which contributes to the reduction of chemicals and pharmaceuticals used in livestock production, and contributes to coping with AMR.

The regularly updated SRA (see above) underpins the CWG AHW's activities in terms of first addressing the most urgent needs and taking into account recent developments.

5.2 Target 2: Safe and just circularity of food systems

Circularity is the way forward for food systems. However, in the veterinary field, when addressing the opportunities for food system circularity, risk assessment is of extreme importance. Information already available needs to be taken into account and completed by research on potential circularization effects that are so far unknown or unquantified, including risk analysis and risk management/biosecurity, thus producing evidence for warranted legislation on food systems circularity. Some examples of risks caused by circularization are ASF, BSE, tapeworm, concentration of pathogenic entities and toxin enrichment. Indeed, some of the most essential progress in animal and human health has been made through the cutting of risk pathways: for instance, we already know that same-species bone meal must be avoided in animal feed, that no kitchen refuse ought to be fed to animals, and that no human faecal material should be used as fertiliser. Moreover, the potential impacts of the circularity approach on animal welfare need to be taken into account.

5.3 Target 3: Substantial increase of biological, social, and economic diversity

Livestock are a key component of the vitality of many European territories (SDG 15) including a wide diversity of production systems. It contributes to the local economy and supports the different local conditions and available resources within a territory.

The sector has the ability to move towards much more diverse systems that may combine with agro-ecological strategies relying on local solutions. The diversity of production systems gives resilience to the entire European production sector and may satisfy a wide range of consumer demands: intensive systems, low input/extensive systems and organic systems are able to offer different products, face different challenges and require different adaptations.

At the same time, the diverse genetic pool of the different available breeds may be key to the control of pathogens: parasites (*e.g.* varroosis, mange), viruses (e.g. Newcastle disease, infectious bursal disease) and bacteria (*e.g. Salmonella pullorum*, *Brucella suis*), thus at the same time aiding in the control of resistance of pathogens against pharmaceuticals.

6. Policies for the achievement of the targets

Research and innovation (R&I) have contributed to the growth of the livestock sector, also with respect to AHW, and in making it competitive and efficient. However, continued and harmonized support of research and innovation is needed to face the challenges caused by new developments and new consumer trends and demands, including new legislation (*e.g.* the animal health law in 2016) and public requirements for higher standards of animal welfare. Furthermore, it is essential to support the implementation of innovations in the farming systems themselves. In order to keep up with societal needs, the AHW sector requires coordinated and integrated interdisciplinary research, a proactive attitude for identifying future needs, and an effective translation of needs into action, research funding and policy making. Strengthening collaborative activities will help avoiding gaps and overlaps/duplication of work, ensuring synergies and facilitating the build-up of a common, efficient strategy for AHW. Several tools are used in this respect, *e.g.* ERA-NETs (EMIDA, ANIHWA, ICRAD), CSA (CASA), and intra-SCAR activities allowing to create synergies with other WGs.

7. Challenges for research

The CWG AHW SRA has to be regularly updated in view of the changing drivers of AHW research needs, and the research gaps have to be identified and addressed with an approach encompassing the research community, industry and the different governmental levels. The updates of the SRA must include structural/political, technological, and specific topics.

STAR-IDAZ recommended conducting an animal health foresight study every five years and formal SRA reviews on a biennial basis. CWG AHW performed an update with the support of CASA CSA that yielded the report "EU Animal Health Strategic Research Agenda: 2017 update" in 2018 (see §4. for the link to the report).

In 2017, the CWG AHW also performed a gap analysis for animal welfare and in 2018, in collaboration with SCAR SWG Fish, on fish welfare (see §4. for the links to both reports). At the moment of drafting this document, the CWG AHW is looking into ways to take part of the planned EU Partnerships under Horizon Europe.

Structural and political infrastructures are essential for creating an enabling environment for research activities. R&I is fundamental to making the European livestock sector more efficient. The high performance expected by the livestock industry, as well as consumer expectations require coordination of actions and continued support from the research sector. In order to ensure synergies and avoid gaps, overlaps and duplication of research, it is essential to enable appropriate alignment and coordination of research activities. *Super partes* leading organisations, such as the OIE, might play an instrumental role in improving international coordination. Through implementation of international networks and additional research, network services could be enabled, complementing those currently offered or planned by single member states research, avoiding duplication of research or funding. Networking contributes to the exchange and combination of information which is a prerequisite for successful research innovation aiming to provide the necessary flexibility to adapt to the wide spectrum of arising challenges. This enables shared learning and new research opportunities, and generates new research projects, joint applications for funds, and technology transfer.

Establishment of international network connections should be independent from the availability of funding, and mechanisms should be created to allocate resources to sustain such networks and their activities.

The key actions advised in order to ensure effective <u>prevention, detection and response to animal health diseases</u>, according to previous results, are:

- to favour the delivery of fast and reliable diagnostics, easy to use in the field;
- to optimise vaccinology, addressing studies on DIVA, new adjuvants, host/pathogen interaction, and technological advances with potential to make vaccine development economically viable;
- to empower basic research and increase sharing of information;
- to establish a science-driven response to disease outbreaks (especially vector-borne ones);

- to engage in preparedness by risk-based surveillance;
- to strengthen knowledge/technology transfer;
- to favour networking among countries;
- to establish biosecurity measures and consider animal welfare as tools for healthy and sustainable production
- to empower research on optimization of management in order to ensure healthy and robust animals.

Furthermore, in the CWG AHW SRA update the following key actions were considered to be of major importance, more than in the previous version of its SRA:

- to encourage public-private partnership, ensuring return on investment to companies developing new animal health products;
- to develop standards for data collection/sharing, fundamental for big data integration;
- to improve integrated surveillance systems and encourage their acceptance;
- to facilitate precision livestock farming;
- to strengthen the One-Health approach;
- to favour econometric studies to demonstrate positive impacts of investing money in research and thus limit cuts to research budgets.

The CWG AHW SRA creates a shared vision toward the animal health future that is in line with the principles of bioeconomy and the Food2030 policy framework, and enables its users to achieve shared objectives and reach common goals and results.

For livestock welfare, some key research gaps and needs were identified by the animal welfare gap analysis of 2017. Among which:

- the development and implementation of automatic data recording systems for animal-based measures;
- to further develop gas mixtures for stunning that would reduce suffering for pigs and poultry at slaughter;
- to analyse causes of cattle lameness and development of an automated locomotion scoring technology;
- to investigate causes of footpad lesions and how to prevent them in broiler chickens, as well as the relationship between footpad lesions and pain;
- to develop better methods for handling poultry during catching and transportation.

Research priorities were also identified by the gap analysis on fish welfare research, and include:

- to define reliable fish welfare indicators;
- to develop fish handling strategies to reduce fish stress, especially before vaccination, at transport, and pre-slaughter;

- to investigate the relationship between stunning and flesh quality, as well as less stressful stunning techniques.

Sources:

- ATF Vision Paper 2019
- Italian Decree Ministry of Health of December 7, 2017
- CWG AHW SRA Update 2018
- ICRAD proposal
- SCAR CWG AHW presentation February 12, 2019
- SCAR CWG AHW banner text
- EU Animal Health Strategic Research Agenda: 2017 update – CASA
- SFU subgroup Bioeconomy/Food2030 Vienna 15-16/7/2019
- SCAR CWG AHW Gap analysis on Animal Welfare research
- SCAR Fish and CWG AHW Strengthening fish welfare research through a gap analysis study
- SCAR 5th Foresight Workshop October 7th, 2019 : presentations and discussions.

FACTS AND FIGURES REPORT – SCAR COLLABORATIVE WORKING GROUP ON SUSTAINABLE ANIMAL PRODUCTION

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1. Presentation of the SCAR-CWG on Sustainable Animal Production (CWG-SAP)

The Collaborative Working Group on Sustainable Animal Production (CWG-SAP) defined Sustainable Animal Production (SAP) as "economically viable, socially acceptable, with minimal impact on the environment" ("p-approach": people, planet, profit). The mission of the CWG-SAP is to provide advice on the coordination of research and innovation for the development of more sustainable animal production systems in Europe to Member States, Associated Countries and to the European Commission. The Group has met 11 times since the kick-off in 2014, having achieved CWG-SAP country reports, ERA-NET Cofund "SusAn", Work on a common vision for sustainable animal production in Europe, Representation of the Animal Producing concerns and to help policy maker by supporting research and innovation in this domain and Action as a "Think tank" in long term perspective The CWG-SAP has a new mandate approved by SCAR for the time 2019-2021. The three main objectives for this new period are:

- Facilitate and stimulate collaboration and networking within the livestock sector
- Build an evidence-based shared perspective and common vision for the development of a more sustainable animal production in Europe

- Support investment in research and innovation by avoiding overlaps and optimizing resource investment (e.g. supporting common cross-border research).

2. Domain covered by CWG-SAP

In Europe, there are other very relevant species such as laying hens, broilers and bees; the latest animal censuses of bovine stand at a total of 89.000.000 animals, 147.000.000 pigs, 87.000.000 sheep and 12.000.000 goats and there are also other “minor species”. Sectorial aspects for SAP systems are identified such as feeding, reproduction, genetics, husbandry, health and welfare, and horizontal aspects like resource efficiency, GHG emissions, environmental and water footprint, waste management and data recording. The interaction between animal production and society is crucial. Therefore the domain of the CWG-SAP includes actors within the primary sector (farmers, advisors, producers, Producers Associations, farm technicians, veterinarians, advisors, food and feed Industry), but also policy makers, consumers associations, research actors and communicators.

CWG-SAP does not cover aquaculture and fisheries as independent initiatives and working groups exist within these areas.

3. Main facts, figures and trends regarding SAP in relation to SDGs and PBs

SAP is from a European point of view a part of the solution of different Sustainable Development Goals (SDGs). SDGs can be affected by livestock production directly and indirectly as outlined below:

Directly**: Goal 13: Climate Action**. Reduction of GHG emission is a key CWG SAP issue. At the same time, the focus is on particle emissions. **Goal 12: Responsible Production and Consumption.** Specific topics in the CWG SAP work directly related to this SDG are animal production without antimicrobials to combat antimicrobial resistance and responsible production with minimal resource use and environmental impact adapted to local situations; **Goal 3: Good health and well being.** Livestock products ensure a healthy life promoting well-being at all ages, and are essential for children's development, pregnant women and the elderly; finally, **Goal 2: Zero Hunger.** The food and agriculture sector offers key solutions for development, and is central for hunger and poverty eradication. SAP will contribute to solve this important SDG, fighting undernutrition and strengthening resilience of the systems

SDGs indirectly affected/supported by SAP; **Goal 6: Ensure availability and sustainable management of water and sanitation for all**. AP challenges water use and quality, but SAP will be also a part of the solution, contributing to cleaner water with reduction of N (less N in feed and mineral fertilizer) use, appropriate manure management and optimizing use of grasslands; **Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all** (With livestock being a part of a circular agriculture, AP will also be a source of energy); **Goal 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.** The EU promotes high standards for working conditions internationally. Farming including sustainable livestock production is key to an adequate and dignified work, mainly in rural areas and **Goal 15: Life on Land** (AP will support life and employment in rural areas).

4. Analysis of the main emerging issues in the SAP

Main emerging issues are maximal reduction of GHG emissions; improved Animal Welfare; Reduced Antimicrobials use (concrete figures different at each country); 100% traceability of the products.

Long-term issues of the CWG-SAP are to strengthen the multidisciplinary approach, the open innovation and the inclusion of the economic and social issues into our agraricultural research, in order to explore the two ways and global interactions between farms and environment, and farms and society. The development of the innovation and appropriately used technique, based on the evidence, will enhance its sustainability. The societal acceptance of the AP systems is indispensable for their sustainability. For this, transparency, fair communication and education in both sides (producers and consumers) is required. Finally, setting the conditions and building guidelines for a Sustainable Animal Production in Europe is the aim of our Group, boosting the positive impacts of SAP, observing SAP as part of the solution.

5. Contribution of the CWG-SAP to the three transitions

Target 1: Healthy and sustainable food for all

Relevance of SAP: Sustainability of the available food for all should be also brought through a Sustainable Animal Production. Livestock has a high potential to contribute to it, also through the sustainability of territories through the supply of agro-ecological, social and economic services.

The influence on climate change related to AP is a main issue. Healthier animal products can be produced directly from improved AP systems, implementing new knowledge.

How can SAP contribute to the transition? Awareness of the effects on the Climate Change; Supporting and promoting research on how to move to the transition to sustainable environments compatible with Animal Production; Identifying the resistance to change at farm, food chain and regional levels; Improving communication and information on SAP to the Society; Influencing (based on scientific evidences) policies, developing regional approaches; Cooperation among actors (farmers, food industry, value-chains, local authorities, NGOs, policy makers) to design SAP systems. **(Quantified) targets that should be set.** Quantifying is a challenge. We aim at 100% of sustainable AP-systems through maximal reduction of GHG emissions / improved Animal Welfare / Reduced Antimicrobials use / 100% traceability of products / improved safety of animal food products.

