Deliverable 4.3

Research and innovation policy for future-proofing the food system

Work package number and title:	WP 4 Exploration of roadmaps for R&I breakthroughs
Lead-beneficiary:	F4L
Work package Leader:	Jonas Lazaro-Mojica
Relevant Task:	T 4.3
Dissemination Level:	Public
Due Date (month):	M17
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This paper is the draft of one of the deliverables of the FIT4FOOD2030 project and aims to provide a set of recommendations to policy makers at European and EU member states level on how Research & Innovation can better contribute to responsibly changing the food system in order to respond adequately to the grand challenges related to food and nutrition security[b].

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[b] The authors of this paper want to thank the members of the Stakeholder Advisory Board of JPI HDHL, SCAR Food System, the FIT4FOOD2030 Think Tank, the FIT4FOOD2030 consortium and European Technological Platform (ETP) Food for Life members for their valuable feedback earlier versions of this paper. Their feedback was collected during four 90 minute workshops that took place in Copenhagen (5th April), Rome (11th April) and Brussel (15th and 16th April) and through reviewing the paper.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No774088

Document History and Information

VERSION	DATE	DESCRIPTION AND COMMENTS	AUTHOR
1.1	26 February	Review from WP4 members: VU, AIT, INRA, ZonMw, ILSI, UniBO, EIT-Food, F4L, Ecsite and IrsiCaixa.	Anne-Charlotte Hoes, Just Dengerink, Floor Geerling-Eiff and Gemma Tacken
1.2	28 March	Review from multiple stakeholders from: JPI HDHL, SCAR, Wageningen Economic Research, FIT4FOOD2030 General Assembly, FIT4FOOD2030 Think Tank, ETP Food for Life, and comments from EC	Anne-Charlotte Hoes, Just Dengerink and Gemma Tacken
1.3	10 May	Review from Mads Dahl Gjefsen, Kris Kok, Sjaak Mesu, Krijn Poppe, Barbara Regeer, Simone van der Burg, Jolien Wenink and Jacqueline Broerse	Anne-Charlotte Hoes, Gemma Tacken and Just Dengerink
1.4	29 May	Review from Barbara Regeer, Jacqueline Broerse	Anne-Charlotte Hoes, Gemma Tacken, Just Dengerink and Simone van der Burg
1.5	14 June	Review from Tomris Cesuroglu	Anne-Charlotte Hoes, Gemma Tacken, Just Dengerink and Simone van der Burg, Kris Kok and Jacqueline Broerse
1.6	10 July	Review from Mads Dahl Gjefsen and Barbara Regeer	Anne-Charlotte Hoes, Gemma Tacken, Just Dengerink and Simone van der Burg, Kris Kok and Jacqueline Broerse

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Contents

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Key message: adapt research and innovation policy for a healthier and more sustainable food system

To solve the grand challenges related to food production and consumption, breakthroughs are needed in research and innovation (R&I) that foster changes in the entire food system, targeting not only the food production chain, but also the social, political, economic and environmental aspects related to it.[5, 6,7,8] In order to realise the needed breakthroughs, European and regional funding systems for R&I need revision. This paper argues the need for three revisions: to include research topics regarding food system innovation on the research agenda, to foster responsible R&I and to add to public R&I funding institutions the task of acting as 'innovation brokers'.

Inclusion of topics on the research and innovation agenda, aiming at breakthroughs in the food system

A research agenda that targets the entire food system and includes R&I topics that support promising designs, start-ups and grassroot alternatives, would foster the development of more R&I projects that contribute to future-proofing the food system. In addition, projects aiming for food system and R&I system analysis are needed in order to find drivers and barriers for breakthroughs. Such analysis depends on high quality and quantity of FAIR (find, access, interoperate and re-use) food data.

Action-oriented responsible research and innovation to improve the R&I system

Responsible research and innovation (RRI) aims to include a variety of stakeholders in a reflection on the value of an innovation for (future) human and animal lives and the environment, during the research and innovation process. Responsible research and innovation (RRI) helps to distinguish societal obstacles which may hinder the implementation of the innovation, as well as the values that innovation allows to help to bring about. Feeding these insights into the research and innovation process in a pragmatic and realistic way can contribute to making innovations that are valued and used broadly in society. Furthermore, as RRI involves stakeholders early on in the R&I process, it helps to identify the changes that are needed across the food system (and competences of the various actors responsible for it) in order to make the innovation successful.

R&I funding institutions taking a more active role, as 'innovation brokers'

In order to bring about changes effectively, funding institutions could be more actively involved as 'innovation brokers'. Funding institutions can assist R&I projects by sharing forecasts, gaps and signalling progress and potential conflict, or they can help to bring about more efficient changes in the food system by broadening their scope beyond the single R&I projects. Funding institutions can take a role in developing programmes that connect several subsystems, such as policy, business economics, and biology and health, in order to bring about change in the entire food system.

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1. FOOD 2030 and FIT4FOOD2030 to work on solving the grand food-related challenges

Europe faces grand challenges related to food production and consumption in the 21st century. Examples are climate change, global population growth, the pollution of the environment, a degradation of public health due to unhealthy diets, migration, and poor economic viability and public acceptance of food production (see a selection of these challenges in Table 1).[1,2,3,4]

Table 1. Selection of grand food-related challenges in Europe, taken from the FIT4FOOD2030 EU think tank policy brief[83]

Urgent problems	Evidence
Adult overweight & obesity	**62% overweight**, including **25% obese** in EU in 2016 [88]
Childhood obesity	Prevalence up to **30%** in EU countries [87]
Double burden of malnutrition	**120 billion euros**/year/EU government[89]
Antimicrobial resistance	**33,000 EU deaths**/year[104]
Soil erosion	**Affects 25%** of EU agricultural land [121]
Greenhouse gas emissions	**26%** of EUs total energy consumption from food chain activities[105]
Pesticide residues	**Found in 83%** of EU soils [109]
Declining crop diversity	**Only 9 crops account for 66% of total crop production**, while more than 6.000 crops have been cultivated[107]
Water scarcity	**66%** of renewable water resources used by agriculture[105]
Vertebrate pollinator loss	**16.5% threatened** with global extinction[107]
Food waste	**88 million tonnes** of food wasted/year in EU[106]

To respond to these challenges, breakthroughs are needed in research and innovation (R&I) that foster changes in the entire food system, targeting not only the food production chain, but also the social, political, economic and environmental aspects related to it.[5, 6,7,8] As a response, the EU initiated a policy framework called FOOD 2030. FOOD 2030 aligns the UN Sustainable Development Goals (SDGs) and focuses on the following priorities to overcome environmental, societal and health challenges that are related to food (see Figure 1):[7,8]

- **Nutrition** for sustainable and healthy diets
- **Climate**-smart and environmentally sustainable food systems
- **Circularity** and resource efficiency of food systems
- **Innovation** and empowerment of communities

Implementing the FOOD 2030 ambitions in the R&I system of the European Union (EU) and of EU member states is not an easy task, among others because food policy and R&I are fragmented[10] as they are structured primarily through specific policy areas and monodisciplinary research fields with own methods, terminology and views that are hard to bridge.[11,12] In recognition of these challenges and complexities, Responsible Research and Innovation (RRI)[13] and the food system perspective[1] have emerged.