- Holistic approach: Questions must tackle local, regional, national and international levels, to identify how different models of livestock and food systems can co-exist, and how interactions can give adaptive and innovative properties to farms to sustainably satisfy global demand.
- Climate change effects: reduced impact
- Promoting effective transfer of knowledge. Helping farmers accept and adapt to change.
- Including social sciences when approaching SAP issues.
- Impact assessment of effects of a restructuration of AP-systems to minimize negative effects.
- Livestock systems adapted to specific environments providing system's resilience as a whole. Integrated management and animal health and welfare
- Linking plant and AP; use of by-products; manure as organic fertilizer; Alternative feed strategies reducing or reliance on soybean.
- Improved information to consumers on SAP, environmental impact and product safety: enhanced traceability and constructive dialogue with society.
- Accomplishing the WHO global plan against antimicrobial resistance (AMR) which requires European farmers to meet tight restrictions for a strong reduction on the use of antimicrobials.

Main barriers to transition

- Ineffective transfer of the existent knowledge in the field
- Complex structure; high Euroepan heterogeneity: diverse solutions for sustainability
- Uncertainty (due to the speed of changing situations; due to global changes) inducing reluctance by producers and food chain actors
- Scarcities on scientific knowledge: no sustainability markers/indicators
- Mistrust among Animal Producers, Society and Policy makers.

- Time pressure. It can precipitate us to wrong decisions with huge negative consequences

Main technological game changers contributing to the transition

- Digital technologies to provide tools for continuous, automated, real-time individual monitoring of data related to production, health and welfare as well as to environmental parameters. Connect data to biological knowledge to develop new concepts for husbandry, processing and marketing.
- Other game changers: Fluctuating economic situations which can unbalance the market; Policies which distributes the properties differently

Main actors contributing to the transition. No benchmarking of relevance intended

- Policy makers / Scientists / Research funding bodies
- Farmers and farmers' associations, Feed Industry. Farmers' best practices should be mean goal.
- Food Industry / Retailers /Multinational companies. Fair and transparent information on traceability given to consumers (quality labelling). Sharing costs.
- Consumers and NGOs. Sharing responsibility (even costs).

Risks related to game changers

- Inadequate adaptation of farmers to changes: societal negative consequences, specifically in the rural areas (desertion, economical depression of these areas)
- If not successfully reached SAP: shortage of Animal Products
- Inappropriate use of information related to AP and Stigma to producers as villains
- Fluctuating economic situations which unbalance the market and the distribution of properties

Target 2: Safe and just circularity of food systems

"Nothing is lost, but everything is transformed and adds value to a more efficient agriculture". The "classical" approach in livestock observing "just" animal production and efficiency has increased production gains but without considering the used resources, linking AP to degradation of ecosystems and subtracting legitimacy of AP. We need a change in paradigm.

Appropriate sub-targets. General target is the change of paradigm approach: rethinking place and role of livestock, its performance and its link to soil fertility.

Sub targets:

- New organization of food chain and new value chains
- Value of byproducts (beyond food) for the soil quality. Increasing bio-energy. Mitigation measures to reduce GHG emissions by ruminants (consideration GHG types) and its circularity
- Efficiency of SAP expressed in animal protein kg/ edible plant protein kg used as feed
- Assessment of the capacity of AP to divers rotations reducing pesticides and fostering soil quality
- Research on best types of SAP adapted to environments (grasslands, animal species, production aptitudes, different levels of intensification in systems)
- Contributing to the *4 per 1000 initiative* via carbon storage under grasslands , using agro- forestry in livestock farming and forest soils
- Strengthening the adaptive capacities of SAP to climate change, price volatility and urban land use pressure.
- Microbiota knowledge and impacts regarding SAP
- Metabolism of agro-ecosystems with animals

Main barriers to the transition pathways related to the domain.

- Controversies about production models and consumers and market's demands
- Uncertainty: assessment of impacts and services
- Management of transition, role of Public policies
- New economic and organizational pathways for new and diversified value chains
- Attractiveness of jobs; decrease in rural society

Main carriers (supporters) to the transition. Policy makers / Research funding bodies / Industry (food chain) and Multinational companies / Farmers and farmers' associations /Consumers and NGOs

Main technological game changers contributing to the transition

- Genomics + phenotyping. Early programming and their links with epigenetic marks
- Neuro-science studies to elucidate mechanisms that govern animal emotions
- Animal microbiome functionalities and microbiota interactions along the food chain
- Innovative technological processes (manure management, waste products)
- Digital technologies

Risks or negative impacts

- Unilateral (not global) productivity goals in the Production systems / Lineal approaches, with wrong efficiency objectives of production
- Insufficient impact assessment: Animal Production induces several impacts

(positive and negative) in the environment. When unbalanced reduced / change, the global impact could be negative globally (loss of biodiversity, biomass…)

- Costs of complexity of the introduction of change of the systems
- Stigma to producers as still the villains of the drama.

Main actors: same as in previous target 5.1.

Why is it so difficult to close the loop (or better spiral)? Lack of integrated, global knowledge; of objective, measurable targets; different situations in European regions, with very different solutions of SAP and different levels of biocircularity.

Target 3: Substantial increase of biological, social, and economic diversity

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) released the "Global Assessment Report on Biodiversity and Ecosystem Services" in Paris, 2019. The report points at deteriorating of biodiversity worldwide. Sustainable livestock production can be part of a system that support biodiversity taking into account securing and balancing food security, climate mitigation and biodiversity.

How can SAP contribute to a transition / sub-targets?

Farming systems have separately and in different ways the potential to support preservation of biodiversity:

- Organic livestock farming with no use of pesticides
- Extensive farming supporting ecosystem services
- Agro-ecological farming including circularity
- Conventional livestock farming leaving land for biodiversity

The many and different livestock species and breeds required in animal production, make SAP a source of agro-biodiversity including high yielding breed as well as local breeds and genetic resource breeds adapted to local/regional conditions.

<u>Sub-targets in biodiversity:</u>

Keeping the range of different breeds broad within SAP

Breeding goals including adaptation of traits to the different farming systems also considering Genome editing

New feed sources based on e.g. insects and algae saving land use

Digitization in agriculture on large as well as small farms for improved monitoring and recording <u>Sub-targets in economic diversity:</u>

Different and new business models Impact of new technology Rethinking subsidies

Sub-targets in social diversity:

Diversification of animal products from the different SAP-systems to different demands from different consumers:

- Consumers in the country side and in big cities
- Young and older consumers
- Wealthy and less well-off consumers
- Responsible consumption
- Behavioral transition

Animal production systems, i.e. traditional production and traditional products vs. conventional production triggers also social diversity in agrarian areas and in consumers, consumer's behavior and final consumption. Maintenance of sustainable animal production systems supports the retention of rural communities with a diversity, depending on the type of animal production associated with it.

Main barriers to a transition. Small farmers' skills with regard to new technologies are limited and in these cases new technologies are therefore more difficult to implement.

Consumers' willingness/ability to pay for support of biodiversity/eco-system services Reluctance of actors in the whole food chain to share responsibility and costs

Linear approach with fixed productive objectives in the animal production systems The speed of changes and challenges in predicting the impact of initiatives launched

Limited attractiveness of jobs in the animal production systems offering diversity: social reluctance. Cost and complexity of transition

Main carriers (supporters) to a transition. A holistic approach to the implementing of new values in the livestock production, which is achieved based on positive effects of certain systems / species

/ breeds.

Main technologies supporting a transition

- Genomics + phenotyping (possibilities to reduce animal emissions, to improve animal efficiency, to increase animal resilience and adaptation to new systems)
- Mechanisms of early programming and their links with epigenetic marks Animal microbiome
- Digital technologies to provide tools for the continuous, automated, real-time individual monitoring of data related to production as well as to environmental

parameters.

Risks of negative impacts. An imbalance between systems that support food security, climate mitigation and biodiversity

Main actors: same as in previous target 5.1.

6. Policies for the achievement of the targets

The achievement of sustainable systems of animal production, the current systems require a deep revision of the regulatory and policy contexts. Several single aspects of the Animal Production have been regulated, but a holistic approach and an assessment of global impact in changes induced by policy modifications have to be evaluated previously.

Encouraging the implementation of existing knowledge that will help in the improvement of the circularity, biodiversity and sustainability of the Animal Production systems.

When possible, regulation should adapt to the high complex and varied Animal Production systems, acknowledging the diversity of climate, regions, and economies at local and regional level. The fragility of certain rural economies is notable.

Research and innovation policies should encourage the development of innovations for small farming and small food business, which are difficult to implement, and that can be however, key changers into sustainability. Measures for intensified systems have to be provided through fair policies and science based solutions. The regulation should imply the whole food chain, including industries, retailers and all market actors, and consumers, sharing the possible increase in producing costs for sustainability.

Policy makers should also pay attention to the fair information, transparency and communication to the society regarding SAP.

7. Challenges for research

A holistic (including social and economic science), multiactor (inclusion of food industry desired, farmers, retailers and consumers) and multidisciplinary (economic research and market analyses need to be included) approach in research is required. A research road mapping of a gradual transition towards SAP is required covering these mean challenges:

» Research on impact assessment: Sustainability Markers of AP holistically approached. Integrating the social science into the impact assessment. Development of targets adapted to regions and situations (different species, breeds, systems…)/ Quantification and description of the impacts (environmentally, societal, economically) of AP Systems in different geographical areas to

» Research into reduction of harmful emissions like fine particles or bioaerosols, applying agro- ecology, low emissions and circularity concepts

» Simulation and modelling exercises e.g. ventilation or remote sensing and geodata for free range husbandry systems, in collaboration with ERA-NET Cofound ICT-AGRIFOOD / Research on effects of reduction of activity or type of animals introducing a misbalance

» Improving animals: genome and epigenome, microbiota, neuro-sciences, immunity linked to overall robustness of animals and related to product quality

» Research on optimal communication and societal behavior regarding Animal Production: How to regain consumer trust, inform the public debate with scientifically sound knowledge on animal product quality and production conditions, on healthy and environmental friendly diets, improve traceability and analyze the links between ethical concerns and willingness/ability to pay the products at adjusted price / Analyses / Strategies on how to transfer knowledge into reality

» Develop socio-technical approaches to support the transition from traditional livestock systems to agro-ecological systems.

FACTS AND FIGURES REPORT - SCAR STRATEGIC WORKING GROUP BIOECONOMY

Strategies and policies for a transition towards a safe and just operating space: elements for a reflection

Stefano Grando (Mipaaf, BSW member)[114]

1. Presentation of the Bioeconomy SWG (BSW)

The Bioeconomy Strategic Working Group (BSW) (www.scar-swg-sbgb.eu) is a thematic working group under the Standing Committee on Agricultural Research (SCAR). The BSW originated from the merging of a biomass-oriented and a bio-refineries-oriented previous SCAR group. Its main mission is to contribute to the further development of research and innovation policies for a sustainable bioeconomy. In this context it has evolved with the ambition to be a central informal platform in Europe overseeing and working together with different initiatives on national and European level related. The BSW brings together representatives from Member States and Associated countries and uses its position to give strategic advice from a MS perspective to the SCAR and the European Commission in the bioeconomy domain.

The peculiar nature of the BSW lies in its wide field of interest, covering the strategies and policies promoting research and innovation for Bioeconomy in general, without focusing on a specific sector or area, as well as in the attention paid to the strategic level of reflection on the development of the Bioeconomy. Thus, the policy context in its evolving features is particularly relevant for the forthcoming activities of the BSW.

Especially in its second mandate, the scope of discussion was extended towards policy and regulation (but still with a focus on the research basis). Furthermore, themes from the 4th Foresight Exercise report delivered new cornerstones that were discussed in the BSW.

[114] The document has been produced in collaboration with the BSW members and with the active support given by the BSW chairs.

The group continued functioning as a platform for an informal exchange among MS on national activities in different action areas, with particular attention to the development and implementation of (national) Bioeconomy strategies.

On the other hand, the BSW aimed at supporting the EU Commission in the revision of the EU-Bioeconomy strategy but also regarding the alignment of other relevant policies and strategies, such as the common agricultural policy and the Circular Economy. This was achieved by delivering specific recommendations based on a comparative analysis aiming at defining the differences between the current EU-Bioeconomy strategy and the needs and key areas of interest of the MS/AC as expressed in their national strategies or through the active evolvement of MS/AC representatives.

BSW recommendations are directed to policy makers, research institutes, and all interface structure with stakeholders (industry, farmers, and consumers).

2. Domain covered by the BSW

As mentioned, the BSW covers cross-cutting topics in the whole bioeconomy sector at a policy and strategy-oriented level. Questions of the 4th Foresight, e.g. about sustainability of the bioeconomy or the involvement of the primary sector, are still relevant for the group.

The Bioeconomy is an important element of Europe's reply to the grand challenges ahead, like adaptation to and mitigation of the effects of climate change, the challenge of feeding the future world population, or the challenge of producing more goods from fewer resources. Moreover, the Bioeconomy is also delivering goods and services for the citizens: on jobs, on sustainable growth and well-being, in terms of ecosystem services. It encompasses the production of renewable, biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products, including chemicals, and bioenergy as well as the related public goods.