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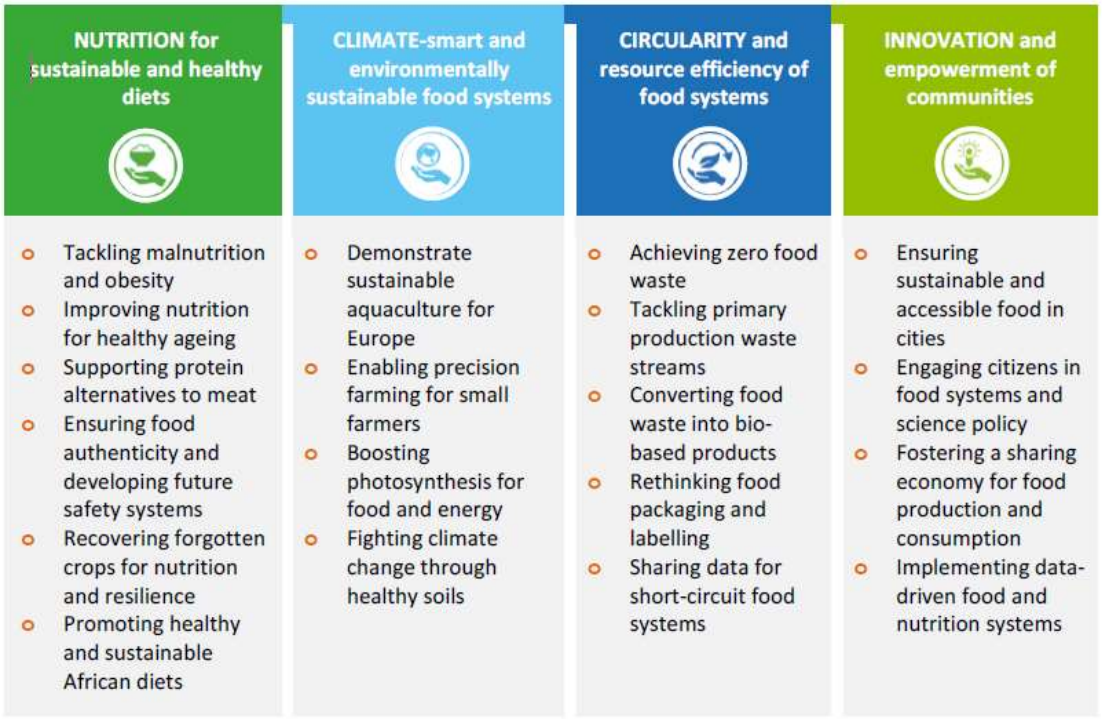

Figure 1. FOOD 2030 goals.[7,8]

FIT4FOOD2030, a Coordination and Support Action (CSA) project within Horizon 2020, supports the European Commission FOOD 2030 policy framework on the urgently needed food systems transformation towards sustainable, resilient, responsive, inclusive, competitive and diverse future-proof food systems through R&I.[14,15,16] To this end, FIT4FOOD2030 aims to (1) strengthen R&I policy coherence and alignment (2) build competences for food systems R&I, and (3) raise awareness. The project has established the FOOD 2030 Platform which comprises three interlinked structures: the EU Think Tank, Policy Labs and City Labs, which interact regularly to exchange information, learn from one another, and plan actions. To support the emerging platform, current trends, policies, showcases and breakthroughs in food system R&I are analysed. FIT4FOOD2030's activities comprise four phases: (1) actor identification/mobilization and visioning/system understanding; (2) developing roadmaps; (3) action planning and training; and (4) scaling up and continuity. Cross-cutting components are: methodology development and transformative learning. See Figure 2 for the envisaged impact pathway of FIT4FOOD2030.

During its first 18 months, the project has laid the foundation for the FOOD 2030 Platform, and has successfully completed the first two phases. After termination of the project, the goal is that the developed FOOD 2030 Platform will continue and keep on working on the transformation of the R&I system to better support the aspired food system transformation.[14,15,16]

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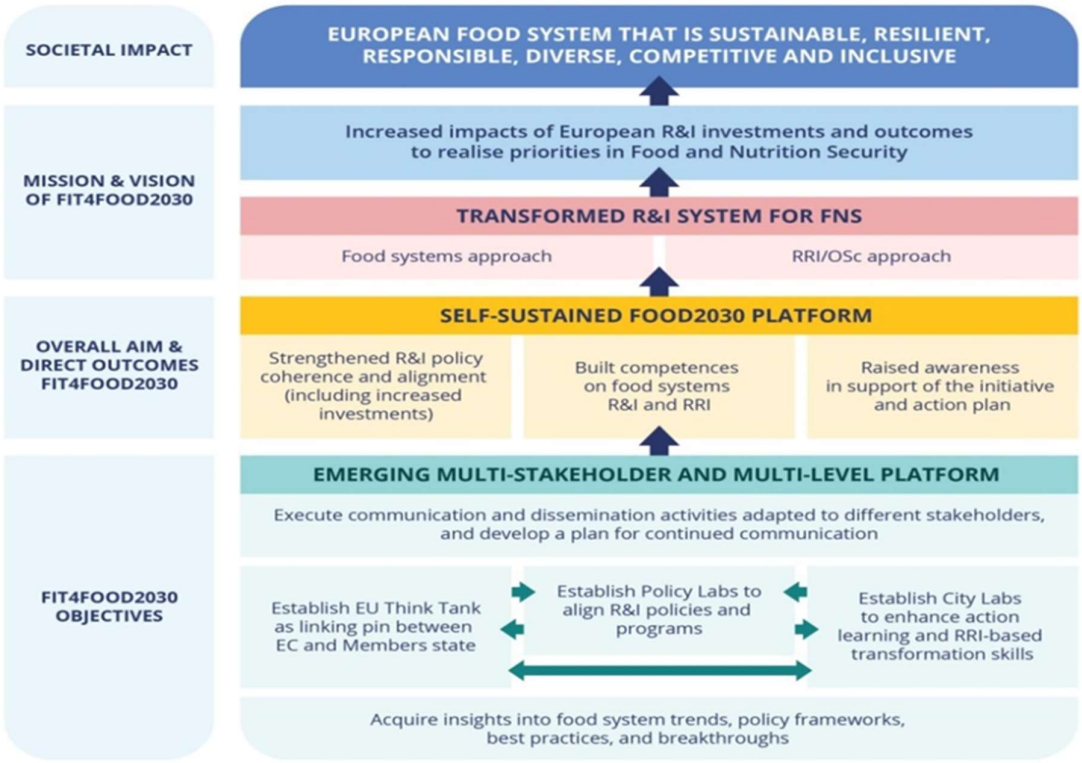

Figure 2. FIT4FOOD2030's societal impact, mission & vision, overall aim and specific objectives.[14]

This deliverable (D4.3) is part of Work Package (WP) 4 on roadmaps for R&I breakthroughs. Based on the outcomes of WPs2&3 (WPs on trends/policies and showcases respectively), a set of conclusions and recommendations are developed here in using the systems approach and the RRI concept to enhance food system transformation. The paper will be used in the City and Policy Lab's dialogues around the urgency, possible good practices and pathways for applications of the systems approach and RRI concept to food system transformation to stimulate improved policy alignment and competence development. It will also be translated into a Policy Brief, so as to inform policy makers at various levels.

Draft versions of the paper were discussed in a series of workshops with the Joint Programming Initiative A Healthy Diet for a Healthy Life (JPI HDHL), SCAR Strategic Working Group on Food Systems, FIT4FOOD2030 General Assembly, EU Think Tank and European Technology Platform (ETP) Food for Life in Copenhagen, Rome and Brussel in the period March and April 2019.

In section 2, we will introduce a complex systems perspective to highlight the challenges of achieving a healthier and more sustainable food system, and will identify drivers and barriers for change, as well as ways to support food system transformation. Section 3 will deal with the way R&I systems are designed and can be improved to more effectively serve as leverage points for food system transformation. In section 4, we will introduce some concrete tools and guidelines for realising food system transformation for (1) policy makers (2) funders and (3) the research community. Finally, in section 5, we will formulate a set of recommendations on:

- Inclusion of topics on the R&I agenda, aiming at breakthroughs in the food system;
- R&I funding institutions taking a more active role as 'innovation brokers'; and
- Improving competences on action oriented RRI to improve the R&I system.

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2. Food system perspective and FIT4FOOD2030 approach

2.1 Food systems go beyond value chains

A food system can be described as an adaptive system that exhibits complex dynamics.[110,111] As a system, food cuts across established sectors and is connected to a variety of (policy) fields – including agriculture, environment, energy, health, education, infrastructure and planning. This means food systems are multi-functional, multi-factor and multi-actor. Therefore, there is increased recognition that traditional models focused purely on food production or linear models such as food supply or value chains are not appropriate to represent such a complex system.[1,5,7,8,30] This complex food system perspective is necessary because these linear models are insufficient for addressing the grand food challenges –root causes and potential solutions are overlooked. Also, without a food system perspective, policy measures for a single issue can create unforeseen negative consequences for other issues.[31] For example, stimulating fish consumption for public health may have unintended negative impact on marine life.[25] Next to that consumers make unhealthy choices in terms of over consumption or unilateral food choice behaviour. The competitiveness between land use for agricultural needs, social and economic needs, and the environmental is another dilemma.[10] Identifying and upscaling co-benefits in the food system for health, economic and environmental policy is the challenges for the next decades.[25]

The High Level Panel of Experts (HLPE) of the Committee on World Food Security defines food systems as "all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the outputs of these activities, including socio-economic and environmental outcomes".[1] This definition goes beyond the division between production led (including sustainable intensification) and consumption led approaches. A food system perspective is more adequate when aiming to stimulate the transformative capacity of a system.[1,108,112,122] Figure 3 is a simplified representation of the food system. Although the figure includes many elements, it still lacks crucial food system aspects such as fisheries, technologies and the R&I system.

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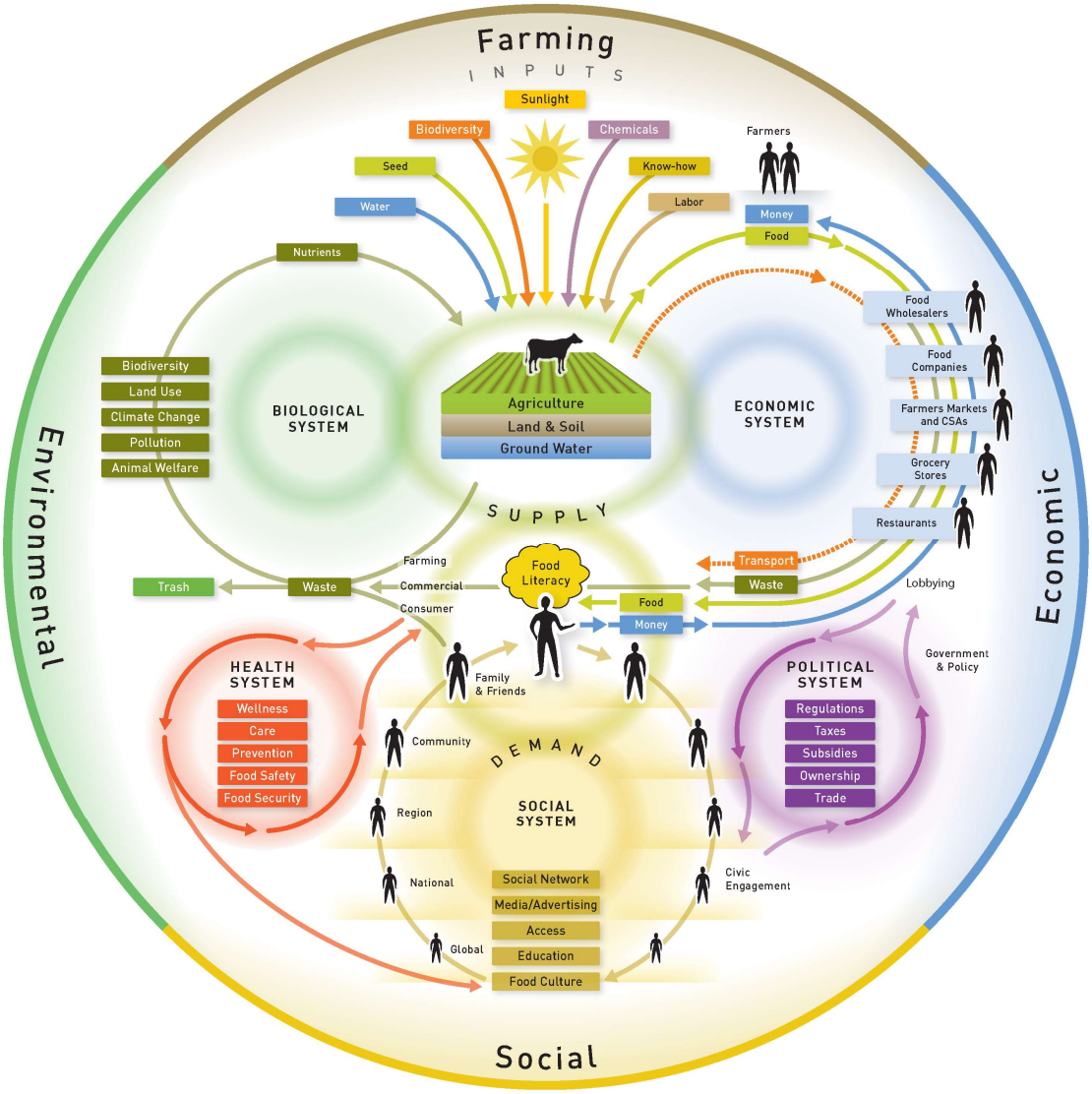

Figure 3. Food system map.[17]

The food system approach is increasingly being used internationally as a useful analytical framework to consider the interaction between public health, ecological sustainability and the robustness of food production and consumption.[1,18,19,20] Recent efforts to apply this approach show how the food systems perspective helps shaping policy priorities and R&I agendas.[2,21,22,23]

Changing current food systems so that they take into account sustainability and health issues is hard due to stability of the system. The stability is a result of existing (1) rules (both formal laws and social norms); (2) dependencies between actors, and; (3) hardware such as machines and infrastructures.[32] Stability is also strengthened due to economic interests, existing power dynamics,[33,34] and practices.[35]

This does not mean that food systems cannot change. The theory of Complex Adaptive Systems (CAS) illustrates that systems do change. They are 'adaptive, because external drivers (climate change, for example) as well as internal changes set chains of events in motion'.[36] However, although interventions may enhance food system change, it is not possible to directly 'steer' the change process in a desired direction. The complex interrelations within the food system make it impossible to fully predict the effect of interventions within the food system[114] as (unexpected) trade-offs, synergies and

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feedbackloops occur. Or in other words, there are too many unpredictable, uncertain and non-linear dynamics to handle complexity in a straightforward manner.[37] This explains why complex problems can trigger unproductive policy responses such as inertia/paralysis expressed as "there is nothing we can do about this problem anyway", or unrealistic expectations of what policy interventions bring.[38, p.2]

There are however more constructive policy responses to food system change which take into account the complexity of the endeavour. This paper argues that pragmatic interventions that regions or countries can take to bring the FOOD 2030 ambitions further are to analyse the food system and to promote R&I breakthroughs that have the potential to transform the food system in the long run.[39,40,41] The next section explains the conceptual model FIT4FOOD2030 applies.

2.2 FIT4FOOD2030 approach for food system transformation

In recent decades within the field of system innovation studies the multi-level perspective (MLP) has emerged as an important framework for analysing complex systems (see Box 1). [32,34,35,39,57,58,64,123] FIT4FOOD2030 adopted the MLP and argues that R&I breakthroughs, such as new proteins, personalised nutrition and health, biobased packaging, precision agriculture and urban agriculture[27,48], are important to solve the grand food challenges. Figure 4 visualises the underlying conceptual model of FIT4FOOD2030 and illustrates that breakthroughs are influenced by trends (or landscape in MLP language, see Box 1), regimes and showcases (or niches in MLP language, see Box 1). R&I breakthroughs cannot be forced but by analysing trends, regimes and showcases and by implementing policies that support promising showcases and reduce undesirable aspects of the regime, chances for successful R&I breakthroughs are improved. Section 2.3 elaborates on why it is import to analyse the regimes and trends of food systems and 2.4 explains showcases further.