Some Member States of the EU have a broader view, in which the Bioeconomy also encompasses medical applications or even more generally all economic activities that deal with living or non-living biological resources (i.e. biomass as well as information gathered from natural systems, e.g. genetic code, design principles, regulatory mechanisms).

The added value of the Bioeconomy lies in the integration of very different fields of science and technology. There is a need for a strategic discussion between MS/AC and the EU Commission what the further development of a sustainable bioeconomy means mainly for research and innovation, but also for policy alignment and regulation.

Given this horizontal cross-cutting remit, it is the strategy-policy level which can be seen as the true domain for the group, rather than a specific sector of the bioeconomy.

3. Main emerging issues in the domain covered by the working group

What argued above leads to consider a range of emerging environmental, social, economic, and health issues, not only from a political and scientific but also from an ethical perspective. The horizontal and wide-ranging remit of BSW makes it difficult and probably futile to try to give a full picture of these issues. Examples are:

- Mainly referred to transition 1 “Sustainable and healthy diets for all”:

  Discussion on the production and utilization of biomass for non-food uses (bio-materials, energy) when there is still hunger in the world (although this seems to have more to do with overall poverty and political tensions than with worldwide food availability).
  Example:
  - Food vs. fuel debate: If farmers are able to derive a greater profit by switching to cultivation of crops for biofuel production, they will. This not only leads to a reduction in the quantity of food available, but the price of food will also rise.

  Discussion on the trade-off between reduced packaging and food safety standards. We can invest in the production of recyclable packaging, but also in the reduction of the packaging with a return to loose products, with pros and cons to be assessed.

- Mainly referred to transition 2 “Full circularity of primary systems” and 3 “Strong increase in the biological and socio-economic diversity of primary systems”:

  Discussion on the pros and cons in the balance between large-scale and small-scale premises and logistics for biomass utilization. How can farmers (and small farmers in particular) be fully engaged in the bioeconomy sector, while retaining centrality for food production? Which is the adequate scale for bio-refineries in relation to the technology they adopt, and to the territorial context in which they operate?
  Example:
  - A biorefinery producing ethanol from straw must reach a certain size to be profitable, but can only grow to a point without the logistics of procuring straw from a large area become environmentally and economically unviable.

  What are the synergies between bioeconomy and circular economy?

  - Technical note on and added value of bioeconomy and circular economy: https://www.scar-swg-sbgb.eu/lw_resource/datapool/_items/item_29/technical_note_final.pdfsynergy

- Mainly referred to transition 3 "Strong increase in the biological and socio-economic diversity of primary systems":

  Discussion on how bioeconomy can contribute to biological and socio-economic diversity and to what extend bioeconomy depends on environment parameters (biodiversity, climate, soil, water…). Examples:
  - Which indicators do we need to quantify the impact of the bioeconomy on the above mentioned parameters? Report on bioeconomy monitoring systems: https://www.scar-swg-sbgb.eu/lw_resource/datapool/_items/item_31/synthesis_on_bioeconomy_monitoring_systems_in_eu.pdf

- Referring to all three transition areas:

  R&I and relevant policies are expected to contribute to the achievement of a large number of Sustainable Development Goals. A comprehensive description of the relations between bioeconomy and SDGs is given in Heimann (2018)[115].

  In our view, the bioeconomy development can influence in particular the achievement of SDG targets (mainly SDG2 "zero hunger", SDG3 "good health – wellbeing", SDG7 "affordable and clean energy", SDG8 "decent work-economic growth", SDG9 "industry-innovation-infrastructure", SDG12 "responsible production and consumption", SDG13 "climate action", SDG14 "life below water", SDG15 "life on land", SDG17 "Partnerships"). Effects on the achievements of these goals are generally positive but potentially also negative. due to possible trade-offs as in the case of SDG2. Those trade-offs need to be discussed and negative effects should be minimized.

4. Reflection on the role of policies and strategies in the transition pathways

Given its nature, BSW has a horizontal, cross-cutting remit, which covers the whole spectrum of bioeconomy-related issues. This makes the contribution BSW can give to the Foresight exercise peculiar as compared to more sectorial groups.

Based on the observation of the policy processes and their outcomes (namely the national bioeconomy strategies), we can highlight some elements that must be taken into account when any transition pathway is designed or studied.

In general terms, a holistic and integrated policy approach is needed, ensuring synergies between policies for environment, agriculture, research and economy and capable to trigger public and private investments avoiding as much as possible overlapping or

[115] Heimann, T. (2019). Bioeconomy and SDGs: Does the bioeconomy support the achievement of the SDGs? Earth's Future, 7, 43–57. https://doi.org/ 10.1029/2018EF001014

conflicting goals. Transition points that represent critical phases of change mark this process. Transition points are achieved through pathways marked by obstacles and resistances, due to diverging interests among stakeholders, conflicts between short- and long-term visions, technological lock-ins and sunken investments, and bureaucratic burden.

Strategies and policies focused on the bioeconomy have a two-fold role to play in this type of analyses.

First, they represent in themselves potential transition points towards new desired configurations closer to the ”safe and just operating space” that the Foresight aims at exploring. This is because the process itself through which a strategy is defined, often based on participatory processes and transdisciplinary reflections, can contribute to create enabling environments for initiatives aimed at achieving those configurations. This can happen through the confrontation of different visions and priorities, through the bargained identification of policy tools, through the allocation of resources to R&I in the bioeconomy sector, through the indication of new regulations or new incentives capable to encourage desired behaviors and practices.

- Examples for policy tools: public procurement of bio-based goods.
- Examples for new regulations: ban on plastic bags; EU-wide ban on plastic straws, knives, forks, Q-tips by 2021.

Second, they can be seen as the (temporary) outcome of a complex process in which different visions, interests, values, are combined and merged into a single document. In this regard, they can be unpacked to understand which priorities are identified in a given space and time. They are transitional objects, by definition, as a strategy aims at achieving certain outcomes that are relevant and (hopefully) achievable in that context, but not necessarily elsewhere or in another moment. Besides, the comparison with other priorities identified in different contexts and embedded in different documents will shed further light on the complexity of any transition pathway.

5. Contribution of the working group to the three transitions

The BSW looks at the transition towards a safe and just operating space from the perspective of the contribution that can be made by the development of a sustainable (circular)bioeconomy, i.e. from the collection or production of biomass to its processing until its final (hopefully circular) utilization.

Given that the strategy-policy level has been identified as the domain for the group, we have addressed the questions only once for the three transition together, to avoid overlapping with other groups with a more specific focus on each sector.

- What is the relevance of the domain to the transition?

The relevance is crucial, as strategies provide the political landscape in which any action can be framed, and in which resources for policies can be mobilised.

Bioeconomy is a relatively new concept, which requires changes in the existing system. The implementation of the (possibly circular, however sustainable) bioeconomy-based approach and the pursuing of related targets have clear systemic implications, as they require a holistic, system-wide change affecting all stakeholders, all sectors and value-chains, and the society and economic system as a whole.

- How can the domain contribute to the transition?

Through the design of strategies that are tailored on national or regional specificities, but also harmonised in a broader common vision. The development and the implementation of bioeconomy strategies and/or R&I policies can support all the three transitions.

- What are the appropriate (quantified) targets - relevant to the domain – that should be set to achieve the goal?

Again, given the nature of our group we do not suggest specific technical or socio-economic targets related to the three transitions.

From our perspective, a political target would be having in each country a national bioeconomy strategy and a related action plan. In the countries where the bioeconomy domain is fragmented into different sectors/strategies, there should be at least a clear bioeconomy-oriented vision cutting across existing pertinent strategies. Regional strategies are also important when regional size and regional autonomy are adequate. Macro-regional and global fora, cooperation and possible strategies represent another crucial target, given the global scale of the challenges ahead.

Moreover, a better understanding of the broader public regarding the potential of the bioeconomy throughout Europe to provide industry and society with solutions for the main challenges that consumers and citizens are facing (not only food production, but also for example bio-based alternatives to highly demanded and daily products…) is a goal/target.

- What are the main barriers to transition related to the domain?

  The three transitions present obstacles and bottlenecks in different forms, which vary among different groups of actors. For example:

  - There is a lack of understanding of the general public, leading to sometimes lack of support and difficulties in changing consumers' behaviour. Generally a true transition implies that people accept to change their behaviour (including adoption of self-restrain habits), must be willing to accept new products and (often) to pay higher prices for "green" products.
  - Even when a certain degree of awareness is achieved, its translation into a bioeconomy strategy, or similar strategic/policy documents, is sometimes difficult to achieve, due to possible inertia, conflicts between different perspectives, lack of planning capacity or funds for investments, etc.
  - For the industry it is hard to invest in new technologies, also not knowing how the marked will behave. Technological lock-ins, sunken investments, property rights protection and other established power assets are just examples of the difficulties for change.
  - From the research side it is hard to model this new system and predict, for instance, the use and availability of materials and, more generally, the critical mass of investments required to pursue uncertain goals can hamper the development of certain research fields. Example:
    - Modelling of the availability of materials must also take into account logistics (mainly transport and storage) and pricing of the biomass.

  These reflections can be broadened to the whole society: how can a well-established system be changed and which role can strategies play in this transition? Systems tend to perpetuate, as the strengths of consolidated habits and the influence of well-established power centres makes it often more difficult to move towards the new, and the uncertain, than to keep business as usual. Sometimes a more radical change, maybe pushed by external shocks and triggered by sharp regulations, can be seen as the best option to modify things; in other cases a gradual transition based on incremental innovation and on soft policy measures appears more suitable.

- What are the main technological game changers that may contribute to the transition?

  Given the policy/strategy-oriented focus of the Group, we leave this point for discussion by more sector-specific or technology-oriented groups.

- Who are the main actors that may contribute to the transition?

  From a strategy-oriented point of view, main actors are policy makers at national and EU level (i.e. countries and EU Commission), but also all relevant stakeholders who are asked to contribute to the design of the strategies, and who are expected to be key actors of their implementation. The business sector, the public and private research and innovation institutions, administrators and local communities, NGOs and grassroots initiatives are all actors whose contribution must be encouraged and considered. Broadening the view, the citizen/consumer awareness is the base upon a strategic vision can be built, developed and successfully implemented. Example:

  - Many stakeholders are, to this point, insufficiently aware and informed about the bioeconomy and its potential. Including them in the process will need new approaches and formats. The Federal Ministry of Research and Education in Germany has started the funding measure “New formats of communication and participation in the bioeconomy” in 2017, specifically so that such concepts could be developed and trialed.

- What are the risks related to game changers?

  As argued before we do not focus on technological game changers and associated risks. With regard to any "change of the game", seen as a paradigm shift or a radical socio-technical transition, there are risks observable from a strategy-oriented perspective.

1. Trade-offs often emerge, giving birth to ethical discussions about the prioritization of the interventions and the post appropriate balance among different interests. Any socio-technical transition is likely to have winners and losers, in the short as well as in the long run. A fair balance of burdens and profits among social groups, interest groups, regions should always be looked for. However, there is the risk of having unbalanced representations of those different and potentially competing interests when strategies are designed and when they are implemented. Besides, trade-offs between different impacts of game changers are not always easy to identify timely and to be translated into agreed and realistic strategies.

2. Strategies always have a temporal lag. The process from the identification of game changers to the full awareness of opportunities and risks brought by these novelties, to their consideration in the strategies, and then to the implementation of these strategies requires time. In the meantime challenges, opportunities and risks can further change, so that strategies can potentially become obsolete already during their implementation. The rapid evolution of climate change trends and extreme events patterns, as well as the unstable political landscape at national and international levels are just the most apparent among the possible examples of this risk.

6. Policies for the achievements of the target

A holistic policy approach is needed, ensuring synergy and alignment between policies for environment, agriculture, research and economy and promoting investments.

The most import European policies in this context are:

- A Clean Planet for all - A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy, launched in 2018 with the EC COM 2018/773 (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018DC0773)
- the EU bioeconomy strategy "A sustainable bioeconomy for Europe - Strengthening the connection between economy, society and the environment" first issued in 2012 and then updated in 2018 (https://ec.europa.eu/research/bioeconomy/pdf/ec_bioeconomy_strategy_2018.pdf);
- the Circular Economy Package, adopted in 2015 based on the the EC COM “Closing the loop - An EU action plan for the Circular Economy” (EC 2015) (https://ec.europa.eu/environment/circular-economy/index_en.htm);
- the Food 2030 initiative, launched after the 2015 Milan World Expo to incorporate UN Sustainable Development Goals and the COP-21 climate agreement into EU food policy (https://ec.europa.eu/research/bioeconomy/index.cfm?pg=policy&lib=food2030);
- the Common Agricultural Policy (CAP), with its first and second pillar, which promotes interventions to support inclusive bioeconomy in rural areas (https://www.consilium.europa.eu/en/policies/cap-reform/).