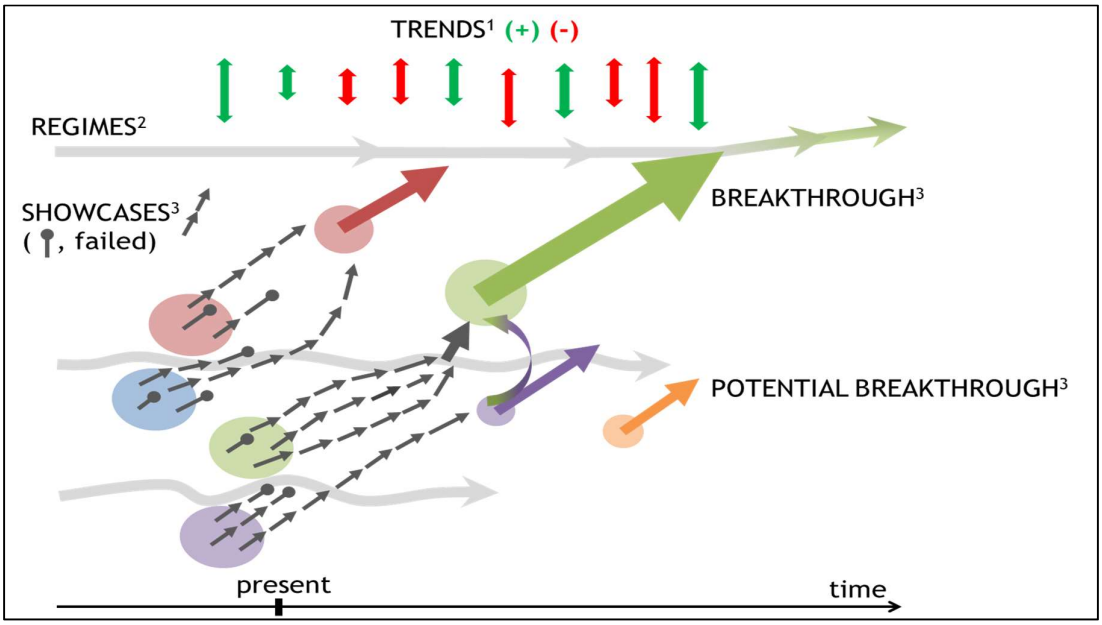

Figure 4. The multi-level perspective applied to the FIT4FOOD2030 project. Different areas of activity are represented by different colours.

Box 1: the multi-level perspective (MLP).[32]

The multi-level perspective distinguishes three levels: the niche (micro level), the regime (meso level), and the landscape (macro level).[57] The regime represents the dominant socio-technical system with its interacting actors, technologies, institutions and infrastructures. Regimes are

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characterised by routines, which are formalised through institutional rules or embedded as norms which makes regimes rather stable. As a result more sustainable alternatives can 'have a hard time to break through, because regulations, infrastructure, user practices, maintenance networks are aligned to the existing technology. New technologies often face a mismatch with the established socio-institutional framework'. [57,p.1258] To overcome these conservative dynamics a crucial role in played by niches.

Niches are 'the pockets of change' in which actors can develop and experiment with fundamentally new products, processes, and technologies that are considered a sustainable and healthy alternative. Niches are sheltered from the regime dynamics by, for example, being financially supported. This protection against the regime dynamics is usually temporary, as the alternatives developed in niches will eventually be adopted by the regime, resulting in a more sustainable regime, or fail.

The final level is the landscape, representing a broad range of conditions and trends at the social or natural macro-scales; such as global political trends, economic markets, wars or environmental pollution. Current trends within the landscape include global warming, population growth, urbanisation, biodiversity loss and the information (or digital) revolution. These usually long-term landscape trends interact with the regimes and niches.

2.3 Food system analysis to identify drivers and barriers for change

To transform complex systems such as food systems, it is necessary to better understand the technological, political, economic and social dynamics that shape the food system and to identify the leverage points where interventions will be most effective. The identification of these points necessitates a systemic approach in which multiple actors, governance levels and policy fields are taken into account.[105,114] A holistic or systems approach means the inclusion of both horizontal dimensions (different fields of action, such as environment, health, infrastructure, and education) and vertical dimensions (all different stages of the food value chain).[124] Within a systems approach, special attention is paid to the dynamics of the system: how the different components of the system interact with each other and how these interactions shape the behaviour of the system. Only with a systems approach in which multiple actors are involved is it possible to better anticipate unexpected and undesired side-effects of (technological) interventions in other parts of the food system and to design portfolios of experiments that will reinforce each other (e.g. at different levels and with regard to different thematic fields). Moreover, it helps policy makers to understand where in the food systems more R&I is needed to forge promising breakthroughs[42,43,44,45] that advance FOOD 2030 ambitions.

As part of a system analysis it is important to conduct a problem analysis to shed light on non-linear processes and feedback loops in the food system, and point to trade-offs between different intervention strategies and to better understand the root causes of problematic system behaviour. This will reveal where there are opportunities to intervene in the food system. Interventions should, however, not always focus on the place in the food system where the problem is most visible or where its symptoms feature. For example, household food waste is an issue that requires looking beyond consumer behaviour alone, to issues of quality and packaging that are to be addressed in a different part of the value chain. By intervening more at the root of the problem or in places that can be changed more easily in the food system, it may be possible to realise more positive impacts than intervening at symptom level. Consequently, policy interventions and R&I efforts might target a very different part of the food system than where the problem is initially detected.[83]

Analysing the food systems, thus, helps to better understand the dynamics and interaction between the different elements (activities, drivers, outcomes). Moreover, it helps policy makers to understand

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where in the food systems more R&I is needed to forge promising breakthroughs[42,43,44,45] that advance FOOD 2030 ambitions. Food system analysis can help identify niches that provide leverage points for transforming the food system. The food system perspective explicitly takes into account that the actors are part of complex adaptive systems. Actors constantly react to their changing environment, requiring adaptive innovation management. This implies that food system interventions should not try to fully plan, control and manage the system, but instead should anticipate events and reduce the chances of undesirable results.[42,46] The system perspective cannot predict outcomes, but it can 'model' proposed policies or other innovative solutions and forecast possible impacts under different scenarios. These insights help strategic decision making on policy interventions and R&I priorities.

Food system analysis depends on good quality data to accurately display trends and dynamics in the food system. Information on different types of outcomes is crucial: not only economic data but also indicators regarding food security, environmental impact, nutrition and health. At the moment, we for example lack detailed and uniform consumer food intake data, which makes it difficult to integrate consumer and public health issues into food system models in more detail.[47] Moreover, knowledge about the drivers of behaviour of different actors (e.g. consumers, farmers) is crucial to understand system dynamics.[43] To produce useful insights, it can be helpful to involve key players in the food system in the food system analysis, making use of their experience to better understand the dynamics and behaviour that shape the food system.[60]

2.4 Support promising initiatives to enable R&I breakthroughs for food system change

In the literature different terms are used than showcases to label promising initiatives, e.g. the aforementioned niches[39], but also grassroots innovations[49] and small wins[38,50] (see Box 2). Although such initiatives might be small scale when looking at the market share, they can be important because they have the potential to significantly impact on and change the food system as these initiatives are:

- incubators for alternatives as innovation and entrepreneurship can be nurtured through projects, public-private initiatives, Start-ups and Small and Medium Enterprises (SMEs);
- provide practical ways of experimenting and learning about changing the status quo in such a way that it will eventually create higher competitiveness; and
- inspire people as they show that sustainable changes are indeed possible.

Despite the importance of promising initiatives, most initiatives do not reach the breakthrough phase as they go bankrupt, funds dry up or volunteers lose interest. Or promising initiatives do not 'break through' and stay small, because it is difficult to gain traction and market share.[54,55,56] Therefore, most fail to achieve their transformative potential due to, for example, lack of competitiveness, proof of sustainability claims and/or citizen acceptance.