7. Challenge for research

There are many challenges that need to be addressed not only with a policy approach, but also by science and research including SSH. The following is just an exemplary list:

- How can agriculture and forest production feed the planet, provide other (ecosystem) services and feedstock for bioeconomy and at the same time contribute to SDG all at once (including biodiversitiy, Climate change,…) ?
- How can agriculture contribute to soil resilience and provide “standardised”, available and usable raw material for biorefinery?
- How can renewable bio-resources be sustainably produced? (Compatibility with low inputs in agriculture, carbon neutral production chain, …)
- How much biomass, including bio-waste, is available and how much of that can be used for a competitive production?
- How farmers can profit from the bioeconomy and how they can get involved as stakeholders? What is new value-added production?
- Assessing effects in the end-of-life phase of bio-based products; methods for assessing these (holistic and reliable LCA)
- New sources for bio-based products with benefits for environment/ climate /etc. with associated processes, taking into consideration ethical concerns on a global scale (e.g. stopping deforestation elsewhere or bio-based product wastes “recycled” in Asia)
- Flexibility of processes and versatile and fast analytical methods for process management based on feedstock properties.
- Impact assessment of bioeconomy implementation: How to quantify the impacts of bioeconomy implementation and which are the relevant indicators to monitor the socio-economical, environmental, industrial effects upon each sector, at local, regional, national or international level? How can we measure the positive externalities of the bioeconomy?
- Public awareness: How can the broader public become aware of the global importance of bioeconomy?

FACTS AND FIGURES REPORT – SCAR STRATEGIC WORKING GROUP ON FISHERIES AND AQUACULTURE

Sustainable fishery and aquaculture

Presentation of the Strategic Working Group (SWG) SCAR-FISH

The Standing Working Group on Fisheries and Aquaculture research (SCAR FISH) current mandate was initiated in January 2015, to increase SCAR's ability to collaborate with member states regarding aquatic production and harvest in both marine and freshwater.

As outlined in the terms of reference for SCAR FISH, the task is:

- To forge a strong linkage between Member states Ministries in charge of Fisheries (including fresh water) and aquaculture and the European Commission (DG Research & Innovation, DG MARE, DG Environment).
- To further develop existing collaboration and initiate new collaborations between member states, on a long term basis, to achieve a cost effective system of research effort in the areas of fisheries and aquaculture that supports the Common Fisheries Policy.
- To develop an agreed list of fisheries and aquaculture common research priorities that need to be addressed by SCAR Fish and that inform the commission and the Member states administrations.
- To collate existing information and where necessary collect new information in the areas of foresight, common research agendas and mapping EU capacities to support a European research area for fisheries and aquaculture.

The particular objectives thus include:

- To contribute to define EU research priorities within relevant initiatives: H2020 Work Programmes, Bioeconomy Strategy, Food & Nutrition security Strategy with inputs from SWG Food Systems, Agro-food and Forestry Strategy, Circular economy
- To collate and analyse existing and new information in the areas of:
    - Foresight
    - Common research agendas

- Mapping EU capacities

To deliver on these objectives and in line with the mission, SCAR FISH engage in a number of core activities, which include in particular:

- Review current programmes on climate induced changes to fisheries, identifying potential gaps and most promising approaches to adaptive management of impacts on capture fisheries and aquaculture
- Work with the European Fisheries and Aquaculture research Organisations (EFARO) on coordination of data collection to meet obligations under the Data Collection Framework and the Marine Strategy Framework Directive
- Engage with Eurofleets+ project to consider potential of greater coordination of fisheries research vessel activity
- Potentially work with marine COFUNDS to develop research programmes based on agreed research priorities, in particular the valorisation of unwanted catches and underutilised raw materials
- Bring forward proposals and develop SCAR Fish approach to land based aquaculture
- Discussions on longer term, cross cutting themes (innovation, governance)

Among recent examples of activities are:

- Production of a gap analyses on how to strengthen fish welfare research (2018)
- The production of a non-paper in collaboration with EFARO and EATIP, aimed at national contact points, which highlighted why Horizon Europe's cluster 6 on "Food, Bioeconomy, natural Resources, agriculture and environment" should consider the importance of aquatic research and innovation, as an integrated component across the suggested intervention areas (spring 2019)
- Production of a report on new developments and research needs within disease prevention in farmed fish (summer 2019)
- Production of a report about national differences in demand for research and innovation within freshwater aquaculture (autumn 2019)
- Delivery of input to SCAR foresight working group (literature, workshop participation) ensuring that the aquatic dimension of the food system is covered (2019)

Domain covered by the working group

SCAR FISH covers all aspects of fisheries and aquaculture research and innovation needs towards the implementation of related policies in a European context. This includes the Common Fisheries Policy in particular, and environmental policies such as the Marine Spatial Planning Directive and the Marine Strategy Framework Directive, as well as bioeconomy and food related policies and strategies.

From a research and innovation perspective SCAR FISH covers aspects of fisheries related to sustainable management of the stocks and minimising the environmental impact of the fisheries activities, as well as developments underpinning a viable sector. Within the aquaculture sector and processing in the value chains, many of the challenges are shared with the agriculture sector e.g. breeding; disease prevention; animal welfare; development of feed; nutrient recycling; valorisation of underutilised raw materials; creation of new circular value chains; traceability; understanding the importance of the microbiome; adaptation to climate change; ability to forecast extreme events, introduction of new technology; capacity building; enforcement of regulation; revisions of regulation; potential in adoption of life cycle assessments, lowering impact on ecosystem integrity, ecosystem services and biodiversity, development of policy advice etc.

SCAR FISH engage with relevant stakeholders in specific activities and have observers in the 3-4 regular meetings per year. These include 1) the European Commission (besides DG RTD it includes DG MARE and DG ENV); 2) Industrial partnerships (e.g. European Aquaculture Technology Platform EATIP), 3) Research performing and advice giving networks (European Marine Board, ICES, EFARO) and; 4) research and innovation programming partnerships (JPI Oceans).

Global state and trends of aquaculture and fisheries

The global production and consumption of fish, crustaceans, molluscs and other aquatic animals (hereafter referred to as "seafood") reached an all all-time high in FAOs latest analyses, based on data from 2017[1]. Globally, the average consumption is 19.7 kg seafood per capita, and 3.3 billion people receiving roughly 20% of their average per capita intake of animal protein from seafood. From a global nutrition perspective, seafood is therefore characterized as crucial by FAO. The level of global consumption have seen consistent growth in recent decades, i.e. 3.2% annually between 1961 and 2016, based on FAOs estimates, thus exceeding e.g. the rise in consumption of terrestrial animals. This consumption level is anticipated to continue grow even further, with FAO projecting a 20% global increase in consumption by 2030 compared to 2016[2].

The observed growth can mainly be attributed to increased aquaculture production, as the capture of wild fish has been roughly at the same level for the past decades, due to already fully or over-exploited stocks. On a global scale the total production (both food and non-food) is still primarily provided by wild capture. However, the rapid expansion of aquaculture has now allowed aquaculture to be the main relative contributor of seafood for human consumption.

In light of the anticipated expansion in aquaculture OECD (2016) projects that industrial marine aquaculture is likely to experience a growth of 303% (in gross value added) and an increase of 152% in employees between 2010 and 2030. Similarly, are the industrial fish processing expected to grow 337% increase in GVA and 206% increase in employees.

From an economic perspective, seafood is already among the most traded food items globally, with China as the largest exporter, and the European Union as the largest importer[1]. According to FAO exports rose from USD 8 billion to USD 143 billion between 1976 and 2016. It is a continued trend, as the value increased 10% to 156 billion in 2017. The fastest growth rates were mainly found in the developing countries.

From an environmental and health perspective, the rise in the relative importance of seafood and aquaculture in particular, is also of interest. Recent high level publications such as the EAT–*Lancet* Commissions "Food in the Anthropocene", for example highlights seafood and aquaculture production as one of the areas in the food system with the potential to provide more healthy food, while operating within the planetary boundaries[3].

From a social and ethical perspective, seafood production and aquaculture in particular shares a number of characteristics with the rest of the food production system. Topics such as animal welfare, use of antibiotics, lowering environmental impact incl. land/sea use, as well as protection of biodiversity are thus key issues. Similarly, jobs in fisheries and aquaculture as well as their related value chains (processing, retail etc.) are important for rural development, where overarching agendas such as the "Blue Bioeconomy" presently aims to integrate their output better into the wider bioeconomy to valorise the products and increase circular use.

In light of the observed importance of seafood production, it will be increasingly important to understand and take advantage of the sectors potential to address the Sustainable Development Goals (SDG) and the sectors connection to the Planetary Boundaries.

In the annex we provide examples to illustrate which of the SDG targets are relevant for fisheries and aquaculture. It is a long list covering much more than SDG 14 (Conserve and sustainably use the oceans, seas and marine resources for sustainable development) as fisheries and aquaculture are both economic activities and as such, they must be focused on technological upgrading and innovation, as well as operating the supply chain, to maximize efficiency involving everyone from producer to final consumer. Both also are marine and freshwater activities, with aquaculture spanning from offshore marine production sites to freshwater lakes, land-based open and closed recirculating systems.

From the perspective of the planetary boundaries' control variables, fisheries and aquaculture are also relevant, either as examples of industries being particularly *impacted*, or as examples of industries which can provide *efficient use of resources* so we stay within the limit of our safe operating space. Examples of the industries relevance for particular control variables are:

> Climate Change – as aquaculture and fisheries is capable of producing animal protein with a minimal emissions compared to many types of terrestrial animal based production
>
> Biogeochemical flows – as aquatic production e.g. shellfish and algae can act as N+P mitigation tools, which recycles nutrients from aquatic environments back to land
>
> Freshwater use – ability to produce animal protein with minimal water use compared to many types of terrestrial animal-based farming, as water can be recycled in many systems
>
> Land-system change – 1) food production can be moved from land to sea, or 2) if produced on land, aquatic animals in general can be produced at much higher densities 3) better feed conversion ratios means less need for protein sources for feed
>
> The food production from aquatic systems may be impacted by:
>
> Climate Change – higher ocean temperatures will shift distribution of species and may change food-web composition.
>
> Biosphere integrity – as the industries depend directly on healthy and sustainably managed ecosystems to provide the fish and other food in combination with ingredients for e.g. feed.
>
> Ocean acidification – as some aquaculture and fisheries depend on ecosystems and organisms vulnerable to ocean acidification, e.g. some shellfish

The state and trends of European aquaculture and fisheries

The European consumption of seafood is presently estimated to be around 24.3 kg, with major differences between EUs countries, e.g. consumption in Portugal is 57 kg[4] per capita. EU28's per capita expenditure is also the highest among the OECD countries with 103 Euros, estimated from 2014 data. This level of demand is however not possible to meet by European producers (fisheries and aquaculture), which are only responsible for 3% of the global production (both food and non-food), where China in comparison supplies 41%. This results in significant import of seafood to the European market. Thus EU only has a self-sufficiency ratio of 41,7%, with the majority of top species (e.g. tuna, cod, salmon) being imported. Consequently EU takes the place as the world's largest trader in terms of value of fisheries and aquaculture products, though this also include products not used for consumption, i.e. fish meal and oil serving as ingredients in aquaculture feed.

The importance of seafood for the European consumers and the lack of European production has not been overlooked in the European research and innovation landscape in recent years based on the number of new and revised strategies and directives aiming at ensuring a sustainable growth in the seafood related value chains. Similarly has the potential benefits of increasing aquatic production also been analysed extensively, considering both the health, environmental and economic potential in relation to e.g. land based production.

In one of the recent key publications "Food from the Oceans" the European Commission's High Level Group of Scientific Advisors thus highlighted both the need for aquaculture expansion due to its "*huge potential and resource efficiency*", and stressed the need to mainstream a "*food from the ocean*" policy paradigm to address future food and nutrition demands[5]. This was also echoed in the European Commission's latest Strategic Orientation about Horizon Europe, which noted that "*Oceans, seas and inland waters can deliver more food with lower carbon and freshwater footprints than land-based production, while boosting profitability*"[6].

Though an overall increase in production will be necessary to meet both the present and future demands in Europe, it is also important to decrease the present waste of aquatic products in the supply chain, which amount to more 30% of the biomass[7]. The waste generated comes mainly from fishing, due to discards of unwanted catches at sea, though loses at the distribution and consumption level are also significant. The most efficient exploitation of the potential of the food system will thus necessarily involve reducing waste along the value chain. In this context the recent introduction of the discard ban, or Landing Obligation, by the European Commission, represent the legal motivation for ensuring progress within the parts of the value chains.

Analysis of the main emerging issues in the domain covered by the working group

The fisheries and aquaculture community, spanning both producers, managers, research and innovation performers and funders, are increasingly becoming aware of the industry's ability to contribute significantly to many of the sustainable development goals, including a future food system that can operate within the planetary boundaries. However, to deliver this development EU must step up its efforts in developing it's aquaculture industry, while continuing its implementation of marine policies.

I light of this, it is becoming consistently clear, that the emerging research issues in aquaculture are familiar to agriculture production (i.e. animal health, breeding, recycling of nutrients etc.), and thus broad research themes need to tackle these holistically. Challenges in production from aquaculture and agriculture system may find solutions in developing circular systems integrating aquatic and terrestrial processes. From a food systems perspective, aquatic production (on land and in water), need to be better integrated with the wider bioeconomy value chains both from an economic perspective and from an environmental management perspective.

From a fisheries perspective, key issues concern the ability of the industry to adapt to management plans, e.g. the recently introduced discard ban, or in other terms, a Landing Obligation. The big challenge is a paradigm shift towards sustainable production, driven by sustainable consumption. In this context, the landing obligation creates the need to ensure economic interest in valorising bycatch species, along with the adoption of a long-term policy to encourage the reduction of unwanted by-catch that are the real cause of discards, looking for the technological tools that can be used to achieve the desired results. More targeted capture and energy efficient capture systems need to be promoted, contributing to the reduction of inefficiencies and energy losses associated with catching, transporting and landing of unwanted fraction of the fishery product, which in some fisheries may far exceed the fraction of target species.

The implementation of the Common Fisheries Policy and the Marine Strategy Framework Directive creates the continued pressure of lowering the environmental impact of fishing. The use of satellite data and other types of environmental observation has great potential in supporting fisheries and aquaculture management as well as ensuring food security. It offers new prospects for monitoring and control of fishing activities, allowing accurate estimates of spatial occupation and pressure exerted by fishing fleets on marine ecosystems and tackling illegal, unreported and unregulated (IUU) fishing, which is currently one of the main threats to food security, contributing to depleting stocks, destroying marine habitats and distorting the markets.

Fisheries management struggle with issues related to e.g. lack of knowledge to produce and evaluate the efficiency of present or future management plans.

From a blue growth perspective, several cross-cutting issues are also emerging. While Land Use, Land-Use Change and Forestry has been an issue on land for years, it is increasingly important to consider the use of the marine space as several maritime industries are expanding – especially the energy sector. This raises the need for integrated ecosystem assessments, and marine spatial planning tools, which in combination will be needed to deliver efficient management and monitoring of the ecosystems and ecosystem services, which both marine aquaculture and fisheries depend on. Finally, the management system increasingly need to connect land as sea as one system, to account for the interconnected nature of e.g. pollution as suggested in most EU policies.

Contribution of the working group to the three transitions

SCAR FISH is anticipating significant increases in the focus on fisheries and aquaculture in the coming years, as European ambitions rise with respect to deliver more and increasingly sustainable and healthy food. With a good overview of research and innovation needs and the mandate to initiate own analyses, SCAR FISH is well positioned to structure and contribute to EUs efforts in the transition towards a better integrated and circular food system, capable of exploiting the synergies within the wider bioeconomy. Given the call for explicit scenarios (radical vs moderate lowering of emissions), it should be noted that EUs bioeconomy and food sector has significant regional differences. This is also the case for fisheries and aquaculture at the present stage, and scenario building should not overlook the opportunities and challenges arising from this diversity, as it relates to both environmental policies, labour market incl. educational capacity, consumer preferences etc. SCAR FISH is however, well positioned to provide advice on this subject, and suggest that several potential targets for the EU should be considered, in order to explore the particular barriers and necessary actors.

A self-sufficient EU

Unlike many other large economies, EU's main supply of seafood comes from wild caught fish. In addition more than half of the consumed seafood is imported from outside the EU. In order to take responsibility for the sustainability of EUs own consumption – a goal of seafood self-sufficiency could be relevant to explore also at regional levels. Well-managed fish stocks may allow larger catches than the current level, and production in aquaculture systems would increase from further development of aquaculture in water and on land independent of feed from capture fisheries.

A climate neutral European fisheries and aquaculture industry benefitting rural areas

To align the efforts along the industries value chains a goal of a climate neutral European fisheries and aquaculture industry by 2050 could act as a strong framework around which particular specialized interventions could be developed. An integrated sub-goal could be to raise seafood's relative percentage of animal protein being exported. This could be achieved while strengthening the economic sustainability and job creation in the food sector in rural areas through the strengthening of low impact European aquaculture using multiple new species of fish, shellfish and algae.

An EU food policy which sees all food production as equal

Fisheries and aquaculture in particular are often not considered alongside other food related policies and research and innovation programmes in both EU and national contexts. A goal of equal consideration of all food related sectors in policy implementation and funding, could be a relevant tool to enhance development. Likewise, a levelled playing field, where food prices reflect the impact and use of ecosystem services would allow food producers to compete on their actual ability to deliver sustainable and healthy food within the planet's safe operating space.

A fully integrated European Bioeconomy

Fisheries and aquaculture are the cornerstones of the blue bioeconomy, and thus depend on smart and systematic integration with the wider bioeconomy to become circular in terms of biomass and nutrient use. To foster this, a goal of a fully integrated European bioeconomy, which connects land freshwaters and sea seamlessly is needed. This connection must be enabled through smart regulation, which allows easy flow of biomasses between sectors, and accelerated transdisciplinary research and innovation to address the challenges experienced by the stakeholders along the different value chains. Successful integration will further enhance the ability to deliver increasingly system-based decision support with regard to nutrition and health as well as the overall sustainability of production within the specific environmental, economic and social context.

Barriers

The four suggested goals for EUs fisheries and aquaculture are connected by their dependence on a number of challenges which if not addressed, are or will become barriers. These include in particular the need to

1. Lack of technology transfer and availability of analytical tools, represent a challenge for all industries in a market economy. This is also the case for fisheries and aquaculture where increased use of technology and analytical tools (advanced statistics, machine learning etc.) is needed to improve the economic and environmental sustainability of present and future fisheries and aquaculture (e.g. reduce waste, discard, underutilised species, seabed impact of fisheries etc.) Aquaculture has particular gaps, given its need to monitor the environment, food, diseases, water recycling etc. Possible game changers could be the development of advanced and efficient hatcheries, genetic breeding tools or novel traceability opportunities.

   For fisheries, game changers are, among others, the adoption of new sensors and other existing monitoring tools, allowing a fully documented fishing activity as well as technology transfer and gear innovation, which is anticipated to reduce the environmental impact of the industry. Technologies developed in this regard should be tested in industrial environment.

   At the fisheries management level new analytical tools in particular, will be needed to overcome barriers connected to e.g. assessing data poor stocks, lack of ability to make long- term management plans, evaluate their effects and estimate long-term impacts. This will be increasingly important as fish stocks move as a consequence of climate change and its effect on ecosystems.

2. Operating at sea is a technical and costly endeavour. To advance marine aquaculture production as a diversified and scalable industry, heavy research and innovation is required alongside designated demonstration sites. To accelerate the development of the sector to a comparable level with agriculture would require substantial effort, but should be worthwhile, as seafood has the potential to be a much more favourable option seen from an environmental, economic and social perspective.
3. The present complex regulatory frameworks is a challenge for businesses and marine management. To solve this, policy frameworks should be simplified where possible, though data collection should be expanded, to address environmental sustainability concerns, without compromising the producers ability to expand their activities, i.e. scale up production, reduce losses, including discards, and move biomass between actors in the value chain.
4. The lack of knowledge about the biological processes, lifecycles and distributions

of fish stocks and biodiversity are reducing the ability to make predictive models needed for assessments and management on biologically relevant spatial scales, in line with EUs plans for policy implementation.

5. The availability and demand for healthy and environmentally friendly food is not always aligned. Consumer attitudes and preferences in the food system should be considered carefully (e.g. consumer safety, health and ethical views), in the development of new production systems, selection of species for aquaculture, transparency and traceability.
6. The ability to predict ocean characteristics must be increased, to project e.g. when and how e.g. harmful algae, marine heat waves, pollution etc. will affect aquatic production.
7. Parts of EUs blue bioeconomy is challenged by the lack of relevant personnel. The profile of the blue dimension of the food system must be improved to attract the necessary personnel, which is likely to have been educated within other areas, i.e. veterinary medicine, engineering, fish physiology, food quality, logistics etc.
8. Integrating fisheries and aquaculture with the rest of the blue economy is challenging, but also holds great opportunities for synergies (e.g. with offshore energy sector). Similarly is it a challenge for all parts of the blue economy, that the level of activities at sea is increasing and thus the demand of its users (i.e. recreational, shipping, energy, fisheries, aquaculture etc.,), creating a highly complex stakeholder landscape, even before considering the land-sea connection which is important since water in most regions moves from land to freshwater, and further into coastal and marine environments, which expands the stakeholder list even further and risk of conflict between these. Among necessary enablers are thus the operationalisation of management plans in support of e.g. the Marine Strategy Framework Directive, and the development of e.g. spatial planning tools for site selection in line with e.g. the ambitions of the Marine Spatial Planning Directive, and developing activities jointly with the other sectors of the blue economy.
9. Sea-basin cooperation on fisheries and aquaculture management, monitoring, industrial development etc. represent a barrier, which must be overcome through continues support to coordination and regional implementation. This will also need to take into consideration , the wider regional bioeconomies, as EUs regions (including sea basins) will need to develop different solutions to address the shared EU priorities.

Annex – list of SDG targets where fisheries and aquaculture play a role

We here provide a number of examples to illustrate how the particular SDG targets are relevant for fisheries and aquaculture. Note that fisheries are both an activity in marine and freshwater, and aquaculture spans from offshore marine production sites to land-based open and closed recirculating systems.

SDG 2: Zero Hunger, and its targets incl.:

2.1 – "*By 2030, end hunger and ensure access by all people*" to "*safe, nutritious and sufficient food all year round*."

2.3 – "*By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular… and fishers*," and secure and equal access to "*productive resources and inputs, knowledge, financial services, markets and opportunities for value addition*"

2.5 – "*By 2020, maintain the genetic diversity of…"* and *"farmed and domesticated animals and their related wild species"* as well as *"promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources*"

SDG 5: Achieve gender equality and empower all women and girls, and its targets incl.:

5.A – "*Undertake reforms to give women equal rights to economic resources, as well as access to ownership and control over…"* and "*natural resources*"

SDG 6: Clean water and sanitation, and its targets incl.:

6.3 – "*By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials*" and halve the "*proportion of untreated wastewater and substantially increasing recycling and safe reuse*"

6.4 – "*By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater*"

SDG 8: Decent work and economic growth, and its targets incl.:

8.1 – By 2030 "s*ustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries*"

8.2 – By 2030 "a*chieve higher levels of economic productivity through diversification, technological upgrading and innovation*"

SDG 11: Sustainable cities and communities, and its targets incl.

11.5 – "*By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses"* caused by disasters *"including water-related disasters*"

SDG 12: Responsible consumption and production, and its targets incl.

12.2 – "*By 2030, achieve the sustainable management and efficient use of natural resources*"

12.6 – By 2030 "*Encourage companies, especially large and transnational companies, to adopt sustainable practices*"

SDG 13: Climate Action, and its targets incl.:

13.2 – By 2030 "*Integrate climate change measures into national policies, strategies and planning*" SDG 14: Life below water, and its targets incl.:

14.2 – "*By 2020 sustainably manage and protect marine and coastal ecosystems*"

14.3 – "*Minimize and address the impacts of ocean acidification*"

14.4 – "*By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans*"

14.6 – "*By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing*" etc.

14.7 – "*By 2030, increase the economic benefits to Small Island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture*"

14.B – "*Provide access for small-scale artisanal fishers to marine resources and markets*"

FACTS AND FIGURES REPORT – SCAR STRATEGIC WORKING GROUP ON FOOD SYSTEMS

Task leaders: Dr. Viktória Szűcs and Dr. Andrea Győrffy, Hungarian Chamber of Agriculture

1. Presentation of CWG/SWG

Here a brief presentation of the group, its mission, its activities, its composition

The **mission** of the SCAR Food Systems SWG is to provide strategic advice and support to the EU Research and Innovation policy framework FOOD2030. The vision of the Food Systems SWG is that the food systems should deliver not only food security but also nutrition security.

The **aim** of the SCAR Food Systems SWG is to contribute to the transition towards a better Food and Nutrition Security and Research and Innovation (R&I) policy coherence as well as R&I strategic orientation by integrating and analysing the different regional and national European initiatives and strategies in place; and to make the food systems more sustainable, responsible, diverse, competitive and inclusive.

Activities and Deliverables:

To achieve its objectives the SCAR FS SWG has carried out several studies, provided policy briefs, organised joint activities with other SCAR WGs and JPIs FACCE, HDHL and OCEANS and collaborated with the CSA FIT4FOOD2030.

1. **Mapping report:**

Assessment of research and innovation on Food Systems by European Members States, Policy and Funding analysis, available at:

https://scar-europe.org/index.php/food-main-actions/mapping and https://publications.europa.eu/fr/publication-detail/-/publication/ed451358-a67d-11e8-99ee-01aa75ed71a1/language-en/format-PDF/source-104957930

The above mapping exercise has provided a baseline assessment of:

- Public R&I funding related to the food systems and their alignment to the FOOD2030 at national and regional levels (quantitative component);
- Existing policies and strategies that are linked to Food and Nutrition Security (qualitative component).

Mapping information across Member States revealed knowledge, gaps and opportunities to collaborate in the future to fulfil FOOD2030 expectations.

2. **Policy brief** – The added value of a Food Systems Approach in Research and Innovation.
3. **Study** – Synthesis of existing food systems studies and research projects in Europe.
4. **Policy brief** – Diversifying Food Systems in the Pursuit of Sustainable Food Systems and Healthy Diets.