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Box 2: Niches, grassroots innovation and small wins

- *Niches* are about entrepreneurship and researchers that experiment with radical new products, processes, organisations and technologies that differ from the current practice and are considered as promising alternatives.[57,63] Strategic Niche Management (SNM) is about offering sheltered spaces/protection to these niches so that actors can experiment and develop these innovations without directly having to compete with the dominant socio-technical system (i.e. regime).[64]
- *Grassroots innovations* are defined as innovations initiated by civil society. They usually have aspects of activism and social innovation.[62]
- *Small wins* are defined as initiatives that gain protection from the dominant socio-political and technical system by 'staying under the radar'. This is realised because they are initially seen as of moderate importance by among others national or regional policy. Other characteristics of small wins are concrete outcomes (instead of promises or ideas only), in-depth change (instead of more of the same or quick wins) and with positive judgement.[38]

To support FOOD 2030, FIT4FOOD2030 identified more than 150 potential (show)cases, that include different types of initiatives.[52,53] Showcases can be R&I initiatives, social movements, good practices, networks, (nationally or internationally funded) projects and programs, case studies, demonstrations, technological inventions, process procedure improvements (e.g. in logistics/distributions), innovative educational approaches, new business models, etc. which offer opportunities for learning and inspiration (even if they might have ultimately failed to deliver on initial expectations) and have contributed to or affected food systems R&I in some way.

Next to the showcases, breakthroughs and regimes, *trends* form an important part of system dynamics. Trends provide the landscape in which showcases and the incumbent regimes exist. Similarly, they interact with showcases or existing practices, serving either as a driver or a barrier for a configuration to further develop. Trends differ over time and their influence may also change due course, and they can act differently on different showcases or regimes. Trends can be difficult to influence by individual actors, organizations or even nation states. Some examples are climate change, scarcity of natural resources and the emergence of big data analysis.

When several showcases towards a common vision are successfully developed, or the same innovation becomes institutionalized in many local geographical and governance contexts, the potential of a breakthrough (process) increases, which may lead to impact on several systems and institutionalized processes at once (be it in policy, in business or education approaches, etc.). In the MLP, showcases that have breakthrough potential act on an existing regime. Moreover, breakthroughs in one specific field can lead to breakthroughs in a different area of activity. Breakthroughs can be driven by technologies, social movements or developing markets. Furthermore, different forms of R&I breakthroughs exist. Start-ups can scale up, tests and designs from research institutes can lead to new business, existing companies can adopt novelties that were developed by others and other forms exist.[39]

In order to understand what drives or hinders the emergence of desired R&I breakthroughs it can be useful to think in terms of drivers (driving particular cases towards breakthroughs) and barriers (hindering the development of cases into breakthrough processes). Traditionally it was understood that while niche actors aim for dynamics and change, regime actors aim for stabilization of the status-quo and thus act as barriers for transitional dynamics. This is, however, not so straightforward and recent research has indicated that in fact there are many different interactions between configurations in niches, regimes and landscapes that can either serve as barriers or drivers for showcases in niches to further develop.[33,34,35,39,116,118,119,120] There can be situations where landscape

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trends serve as a barrier for the development of a showcase (for example of underdeveloped global markets hindering algae to food practices), or where regime actors cooperate with actors in niche showcases to actively drive new innovations forward. Drivers and barriers act very specifically on different showcases. What drives the development of one showcase might hinder the development of another showcase (e.g. government funding competitions for sustainable social innovation might drive the development of the winning initiative, at the cost of another initiative that now faces more competition (barriers) to develop). It is important to note that drivers and barriers can thus be landscape trends, but also interactions between showcases, internal developments in a showcase, interactions between regimes and landscape or interactions between regimes and niches or specific showcases within them.

Identifying promising initiatives and monitoring their progress with learning evaluation approaches, such as the Reflexive Monitoring in Action (RMA) approach[60], is a way to provide support. Most promising initiatives start with small groups of dedicated individuals that are easily overlooked by policy makers, companies, and researchers.[54] As some of these showcases play an important role in changing the food system, it is wise to gain more information about which promising initiatives are taking place and to decide which of these contribute to societal goals and should be offered broader public support. For understanding how future breakthroughs might be enforced through (R&I) policies it is therefore crucial to understand the interactions between showcases and their environment, as well as the drivers and barriers that showcases experience.

With this complex system perspective in mind and in order to understand how the R&I interventions could be designed to foster transformations towards more sustainable, inclusive and resilient food systems, it is important to identify not only cases that can be considered best practices, but also to identify pathways through which these best practices can be scaled-up to significantly and positively affect the food system. There thus is the need for identifying those best (novel) practices (showcases) as well as the need for understanding how these showcases have the potential to affect systems in a way that leads to large-scale structural transformations towards futureproof food systems (breakthroughs).

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3. Ways to improve the impact of the R&I system

3.1 R&I dynamics that weaken co-creation and reduce societal impact

One type of policy instrument to work on food transformation ambitions is to invest in R&I. R&I as an instrument to support societal change has a rich tradition[65] such as the Green Revolution, or Third Agricultural Revolution which during the 1950s and 60s increased agricultural production worldwide and facilitated demographic change.[66]

If R&I is to contribute to FOOD 2030 ambitions effectively, it is important to ensure that the relevant FOOD 2030 R&I topics are on the relevant research agendas. A food system analysis with a multi-stakeholder approach can assist in identifying relevant FOOD 2030 R&I topics. In the case of FIT4FOOD2030, the City Labs and Policy Labs provide an experimental space where the interaction with multiple stakeholders is facilitated and relevant R&I topics are identified, connected and addressed.

An assessment by the EU member states of current R&I focusing on food shows that most budgets are allocated to primary production and processing rather than to issues related to consumption or food waste.[67,68] Especially, limited R&I was found which links the domains of food and health. The report recommends to include health and consumers or citizens in the domain of food research as a way to improve public health.[68] The urgency to include health and consumption is also highlighted in the study executed by FIT4FOOD2030.[69] The scenario and modelling study executed here indicates "further growth in excess consumption, and rise of diet-related non-communicable diseases" in the EU.[68,p.10] In addition, more research is done on the production and consumption side of food instead of on the processing, marketing and retail aspects or on the impact of the 'food environment' on consumption.[30]

Similar to the food system perspective, R&I can be perceived as a system. The R&I system includes among others universities, research institutes, education, R&D of companies, online platforms, start-ups, community/citizen science, policy as well as other socio-economic elements. Also, similar to the linear food chain perspective, there exists a linear model of R&I, which assumes that innovation starts with the results of research, which are further developed by the industry, and then introduced in the market, where the innovation is sold and used. This linear model is criticized because it does not conform to the reality of the innovation process, including innovation contributing to solving the grand food challenges.[12,70,71]

Research in the linear R&I model is often mono-disciplinary and primarily produces highly specialised knowledge, which is communicated in scientific articles intended for scientific peers.[12] Mono-disciplinarity is also reflected in the organisation of universities. While there are more and more multidisciplinary studies nowadays, most universities still have faculties representing mono-disciplinary research fields with their own methods, terminology and topics.[11] Examples include nutrition, animal sciences and agricultural economics. Academic institutions reward scientists for their production of high quantity and quality scientific papers intended for scientific peers.[72,73] These articles mostly seek to push the limitations of previous research in a specific field, but usually do not see it as their most important task to address societal issues, such as the ones related to the grand food challenges. This academic focus of research could eventually hinder food-related innovation, as the connection of research to a societal wish or need is not always present. Addressing societal problems such as food waste or unhealthy behaviour, requires moving away from the focus on monodisciplinary research, which advances a specific scientific discipline, but can also constrain the exploration of new topics which demand collaboration across and beyond disciplines.[74] The grand

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food challenges demand such an interdisciplinary approach in order to move the entire food system towards the FOOD 2030 ambitions.[12]

Next to an interdisciplinary approach, innovations also demand involvement of actors outside of universities. Successful innovations are increasingly acknowledged to be the result of a 'co-creation process' between civil society, industry, academia and governments (see the quadruple helix model).[75,76] When all of these actors have a role, the innovation process is likely to be more effective. It helps to attune R&I to societal challenges and to find appropriate investors. Big, medium and small enterprises and start-ups play an important role in this innovation process, as they invest in the further development of innovations, commercialising them and making them easily and widely available as products and/or services. It is questionable to what extent companies and entrepreneurs are nowadays stimulated to invest in R&I that contributes to the FOOD 2030 ambitions. It is unlikely that established companies or start-ups will invest in such complex innovation challenges without outside incentives or pressures[39] as investments are high and long-term while returns are uncertain.