Joint activities:

ACTIVITIES	DELIVERABLES
17th October 2017, Brussels - joint workshop with **SCAR AKIS**	**Workshop report** – "Agri-food SMEs collaborating for innovation along the supply chain – What, Why, How?"
6th April 2018, Rome- Joint workshop with **SCAR AKIS, ARCH** and **FOOD SYSTEMS** SWG	**Policy brief**: "Programming Research and Innovation for Improved Impact"
13th June 2018, Plovdiv - Joint workshop with **FOOD SYSTEMS SWG and JPIs FACCE, HDHL** and **OCEANS**	**Workshop report and Joint statement letter** : "Future –proofing food systems"

Members: **21 Members States** and **Associated countries**: AT, BE, DE, DK, EE, ES, ***FI***, **FR**, HU, IE, IT, LT, LV, MT, NL, NO, PL, RO, SE, TR, UK, open to all SCAR participating countries that can join at a later stage. (FR – coordinator and Chair/ FI- co-chair)

First mandate: 3 years – from December 2016 to December 2019 (the youngest SCAR SWG)

2. Domain covered by the working group

What are the actors and the activities of the food systems addressed by this working group?

Actors:

- EU Policy makers (EC- DG RTD, DG AGRI);

- EU Member States - Representatives of National Ministries (Agriculture, Food, Rural development, Research and education, Economic development, Health);
- researchers (Institutes and Universities);
- JPIs – FACCE, HDHL, OCEANS.

Activities:

- To carry out investigations in order to contribute to policy coherence in the R&I area on food systems and to the R&I policy alignment.
- To provide strategic advices and support to the R&I policy framework FOOD2030.
- To provide strategic input for better synergies in future programming.
- To help to move towards better Food and Nutrition System R&I policy coherence.
- To share the best practices, experiences, knowledge and data.
- To analyse different regional, national and European initiatives in place.
- To try to find impactful solution to future proofing food systems.

3. Main facts, figures and trends regarding the domain covered by the working group

In this section environmental, social, economic, health, ethnic facts and figures of the domain relevant to the Sustainable Development Goals should be reported

Food systems should continuously provide healthy food and diets for all, in a healthy, resilient, green and blue, living environment. Interventions designed to change dietary choices and behaviours at population level has shown limited success till now.

We need **better understanding** how the interplay of biological, psychological, environmental, economic and social factors affects healthier, more sustainable lifestyle choices as well as joint strategies of industry, policymaking and the public in real-life European food cases.

The **Food systems approach** attempts to understand the natural, technical, economic and social aspects of several interlinked activity areas from primary agriculture to consumption; and should improve the understanding of the interdependencies between key parts of food systems at various scales (complexity) and the desired and un-desired outcomes in terms of food, health, environmental and climate impact etc. It also helps to identify systemic lock-in feedback loops and trade-offs and could pinpoint synergies in terms of changes. Therefore, an adaptive food system approach is required in order to support the transition (systems thinking, resilience, adaptability, trade-offs, leverage points, monitoring indicators).

The impact of **diversity within food systems** on sustainability and its drivers or barriers is important. It includes (i) diversity in agricultural, and aquatic production (e.g. agroecology concepts under different (local) environmental and soil conditions), technological innovations and genetic diversity (ii) diversity in (processed) products responding to consumer demands, (iii) diversity in the nutritional profiles of diets and microbiota from a health perspective, and (iv) diversity related to the rich European cultural food heritages and local traditions. In particular, the concept of diversity should be looked at in light of climate change, decreased crop resilience, migration of fish stocks, growing population, increasing demand for meat, increasing diet-related diseases and nutrient deficits, increased pressures on natural resources, new trade agreements and price volatility.

4. Analysis of the main emerging issues in the domain covered by the working group

In this section, emerging environmental, social, economic, and health ethnic issues characterising the domain should be analysed in light of Sustainable Development Goals.

Emerging issues:

- ✓ Food systems should utilize water, essential nutrients, plant, animal and microbial resources and maritime resources in a sustainable and responsible way. For a **better recycling of resources** enhanced circularity, increase efficiency and reduce food waste are needed.
- ✓ Dietary changes, use of lands and the sea, agriculture and aquatic food production's interdependency linked with **climate change** and **biodiversity**.
- ✓ Find the potential **synergies between the blue and the green**. Environmental impact of agriculture and food consumption on the aquatic environment and fish stocks.
- ✓ Reduce diet-related chronic diseases, improve public health in general and hasten transitions to more **sustainable diets** and **production methods.**
- ✓ Development of appropriate **monitoring systems** that follow consumption patterns at different scales, thus enabling benchmarking of both health and sustainability outcomes.
- ✓ **Citizens** and **population engagement** in food systems development- citizens should be integral players in the food systems.
- ✓ **Consumer trust.**
- ✓ Mobilizing **multiple actors**, **sectors** and **policies** (system approach).

✓ **Food safety**, quality and health, integrity and authenticity.

The importance of these challenges is reflected by their prominence in most of the 17 UN Sustainable Development Goals (SDGs).
SDGs: Ten out of the 17 global SDGs are directly linked to food and nutrition security. The SCAR FS SWG addresses and contributes to following **SDGs**:

(1)No poverty ; (2) Zero Hunger; (3) Good health and wellbeing; (4) Quality Education; (6) Clean Water and sanitation; (8) Decent work and economic Growth; (9) Industry, innovation and infrastructure; (11) Sustainable cities and communities; (12) Responsible consumption and production => 12.3 Reduce food loss and waste; (13) Climate action; (14) Life below water; (15) Life on land; (17) Partnership for the goals.
The 6 actions identified for the next mandate also tackles the above SDGs: 1) Monitoring impact; 2) Translate science into policy; 3) Food system waste management; 4) Consumers; 5) Digitalisation; 6) Food systems of the future.)

1. Contribution of the theme to the three transitions

General responses:

- **What is the contribution of the theme to the transition?**

It is essential to better understand the complex system dynamics which requires looking at all elements, their interactions and connections influenced by internal and external challenges. As health and sustainability are the responsibility of all actors of the food system a holistic approach is essential for the transition. Existing knowledge, experiences and good practices in different fields can make a significant contribution to the transition and acting as a beacon to other actors. In addition, possible adaptation of other industrial sectors' (e.g. vehicle or pharmaceutical industry) good practices should be considered. R&I can deliver the evidence-based knowledge as well as targeted and practical R&I results and databases can support the transition efforts. Furthermore, practice-oriented innovation is needed to achieve the transition goals. The relevance of H2020 thematic networks and their results are high due to the accumulation of existing knowledge in given fields.

- **What are the appropriate (quantified) targets - relevant to the domain – needed to perform the transition?**

Widening participation of the relevant stakeholders on MS level is recommended.

Transition requires the presence of transparent regional, national and EU level strategies and policies without overlaps and/or conflicting provisions. The creation of policies requires dialogue-based stakeholder network and a public consultation process preferably directly targeted to the citizens. Based on the FIT4FOOD2030 project presence of a relevant stakeholder network and a core group of key experts can be an effective tool. Discussing certain fields might require the forming of hubs. In addition, it is essential to support focused research with goals in mind.

- **How to achieve the transition? What are the main barriers?**

A bottom-up, MS-based data collection, followed by a top-down policy framework legislation and the related public consultation combined with integrating innovative approaches (e.g. "Responsible Research and Innovation", open innovation) might the smooth transition process. Promoting positive and cooperative attitudes through increasing the motivation of food system actors might enhance transition. Attention to responsible food handling (e.g. consequences, interactions) is warranted for all actors in the system.

Thinking in silos as wells as a lack of recognition of the need of transition and a system approach are serious barriers of the transition.

- **What are the main technological game changers that may contribute to the transition?**

Digitization and artificial intelligence has also appeared in the food system. However, the relevance and penetration rate of digitization varies among the parts and players of the food system as well as among Member States. The role of influencers and innovators is significant in a reasonable and profit-making introduction of digitization into food systems, so their integration into think tanks and utilizing their experience can contribute to a successful transition.

- **What are the related risks?**

Successful implementation of digital / artificial intelligence solutions require appropriate attitudes of stakeholders, regulatory environment and financial resources. Without the necessary components digitization might become a "trendy" but idle and expensive solution. The complexity and difficulty of research systems' structure and funding can also endanger the transition. Innovative ideas might not be supported, due to the specificities of the research systems and the distorting effects of research funding. The lack of system-level, long-term vision poses a serious risk to the transition. Furthermore, for tailor-made (for the given Members State, for the given region, for the given food system) solutions the appearance and active innovation in digitalization / artificial intelligence innovative hubs / start-ups / clusters are indispensable.

Transition specific responses:

5.1 Transition 1: Healthy and sustainable food for all

It is essential to better understand how the interplay of biological, psychological, environmental, economic and social factors affects healthier, more sustainable lifestyle choices. All components of food systems can inherently contribute to providing healthy and sustainable food for all. However, due to its interlinked nature, food systems are vulnerable to effects working against healthiness and sustainability. Cooperation of a broader policy maker and expert community (including public health and environmental experts) and the society, as well as an impact monitoring system is needed to perform the transition. It might be worth overviewing and analysing of successful national intervention (e.g. Hungarian regulation on trans-fatty acids), communicate in a more focused way (even independently from possibly fragmented project communication campaigns), and making all actors aware of their responsibilities. Transboundary emerging risks and diseases call attention to the need to develop rapid detection methods. State involvement might be necessary to initiate transitions that are not/less profitable or would put a heavy financial burden on consumers.

5.2 Transition 2: Full circularity of food systems

The key to full circularity is ensuring the closing of the food system cycle at the phase of waste streams and waste management, involving relevant stakeholders - basically primary producers, industry, markets and consumers. However, circularity suggests a closed system. Applying the principles of bioeconomy combined with circularity might enhance both diversity and recycling rate: bioeconomy, as an open system, focuses on channelling bio-based materials (regardless whether they originate from the given food system or not) into pathways that lead to value-added products. Targeted innovation project calls and adaptation of selected global good practices might initiate the development of relevant practical procedures. State involvement and/or a national incentive system (e.g. built in the waste management) can also be tools to empower circularity. An EU-wide network of pilot plants and related advisory services could help producers to select the investments best suited to them. The potential public, animal and plant health effects and risks of circularity as well as bioeconomy still needed to be investigated. Based on the characterization of risks, standardized protocols should be developed to eliminate potential adverse effects.

5.3 Transition 3: Substantial increase of biological, social, and economic diversity

It is important to understand the impact of diversity on sustainability goals and its drivers or barriers. Food systems can contribute to the increase of biological, social and economic diversity mainly on the input side. Diversity occurring at the input side will – though to varying degrees – appear throughout the system. Therefore, the openness of food systems is an important factor in diversity. Inspiration of development of food system elements that are responsive to the changes and challenges should primarily be started in a local dimension involving local communities applying the results of socioeconomic research. Such initiatives could be demonstrated in “local innovation centres” as model farms and plants. Lack of confidence, however, might be a big hurdle on the local, regional and national levels. Lack of appropriate data, information and knowledge can also be barriers. When diversifying input channels of food systems, care must be taken to ensure that the balance between existing and new input channels is maintained and food security remains on the first place. Involvement of gene conservation centres is indispensable for the diversification of food systems input channels. Long-term impact of ongoing changes should also be investigated.

6. Policies for the achievement of the targets

To be able to embrace and enhance challenges that force food systems to transform, EU, national, and regional policies must be coherent, holistic, aligned and developed through co-design and co-development, involving all stakeholders, including society. Incentives should be preferred to regulatory policies.

According to the results of the quantitative mapping performed by the SCAR Food Systems SWG, agriculture, food production and food safety aspects and support were most prominent in R&I of the Member States. In contrast, food innovation and nutritional aspects to health were scarce in the national policies. Based on the results of mapping, aspects necessary to the transitions should be integrated into national policies. In addition to the recently updated EU Bioeconomy Strategy, 9 Member States have developed a dedicated, national bioeconomy strategy, while more than 50 EU regions possess a bioeconomy-related strategy. Members States currently developing their bioeconomy strategies could include the food system aspect with particular emphasis on waste management.

The FIT4FOOD project has mapped more than 400 food policies adopted by the EU as well as the Members States. The collected policies are classified according to policy goals (further broken down into sub-goals), target (primary target and ultimate beneficiary) and instruments. The sources of the policy mapping were the already existing collections (NOURISHING database, SCAR qualitative mapping), governmental websites of EU member states, website of the European Commission, as well as academic databases (Web of Science, Scopus, Google Scholar).

7. Challenges for the research

In this section main research questions and topics generated by the analysis of the transitions should be synthesized

- ✓ **Systems thinking** and **transdisciplinary research** are required to tackle global challenges (including climate change, population growth, urbanization, ecological footprints)
- ✓ R&I should focus on the **mismatch between** the **food we grow** and **the food we need** for health, via a dynamic approach. Possibilities and risks of integrating food systems into circular bioeconomy should also be investigated.
- ✓ **Specific** and **tailored R&I programs** - to gain a system understanding and to learn from each other's strengths, e.g. introduction of systems thinking from ecology and systems biology into food and nutritional sciences, insights from other sectors like energy, health, transport, etc.
- ✓ **A sustainable Health-Safety-Quality approach** is imperative for the European Food Agenda of the future
- ✓ What defines healthy and sustainable **diets for specific groups of citizens** in their particular environments?
- ✓ How to tackle the rise of chronic diseases through choosing healthy and sustainable diets?
- ✓ Understanding the consumer (changing lifestyles, demand for food, food waste, nutrition).