It is often mentioned that the impacts of innovations are difficult to foresee.[37] Innovations can become a success, or they can create unforeseen negative side effects[77] and might harm (or put at risk) the interests and desires of people.[40] Concerns about safety and risk, have called for legal and ethical protection. While regulation regarding scientific research differs across European countries, usually they attempt to protect the health and wellbeing of research subjects and research animals, or prohibit specific types of research which have a so-called dual (military) use or which uses human embryos for research. To assess ethical aspects of research protocols, ethical committees have been installed all over Europe. A downside of the ethical assessments carried out by research ethics committees is that they only focus on protection against harm: it is their job to set limitations for research and innovation. This is a very narrow conception of what ethics is (focussing *only* on protection against harm) and does not enhance creative thinking about innovations that can actually contribute to improving the quality of (human) life and wellbeing. To enhance creative reflection about innovation, some social scientists and ethicists have started to include other stakeholders into the R&I process, such as policy-makers, companies, NGOs, retailers, transporters and envisioned end-users (citizens/consumers). They are experimenting with multi-actor approaches in which diverse voices and perspectives are included during the R&I process.[78] Including these stakeholders will help to align R&I to societal needs and values, which will increase the chance of them being valued and broadly and effectively adopted. To speed up such a co-creating innovation process and to keep investment low, different methods can be adopted. Innovators can, for example, use an RRI approach when working on FOOD 2030 ambitions.

3.2 RRI can contribute to improving co-creation and societal impact

To make R&I more responsive to the needs and values of society, the term Responsible Research and Innovation (RRI) emerged in the European Union's Framework Programmes for Research and Technological Development. René von Schomberg proposed the following definition for RRI:

"Responsible Research and Innovation is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society)".[13]

According to RRI, research and innovation should offer innovations which are appreciated by society, which demands to include members of society in the innovation process. The following quote explains that it aims to move 'from science in society to science for society, with society'.[79] Successful examples of society and science engagement is the inclusion of patients in different phases of (biomedical)

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research, such as the setting of research agendas[80] , the involvement of patients in an assessment of rivalling future applications of early Alzheimer detection[128], or co-designing a new husbandry system.[81]

R&I is perceived as responsible if certain conditions are met with regard to outcomes and process.[82] With regard to outcomes it is argued that RRI aims for (reflexive) learning and R&I outcomes that contribute to solving societal challenges. Both aims are interconnected: stakeholders, including end-users, are asked to reflect on the desirability of intended innovations which allows them to learn about innovations and prepares them for what is to come; but it also allows them to give input to researchers and innovators who are therewith allowed to learn about the users' evaluations of alternative possible realizations of the innovation. The process requirements for RRI are: diversity & inclusion, openness & transparency, anticipation & reflection, and responsiveness & adaptive change. Figure 5 shows in the centre the main RRI fields of ethics, gender equality, governance, open access, public engagement and science education. The orange circles in the corners reveal the process requirements that are explained below.

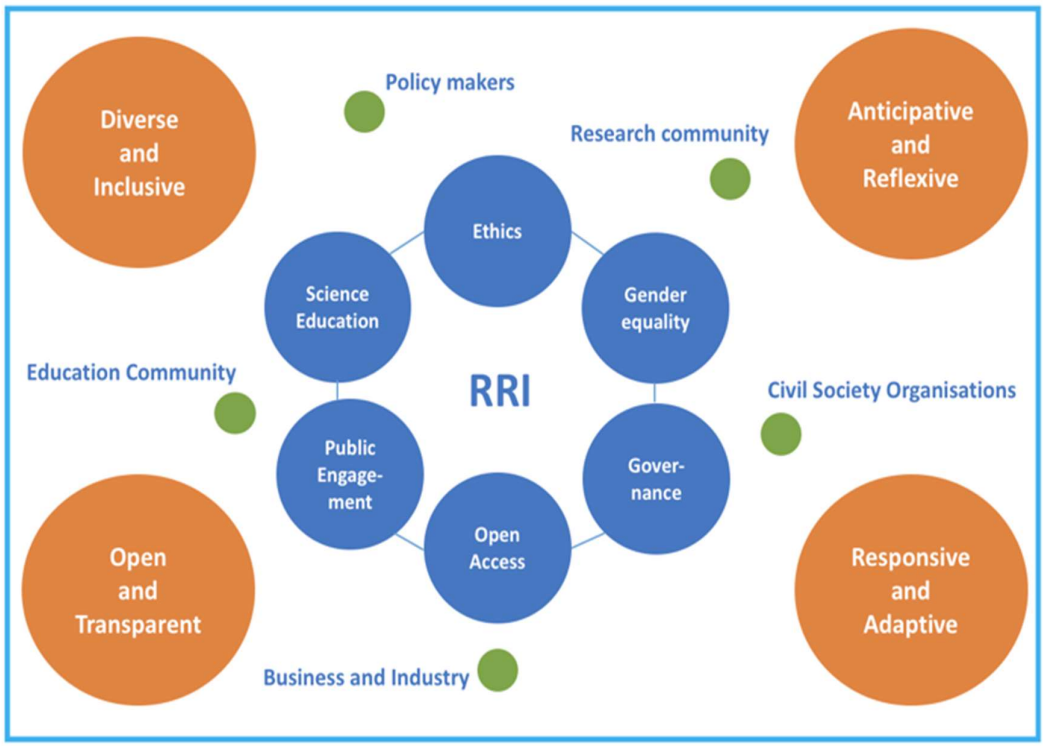

Figure 5. Responsible Research and Innovation (RRI). Model retrieved and adapted from RRI Tools (https://www.rri-tools.eu), published in FIT4FOOD2030 policy brief 1.[83]

As RRI aims to be responsive to societal needs, it is important that a broad selection of stakeholders is involved in research and innovation. The requirement *diversity & inclusion* is met when a variety of stakeholder groups/relevant voices are involved during the R&I process. Different tools have been developed over the years to enhance reflection of participants during public engagement activities.[84] RRI also fosters *openness & transparency* about the ends that are pursued by R&I projects: R&I is no longer a field that is dominated by experts, but the public is able to influence the topics chosen for research and innovation, its process as well as its outcomes. This serves accountability/liability of scientists and innovators towards the public, but it also supports sharing insights and information with the public, or educating them about science and innovation. *Anticipation* of the future is also important. R&I aims for improvements in the future, but the imagination of scientists and innovators is usually quite limited: they usually create an innovation which is to substitute current technology

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with a new one because it is cheaper or more effective, but it does not take into account the broader changes that innovations can bring about in human (social) life. RRI activities aim for a broader imagination, which includes also the effects of innovations on the ways human beings (inter) act, deliberate or relate to each other and the world around them. *Reflection* is needed to assess the plausibility and desirability of rivalling anticipations of the future and to examine current issues, practices, values and assumptions underlying research and innovation projects. *Responsiveness and adaptive change* are about the ability of scientists and innovators to adapt the products of their R&I activities to the societal evaluations, in order to make sure that they are valued. It includes flexible process management and monitoring/evaluation during research, development and/or implementation.[82]

RRI highlights the need to take into account diverse values, interests, contexts and knowledge. In that respect RRI belongs to the school of multi-actor approaches that argue that multiple stakeholders need to be involved to co-decide on and co-create solutions.[78] This is supposed to help innovation, as it supports tailoring the innovation to the needs and values of the public.