FACTS AND FIGURES REPORT – SCAR STRATEGIC WORKING GROUP ON FOREST

Presentation of SWG Forest

MISSION AND AIMS

- Strengthen transnational research and cooperation on forests and forestry in order to tackle climate change and other risks, to support biodiversity and ecosystem services, and to develop bioeconomy with regards to sustainability and competitiveness of the EU's forest-based sector.
- Promote forest-based system and value-chain approaches with consideration of other sectors and regions of the World.
- Be a source of advice for a coherent forest-based research and innovation area, and the elaboration of national and EU policies or strategies.

MAIN ACHIEVEMENTS

- It has been shown extremely important, for a fragmented forest-based sector (ownership, SMEs, public policies, research and innovation), to develop networking actions, private/public consortia, and partnerships between national funding agencies, with simple supporting instruments implemented with enough continuity.
- Digitalisation and robotisation appear to offer extraordinary opportunities for the forest-based sector where their use could and should be reinforced.
- System approaches have still clearly to be developed in the forest-based sector in order to meet global challenges.

CURRENT ACTIVITIES

- Support, develop and improve networking actions as well as research and innovation funding partnerships

- Contribute to defining priorities for the next National and European framework programs for research and innovation
- Broaden the scope of international cooperation in relation to agricultural issues and global challenges.
- Stay tuned to developments in public policies related to the forest sector to feed them as needed.

COMPOSITION

- Member states: AT, BE, CZ, DE, EE, ES, FI, FR, GR, HU, IE, IT, LV, LT, NO, PL, SE, SK, UK ...
- Other potential members (contacts): BG, PT, TR
- Observers: EU DG AGRI, EFI, INNOVAWOOD, IUFRO, FORESTVALUE

Domain covered by the working group

Forests and other wooded land cover about **44% of the EU land area**, that means slightly more than agricultural land. They include a **wide variety of ecosystems** from the boreal zones of Scandinavia to the outermost regions of the tropics, including continental, oceanic and Mediterranean areas. They constitute an exceptional reservoir of **biodiversity**, an irreplaceable element of the **landscape**, a huge and increasing **stock of carbon, wood and non-wood resources**. They offer a **large set of ecosystem services** (Common international classification of ecosystem services – CICES) from regulation (climate, water, soil, air and biodiversity) and provisioning (nutrition, materials, energy and genetic material) to cultural amenities (human interactions with natural environment). Although the proportion of the territory they occupy worldwide is slightly lower (around 30%), forests have the same importance at the planet level.

Because of its overall weight and provision of numerous fundamental services, the forest-based sector is essential for societies worldwide and particularly in Europe. It is a primary component of **environmental and societal wellbeing**, and makes a significant contribution to **local and national economies, rural development and individual livelihood**. It must all the more be considered that it is subject to **various major and increasing risks and opportunities**: climate change, biodiversity conservation, illegal timber logging, deforestation, social expectations, development of bioeconomy and ICTs, etc. These changes have a particular resonance due to the **length of forest cycles** to which they add to challenge the **resilience** and **sustainable management of forests**. The development of **bioeconomy** finds with forestry a strong ally producing services and goods, among which wood, that is to say of a renewable, natural, and energy-efficient resource, with singular properties in terms of aesthetics, insulation, acoustics, resistance, chemical compounds ...

However, the forest-based sector is **highly fragmented** among multiple and often non-professional forest owners (on the resource side) and mainly SMEs (on the industry side). It is also torn between several forest-related public policies or strategies that are partially linked but often lacking connections between them: biodiversity, rural development, climate, energy and bioeconomy, sustainable development, forest and timber and, of course, research and innovation.

Main facts, figures and trends regarding the domain covered by the working group, as regards Sustainable development goals

Forests provide human societies with many benefits in the form of goods and services. They are concerned by almost all sustainable development goals (2015) as it is commented below.

(1) forests play an important role in the fight against **poverty** by providing livelihoods for the 820 million people living in the tropics near forests, 251 million of which are below the poverty line (40 % of people below the poverty line) and providing regulatory services to small-scale rural agriculture (FAO, 2018)[2]; this reality is subject to the rights of people to access, participate in and manage forests, while about three-quarters of the world's forests have national status; note that food consumption in developed countries influences deforestation in the tropics; deforestation in the World is mainly due to agriculture that explains 53% of causes and 70% of causes that can really be explained; a significant part (13%) of the products is consumed in developed countries after importation.

(2) forests contribute directly or indirectly to **food security**; directly, they produce dietary supplements to more than one in 10 people worldwide (FAO, 2016, Vira et al., 2015); indirectly, they very often provide the energy of cooking food and ecosystem services (pollination, water and soil protection ...) benefiting food crops around;

(3) the role of forests in **human health** is now well referenced; forests contribute to human health through food and medicinal plants; moreover, silvicultural experiences are increasing and the forest is in any case a privileged place for recreation and nature activities;

(4) forests participate in a quality **education** by constituting a real school of nature where can be observed and studied many animals and plants, some emblematic (great apes, ungulates ...) and the functioning of ecosystems;

(5) with forests, **women** have the opportunity to participate in the governance of natural resources, which is in line with a better gender balance; in developing countries, they are often responsible for managing the supply of fuelwood and non-timber forest products, including medicinal goods; they occupy more and more forestry jobs, both in developed and developing countries; but they must still progress in the hierarchy to assert their presence at the decision-making level;

(6) forests are essential in terms of **water** cycle and purification; they regulate water flows by favoring rainfall, allowing groundwater recharge and returning moisture to the atmosphere by evapotranspiration; they avoid soil erosion and promote the quality of the water they filter; more than three-quarters of the world's usable water supply would come from forest watersheds around the world (FAO, 2018) and more than half of the world's population would depend on them for domestic, agricultural, industrial and environmental purposes;

(7) forests provide basic **renewable energy** to about 2.4 billion people worldwide for cooking and heating; wood energy also supplies industries (including for electricity generation and cogeneration of heat and electricity, according to the international energy agency, renewable energies account for nearly 20% of primary consumption of energy, and wood accounts for about 40% of these renewable energies, as much as solar, hydroelectric and wind energy combined (FAO, 2018), by protecting the soil from erosion, forests also promote energy production. (FAO, 2018 citing FAO, 2014), however, woodfuel is criticized for polluting the air and not effectively combating the greenhouse effect because of the low efficiency of many households, which argues in favor of efforts to solve this problem, and the substitution of wood energy for fossil fuels is not a panacea to mitigate competition from other uses of wood, especially in the form of material, more virtuous in their fight against the greenhouse effect;

(8) forests are at the base of **value chains** in the fields of timber and tourism; they contribute to the gross domestic product, the balance of the trade balance and employment (especially in rural areas) in a very significant way;

(10) by meeting the needs of the poor and those in remote rural areas, forests help to reduce **inequalities**;

(11) forests contribute to the security, resilience and sustainability of **cities**; In view of the large proportion (over 50%) and increasing proportion of the world's population living in cities, as well as climate change and the loss of biodiversity, urban and peri-urban trees and woodlands play an increasing role. landscape and relaxation space for urban dwellers, the fight against heat islands and air pollution, ecological corridor; forests therefore deserve to be integrated into urban planning projects from the earliest stages of their design; moreover, a considerable part of the city's drinking water comes from rural forest areas;

(12) The forest-based sector is based on renewable resources (timber and non-timber forest products) that can be used in multiple cascades that illustrate the concept of **sustainable**

production and consumption, which does not exclude that progress can be made (what has been and is still the case) to enhance the value of by-products (eg for panels and the paper industry), to better recover and recycle waste paper and other wood products, and to produce energy preferably at the end of life; in particular, wood is an essential resource for a successful transition to the bioeconomy; over the past five decades, industrial roundwood harvesting has developed (Figure), particularly from 1970 to 1990 and since 2000, with a period of stagnation between the two; it is remarkable that an even faster evolution has taken place for sawnwood and panels, which reflects a better use of the material; in terms of population, the consumption of sawnwood and panels is not higher today than 50 years ago;

(13) the forest-based sector makes a remarkable contribution to the fight against **climate change**, in various forms: carbon sequestration in the forest by growing trees; storage in living biomass, then dead biomass and soil organic matter, finally in products, after logging and transfer to the economic sphere; saving fossil energy during the processing of wood, which generally requires less energy for processing than most of its competitors (cement, clay, ceramics, glass, metals, etc.); also direct substitution of bio-energy with fossil fuels for the production of heat, electricity, fuel ...; therefore, reducing deforestation, afforestation and sustainable management of existing forests (sources of wood material and energy risk-resilient) are actions that contribute to mitigating climate change;

(14) Forests also contribute to the protection of **aquatic fauna and flora**, including riparian formations that prevent soil erosion and provide a filter for runoff water;

(15) Forests play a crucial role in the protection of **terrestrial fauna and flora** in the context of sustainable forest management, which is in line with the Sustainable Development Goals above.

(17) The above scan shows the strong contribution of the forest to most of the **global objectives**, at least 14 of the 16 above objectives; the basic forestry issue is to take into account each aspect to find the best possible compromise between them in liaison with the various stakeholders; it therefore requires appropriate governance.

Analysis of the main emerging issues in the domain covered

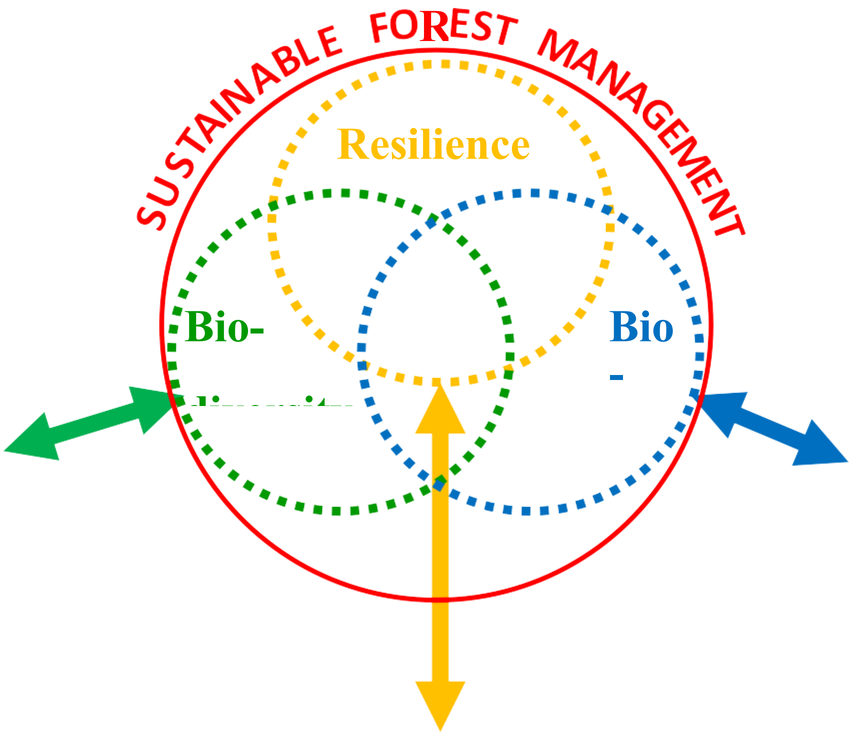
In this section emerging environmental, social, economic, health, ethical issues characterizing the domain should be analysed in light of Sustainable Development Goals.

Forest research got quickly a good comprehension of changes, risks and uncertainties which, however, question the way in which medium and long-term projections are constructed from past observations and experiments. In addition, the field of research is expanding and evolving towards **more interdisciplinarity to fully integrate change, risk and uncertainty management into decision support**. (SDG13)

Ecosystem services are now better analyzed than in the past when wood production was mainly under consideration. Nevertheless, **analyses on multiple and interacting ecosystem services should be better coordinated with more attention on synergies and trade-offs between them at different spatial scales**. (SDGs 1, 3, 6, 7, 8, 11, 12, 14, 15)

Bio-based activities showed a real ability to organize networks at the European level and their high potential for innovation. But much **more efforts are necessary to create and market new products** (be they goods or services), increase productivity, use all the resource potential, promote wood against other materials and energies, and add socioeconomic to technical considerations. (SGDs 7,8, 12, 13)

Overall, there is a need to support the forest-based sector in its difficulty **to act simultaneously on its decisive contributions to major issues such as biodiversity, bioeconomy or resilience that cannot be treated separately. Such overall coherence is all the more needed as these issues are intensifying.**



Contribution of the working group to the three transitions

Analysis should address the following questions:

Target 1: Healthy and sustainable food for all

Forests and forestry are mainly concerned through:

- Picking of mushrooms and berries; in Europe, it is generally more a goal for recreation than a true contribution to food.
- Production of honey, much of which comes from forests.
- Hunting game; in Europe, hunting is also a leisure activity but it provides some quantity of meat that is likely to be valued at about 1 billion €/year; regarding particularly large ungulates, the population of whom is increasing everywhere, there is a potential to increase the hunting board with several effects.
    - Target: increase the hunting board for ungulates; it will contribute to food provisioning and, in the same time, to silviculture (prevention of browsing or

fencing), on adaptation to climate change (larger set of potential species), on the health of wild animals and on the health of domestic animals that could be contaminated (see for example the case of the African swine fever); the target cannot be set very easily and depends on species and local conditions; but a significant increase is needed in many places;

  - Enablers: the number of interests beyond food could help to reach the target.
  - Barriers and risks: hunters generally prefer to manage a lot of game and maintain high levels of populations; the number of hunters tends to diminish in Europe; a large part of society also prefer to see as many deer as possible.