3.3 Barriers in R&I systems hindering transformation

RRI and other multi-actor approaches are hopeful developments, but they have not yet reached their full potential. While there are many promising activities in these fields, there is also a lot of debate over RRI methods and purposes. For example, some RRI experts debate the effectiveness of public participation in formal workshops with respect to more traditional expert analyses.[85] Others debate the meaning and purpose of the results of public engagement activities, as a broadening of reflection and inclusiveness sometimes remain quite 'conversational' but do not always lead to actionable advice to researchers and innovators.[86]

Apart from discussion on the effective operationalization of RRI, barriers to its implementation in policy and research have been observed. Currently a fragmented landscape of separate disciplines and sectors exists, which has successfully dealt with individual compartmentalized parts of food systems such as agriculture, food safety and nutrition, but rarely takes an integrated perspective. Furthermore, the active involvement of citizens, Civil Society Organizations (CSOs) and users such as farmers and consumers [108,114], as well as private sector actors, is rare and often has low priority. Not many researchers and policy makers value citizens' views, visions and local and traditional knowledge. There is a need for a better understanding of how to organize and stimulate stakeholder interactions during the research process as well as on how to interpret the outcomes of these interactions[108]. In addition, the academic incentive structures and R&I funding programs often focus mainly on food production-oriented research[67] and/or do not support the use of inter- and transdisciplinary research approaches.[108,114] Finally, many member states fund research mainly through open calls instead of system-oriented calls that consider strategic relevance, making it more challenging to establish R&I priorities for tackling grand challenges in food and nutrition security. Despite member state-driven programming initiatives, such as the Joint Programming Initiatives (JPIs), there is still a need for appropriate tools and incentives to support the development of an appropriate innovation culture both within R&I policy programs, and food-related policies and regulations[114] as well as to connect them in an effective way.

RRI started in the context of science and builds on a rich tradition of ethics, technology assessment and science and technology studies. Currently there is also a growing emphasis on responsible innovation in business settings.[91] Tensions emerge, however, when applying responsible innovation principles in business settings. For example, companies operate in competitive markets and are under pressure to exploit their innovation as quickly as possible and therefore, commercial actors might see RRI principles such as stakeholder engagement and transparency as hampering the innovation

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process,[91] or as less relevant. Moreover, tensions also arise when RRI principles such as anticipation, inclusion, responsiveness, and reflexivity[92] result in incapacity of research and policy to take decisions and act.[37] These tensions are part of RRI and it is important to both be pragmatic and take action while also being conscious about the RRI principles.[37,91]

We therefore need strategies for triggering a double transformation in both food systems and the R&I system. The next section elaborates on this.

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4. Tools to foster R&I to contribute to food system transformation

4.1 R&I funders supporting innovation

A way to support sustainable and healthy innovations is to have actors that take the role of 'innovation brokers'. Innovation brokers have the job to catalyse innovation through bringing together multiple actors, compose networks and facilitating their interaction.[46] Innovations which target the entire food system can be more successful if a broker helps to activate and connect all relevant actors. Furthermore, their relatively impartial third party position enables them to keep the general overview, evaluate progress and manage conflicts.[46]

Researchers, government and businesses don't find each other easily and automatically to implement this innovation broker role. Researchers have closest contacts and network with other researchers in their own specialization, since journals and conferences are normally expertise or theme oriented. Researchers of (large) companies are often in the same network and in their own company network. Small and medium enterprises often don't have the budget to invest in research, so they mainly are in contact with suppliers and clients and get inspired by their demands, wishes and ideas.

To overcome this difference in access to research and innovation, the EU has invested the last decennia in (1) transdisciplinary research and innovation and (2) the connection between research and small and medium enterprises. In Horizon2020 projects were defined where SMEs had to be invited explicitly. Next to that instruments like COST (cooperation in science and technology) and ERA-NET (European Research Area Network) were developed that bridged governments of different countries within the EU, research and businesses and between expertise.

All these initiatives teach us that collaboration not automatically ensures understanding and solidarity.[126, 127] In the network approach literature it is emphasized that members of a network should have a common goal and outcome. In extensive transitions like this, the goal is long-term and the outcomes cannot be pre-defined.

This paper proposes R&I funding agencies to take the role of innovation brokers. Although the value of an innovation broker is well-known, finding long-term funds for such a job is problematic.[46] If funding institutions would expand their role and also become innovation brokers this would probably improve the impact of the R&I projects that the funding organisation finances. Such a role could fit into the development of the past eight decades during which funding institutions across the world have gradually accepted more responsibility to care for the societal impacts of R&I.

While up until the Second World War scientists were more or less independent and could decide for themselves what research topics they wanted to pursue, this has gradually changed over the past era. During the 1950s and 1960s, when the economy in most western countries grew, scientific research was increasingly required to contribute to economic activity and competitiveness. Now, a transition to a third phase is underway, in which science is seen as an activity that serves a broad variety of societal goals. Science is increasingly understood as a research practice on which society depends for important benefits such as the preservation of health and wellbeing and for solving important problems such as climate change.[93,94]

The changing expectations of scientists is reflected also in the ways funding institutions evaluate project proposals. Evaluation systems include no longer only the scientific value and market value, but also the so-called 'broader' societal impacts. Evaluation of societal impacts demands to anticipate the ways in which R&I changes human social life, which leaves room to cover the various components (individual, social, political, institutional, environmental) of the food system.[95,96,97] While funding

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institutions have still predominantly evaluated research proposals in a quantitative manner, [98,99,100] there is a growing acknowledgement of the ways in which R&I is able to influence human lives in qualitative ways. Funding institutions have therefore increasingly demanded scientists to reflect about the ways they influence society by requiring them to collaborate with members of the industry, with (associations of) end-users, or by offering trainings, informative websites or toolkits fostering RRI. Examples include various European endeavours that have invited social scientists and ethicists to develop projects which enable scientists to learn about or engage in RRI: https://res-agora.eu/rri-resources/); an RRI toolkit for researchers presented over a web site and related modular trainings: www.rri-tools.eu/nl/about-rri; and formation of communities fostering conversation between scientists about RRI: www.euroscientist.com/theme/responsible-research-and-innovation/.

Taking a role as an innovation broker could be seen as the next step in this development within research funding institutions. How this should be done should be the topic of careful reflection and experimentation. In this paper we can only give some initial ideas. To get practical ideas on how funders could fulfil an innovation broker role, an exemplary case study is analysed (Transforum, see annex 2 for case description). The theory of change of this funder was to be a partner for selected promising initiatives and to fund research activities for these promising initiatives. Analysis of the detailed case description and well-documented lessons learned (see annex 2) resulted in the following recommendations during the start-up, execution and ending of R&I projects.

Start-up
The transformative potential of the funder is dependent on the success of the funded R&I projects. As such, the selection of R&I projects that are going to be funded is a crucial steering mechanism. This idea is if course not new and thinking about the composition of the R&I agenda as well as the selection procedures of projects which have potential to bring about desired changes in the food system is important. Thorough thinking on food systems complexities can lead to the inclusion of a situational system analysis for a specific challenge with root causes, undesirable effects, feedback loops and leverage points (see section 4.2). Networking and internet searches can be used to scout for promising 'no regret' initiatives that can contribute to realising the societal goal of the R&I that is funded.

Execution
The transformative potential of R&I projects increases if the innovation brokers are actively engaged in the projects. Innovation brokers can play an intermediary role, reflecting on opportunities and risks related to the project and seeking appropriate answers to it. Also, they can play a role in detecting potential obstacles to the innovation and aligning actors in the food system so that the innovation is more likely to be effectively realised; such as policy obstacles or hindered market access.

Ending
Although an R&I project ends, and delivers certain outputs, it is unlikely that the R&I 'breakthrough' is achieved when R&I projects close. Such system innovation processes usually take much longer than a single project. 'Breakthroughs' are a result of an interplay of numerous initiatives, projects, trends, windows of opportunities, etc. Thinking about the next steps and spin-offs during the last year of the project is important. Otherwise the momentum could be lost, with the risk of shelving the results of the project.