- Water quality can be improved by good forest practices, for example around catchments; in some cases, reforestation is also a way to limit erosion, to facilitate infiltration and to lead to a better water quality.
- Agroforestry that is a way to find a synergy between agricultural productions and trees.
- "Imported deforestation": in that case, the problem is linked with consumption behaviors in Europe that are partly responsible of deforestation in the tropics; last July, The European Commission published a communication to the European Parliament, the Council, the European economic and social Committee and the Committee of the Regions in order to step up EU Action to protect and restore the World's Forests;
  - Target: the objective is to halt global forest cover loss by 2030; it needs much improvements in terms of land use change monitoring, trade modelling, certification schemes.
    - Enablers: consumer associations that can make a pressure on firms to avoid deforestation, firms that are encouraged to look after consumers; regulations, tax systems and certification schemes that promote good practices.
    - Barriers and risks: Leakage is a potential risk that could just transfer the problem elsewhere.

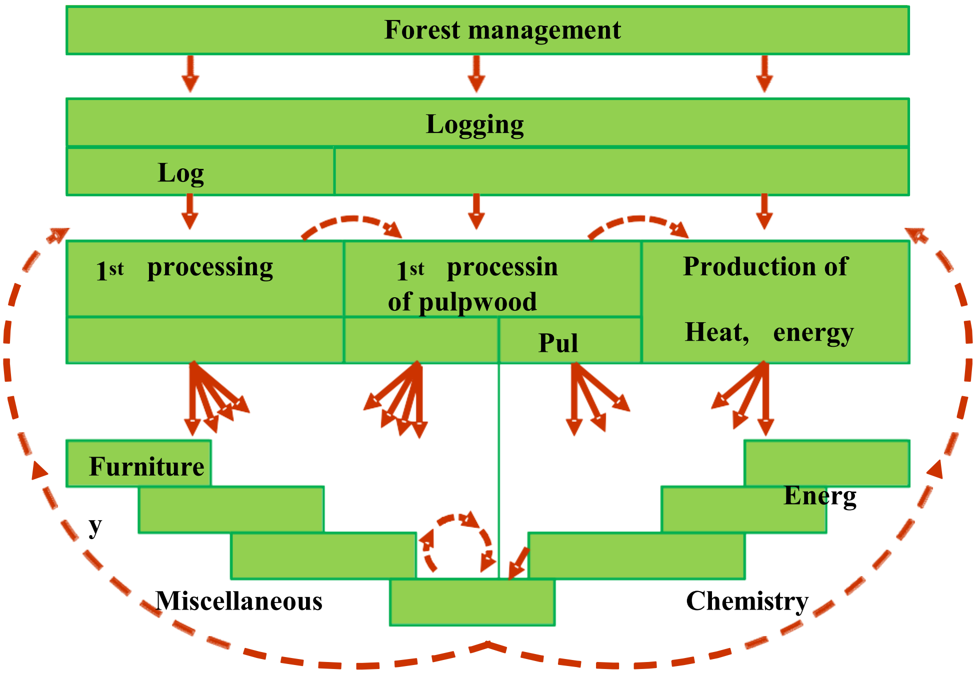
Target 2: Safe and just circularity of food systems

Circularity is an important concept for forestry as a source of materials and energy. Here, the link with food systems is still tenuous but twofold:

- The marketing of food products uses packaging that comes largely from the forest-based sector (wooden crates, cheese boxes, and pallets; paper sheets or bags and paperboards…); agriculture also uses (and could use more) forest products for fences, buildings…

- The forest-based sector is based on biomass that is also a by-product of food systems (and sometimes a product): it is complementary to the agricultural sector.

The figure shows schematically the forest-based sector with the main elements of circularity that are implemented: sawmill residues are used as pulpwood or for energy; some products are recycled such as wooden pallets that are reused and recycled; more and more product are processed again at their end of life, following the example of waste papers; end-use of end-of-life products may finally be energetic.



In Europe, there is a potential for a better use of forest resources because the felling rate is much below the level that could be reached under sustainable forest management.

- Target: development of the use of wood as a material, for example in construction: sawnwood, plywood and veneer sheets, other wood-based panels using silviculture and first processing residues, recycled products, new products from recovery of end of life products; a secundary target is to adapt the production of paper, paperboard, chemistry and energy to the demand in the frame of sustainable forest management.
- Enablers: the biological nature of wood, its renewable nature, and its sobriety in terms of carbon emissions that make it a major candidate to develop

bioeconomy.

- Barriers: the difficulty for a sector made of many SMEs to be organised facing the competition with other materials such as concrete, glass, iron, plastics…

Target 3: Substantial increase of biological, social, and economic diversity

Diversity is a crucial driver of the forest-based sector for many reasons:

- forests are home to a major part of terrestrial biodiversity, which is also important to ensure the stability, the productivity and the resilience of forest stands;
- the length of forest cycles creates some uncertainty on the future of resources; but diversity is a way to prevent ecological and economic risks or uncertainties;
- climate change is an additional issue that reinforce the need for diversity; the forest-based sector can mitigate climate change partly but effectively if, and only if it is adapted enough to resist to impacts such as drought, wild fires, pest outbreaks, windstorms; forest adaptation to climate change is a difficult task that still need to be analyzed; there is much uncertainty about the future because the climatic scenario that a tree will experience depends, due to the long life-cycle of trees, on the future actions that will be taken outside of the sector in order to mitigate climate change.

One main objective of sustainable forest management is to implement, maintain and improve a forest multifunctionality that ensures that ecological, social and economic issues are taken into account.

- Target: increase sustainable and multifunctional forest management
- Enablers: payments for environmental services will facilitate the implementation of a balanced forest multifunctionality and allow to support common or public goods such as many forest ecosystem services
- Barriers and risks: Many actors see forests under one dimension only and could consider that forests are an adjustment variable for their own strategy:
  - When and where there is deforestation, farmers and developers often consider forests first as a land reserve.
  - Some actors from the forest-based sector see forests as a wood resource only.
  - Energy specialists expect energy wood from forests and would like to increase the share of renewable energies (but another way to increase this share is to save energy consumption, which is why solid or reconstituted wood products can perform very well).

- Hunters would like that we consider mainly the game populations.
- Naturalists are in favor of the development of biodiversity and often think that biodiversity will increase with some limitations on the roundwood harvest
- People in charge of climate change mitigation would like to manage carbon first, and sometimes to store carbon in forest and to decrease fellings (that would reduce jobs and income, and increase imports or the demand of other materials than wood, and thus increase carbon emissions and climate change impacts.

Once multifunctionality is organized, diversity may be developed in many other ways

- Stand and tree diversity (species, ages), potentially with an insurance system.
    - Target: maintain or increase tree species and ages diversity in stands (climate change reduces the set of possible species that should then be considered more broadly).
    - Enablers: natural regeneration or plantations with accompanying vegetation; possibility to make decisions at the local level; a sufficient level of fellings is necessary;
    - Barriers and Risks: to increase or adapt the age and species diversity of a stand may need a whole forest rotation (cycle), that means several decades and often one century or more: the risk is that this rhythm could be insufficient in the face of climate change; beyond this technical risks, a question is what changes society is able to accept, or adopt.
- New forest products in order to increase the set of production options.
    - Target: develop new products.
    - Enablers: wood is a complex material (physical structure, chemistry) that has not yet been completely covered.
    - Barriers and risks. Powerful concurrent sectors of wood. Time required to obtain authorizations and put a new product on the market.

Policies for the achievement of the targets

The forest-based sector is a part of multiple public policies, and particularly the following ones:

- the biodiversity strategy that has been elaborated in Europe in 1998, after the Council Directive on the conservation of natural habitats and of wild fauna and flora (1992) and the UN Convention on Biological Diversity (1992), then renewed for the period 2011-2020; it is about halting the loss of biodiversity and ecosystem services, controlling invasive alien species, developing green infrastructure, enhancing the sustainability of agriculture and forestry;

- the bioeconomy, climate and energy strategies that follow the UN Framework Convention on Climate Change (1992) and its Paris Agreement (2015) with targets in terms of reduction of greenhouse gas emissions, an increase of the share of renewable energy in energy consumption, and an improvement in energy efficiency;
- the Common Agricultural Policy “second pillar” aiming at the development of rural territories and considering forestry measures contributing to sustainable development;
- the forest strategy of the EU partially compensates for the lack of a forest policy as such (that is let to EU members); it calls for a holistic vision and a multifunctional forest that contributes to both rural development, business, environment, bioenergy and climate protection, supported by research and development;
- the strategies regarding forests outside Europe are also important for the European Union; they aim at preventing illegal logging with the FLEGT program (Forest Law Enforcement, Governance and Trade, 2003) and its EU timber regulation (2013); they could also prevent deforestation (often caused by agricultural extension) after the EC Communication for Stepping up EU Action to Protect and Restore the World’s Forests (2019);
- the approach to sustainability that follows the UN sustainable development goals (2016-2030) and claims to consider all the previous aspects together.

These policies or strategies provide a good basis for a transition to sustainable and multifunctional forest management. These policies or strategies provide a good basis for a transition to sustainable and multifunctional forest management. Their harmonization is however not easy and must be organized all the time. In addition, some pitfalls must be avoided, including the following:

- an exit from the era of fossil energies emphasizes the development of renewable energies; as for wood, an interesting strategy is to first develop the use of wood material rather than that of wood energy as one might think; indeed, the use of wood material saves energy compared to the competitors of the wood, thus reduces the denominator of the fraction which makes it possible to calculate the share of the renewable energies and thus increases this one mechanically; in addition, the wood material can be used for energy purposes at the end of life;
- Biodiversity protection justifies combating deforestation, but does not necessarily preclude either increasing timber removals when these are lower than the net biological increment of forests, or increasing hunting when the density of large ungulates exceeds the carrying capacity of a resilient and productive forest;
- The reduction in wood removals, which a part of society tends to claim, favors either imports of wood products or products from more energy-intensive industrial processes

than the forest- based sector, and thus leads to greenhouse gas emissions to enhance climate change when it needs to be mitigated;

- Although the long-term goal of Paris Agreement is to keep the increase in global average temperature to well below 2°C above pre-industrial levels and if possible to about 1.5°C, forest adaptation should be managed taking into account a range of other scenarios because setting mitigation goals does not necessarily guarantee that they will be achieved;
- High biodiversity is a good ally in the face of climate change, but is not necessarily enough to withstand it, depending on the climate scenario that the forests will have to undergo.

Finally, a good way to harmonize forest-related public policies is to consider that, apart from a network of a few well-distributed protected areas ensuring the entire ecosystem cycles, the search for a quality production objective, providing many ecosystem services and wood material of appropriate size for industrial uses contributes to a high level of biodiversity, landscape, regulation of biogeochemical cycles, economic wealth and resilience to risks.

Challenges for research

Research has to overcome some difficulties encountered by the forest and forestry domain:

- the complexity of the forest-based sector in the ecological field (long life cycle, ecosystem functioning and diversity, spatial variability, interface between the soil and the atmosphere, in the middle between cultivated and natural assets), in the socioeconomic sphere (multiple forest owners and SMEs, many and strong social expectations) and the policy arena (many forest- related policies including biological diversity, climate and energy, bioeconomy, rural development, trade…);
- the need for coherence, improving synergies and minimizing trade-offs between all these dimensions (biodiversity, bioeconomy, resilience, societal expectations) that could conflict with each other in a counterproductive way;
- global change that comes in addition to long forest life-cycles and increase the uncertainty about the future and the difficulty to support decision making;
- the fragmentation of research to deal with a very

multidisciplinary field. Some directions for future research are thus

based on the following principles:

- the development of system approaches in order to find consistent solutions;
- the need for interdisciplinarity and transdisciplinarity;

- the support from a high potential for innovation and progress in forest management (monitoring, delivery of ecosystem services, sustainable wood mobilisation) and forest industries (new resource-, energy-efficient and environmentally sound processes and products, advanced wood-based materials and chemicals, new value-chains; incl. among other things dedicated R&I initiatives addressing hardwoods and dedicated R&I adopting and advancing digitalisation);
- the development of trans-national collaborations that will speed up the innovation process, make it more efficient, and will foster the development of the forest-based sector;
- the need to intensify exchanges between science and policy and to develop also communication between scientists, experts, decision-makers, professionals, stakeholders and the general public.