4.2 Decision-support tool for R&I interventions and programming

A good example of food systems analysis to support the selection and development of R&I interventions and R&I programming is a recently developed food systems decision-support tool, which lays out a step-wise approach to translate food systems insights to practical entry points for policy and research.[42] The tool contains seven steps in which policy makers and researchers can use food systems

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analysis to identify leverage points for change, develop interventions and R&I programming. Within FIT4FOOD2030 we combine this tool with the Theory of Change model.[125] The Theory of Change defines long-term goals and, after a thorough problems analysis, maps backward to identify necessary preconditions – the outcome pathways (statements of why one outcome is thought to be a prerequisite for another). The combined model, which we have called the reflexive FIT4FOOD2030 Systemic Transformation Support Tool (STST), can provide a comprehensive instrument to identify small and realistic interventions or R&I projects that will have a large impact on the food system. It may support policy-makers at European and member state level on how R&I can better contribute to responsibly changing the food system in order to respond adequately to the grand challenges ahead (see Figure 6).

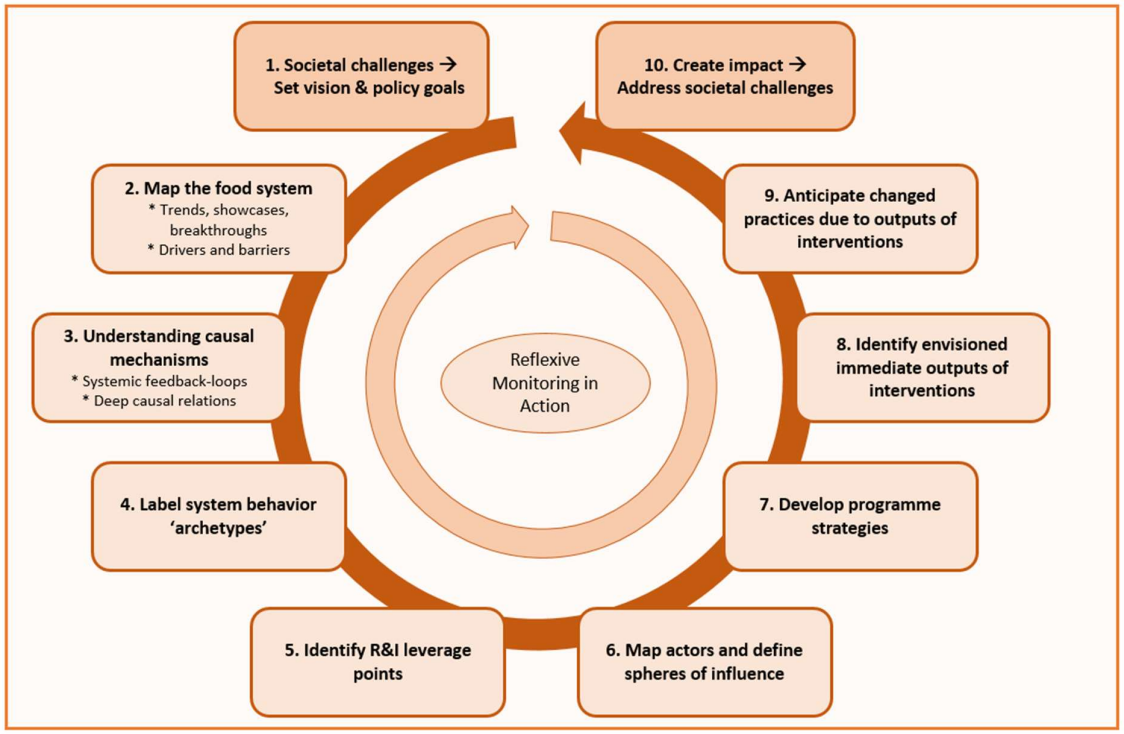

Figure 6: The reflexive FIT4FOOD2030 Systemic Transformation Support Tool (STST), adapted from[42] and[125]

The food systems decision-support tool starts with defining the scope of the food systems analysis by formulating the challenge and identifying the relevant policy goals and the ultimate envisaged impact (step 1). This is followed by mapping the food system to identify trends, showcases and breakthroughs, analyse drivers and barriers and formulate trade-offs and synergies in the food system (step 2). Having identified the key elements of the food system, a more in-depth analysis is made of the dynamics (causal processes, root causes and feedback mechanisms) in the system (step 3). Consequently key archetypes of system behaviour are identified (step 4) and the leverage points that could positively change this system behaviour (step 5). A stakeholder analysis is done to define the key actors in the food system, their interest in changing the system and their sphere of influence (step 6). Together with the policy objectives defined in step 1, this helps to make a selection of most feasible leverage points, which - taken together - form the basis of a programme strategy (step 7).

In the next three steps, the pathway of change is made explicit. After identifying the most immediate outputs that will result from the envisaged intervention activities (step 8), the changes in practices (who will adopt, what interventions, to what extent and why) that are anticipated to emerge from the outputs are mapped (step 9) as well as how these outcomes may ultimately lead to the policy goals (impact, step 10) as formulated in step 1.

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Overall, this decision support tool helps policy makers to intervene in those parts of the food system where limited efforts can offer a large positive contribution to food & nutrition security. Moreover, the tool can help to identify promising niches, grassroots innovations and small wins that provide leverage points for the breakthroughs that are necessary to transform the food system.

4.3 Developing transformative competences in researchers, policy makers and other actors

Using a systems approach and RRI principles in conducting research and innovation requires new competences from not only researchers, but also all other stakeholders (policy makers, industry, food chain parties, NGOs, CSOs and citizens). Deliverable 6.1 of the FIT4FOOD2030 project, called 'Catalogue on analysis of contents and formats for, and needs on trainings', identified 10 clusters of competences required by the next generation of professionals to serve as a vision as to the kind of skills, abilities and qualifications needed for new' food systems and food system transformation (see Box 2). The researchers and other actors are generally lacking many of these competences or do not completely master them. In the transformation process, the development of appropriate competences across a wide variety of stakeholders is crucial. Although some of the competences identified (e.g. responsibility) might be more suitable to be developed during one person's psychological development (e.g. adolescence), lifelong learning helps to work on the rest. In line with this, City Labs of the FIT4FOOD2030 are developing training modules targeting a large variety of stakeholders in variety of ages, including school children, university students, and other actors across the food systems.

Box 2: Clusters of competences required by the next generation of professionals

- *'Anticipation and future-oriented competency'* revolves around understanding and evaluating multiple futures via, for example, future studies, foresight, creating visions, etc.
- *'Communication'* competency covers both the nature of the communication (e.g. multi-perspective, inter-cultural) and the specific means (e.g. openness to dialogue, ability to open dialogue).
- *'Collaboration'* is one of the key competences that enable multi-stakeholder processes, covering "what" (learning from others, empathy, empathic leadership, etc.) and "with whom" (multiple stakeholders, involving unusual suspects, inter and transdisciplinary, etc.).
- *'Creativity'* is another key competence that is needed to devise innovative new ways of addressing problems.
- *'Critical thinking'* on the other hand, helps the professionals identify, analyse and evaluate situations, ideas and information in order to formulate responses to problems.
- Next generation professionals need to *'empower for transformation and act as change agents'* which requires bringing together several competences and characteristics such as resilience and adaptability, participatory ability, self-regulation and other self-oriented competences.
- *'Systems thinking'* is a requirement in order to tackle complexity and analyse and devise solutions to wicked problems.
- The concept of *'transdisciplinarity'* facilitates addressing complex challenges such as the ones we can find within the food system by facilitating inputs from across scientific and non-scientific stakeholder communities and facilitating a systemic way of addressing a problem.
- *'Reflexivity and awareness'* is another self-oriented competence where one reflect his/her own role in the community and society as well as the norms and values that motive this/her actions, and evaluates those actions.
- Finally, *'responsibility'* is identified as a competence as the core concept of RRI in terms of both a sense of individual and shared responsibility among diverse actors towards making trade-offs to advance towards R&I that address grand challenges.

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5. Future-proofing the food system through R&I

5.1 Future-proofing the food system

The current food system is not future-proof
Transformative changes are needed to address the 21st century grand food challenges such as:

- population growth and climate change
- the degradation of public health due to unhealthy diets
- the pollution of our environment due to intensive food production and
- the depopulation of rural areas among other due to poor economic viability.

This requires action from all actors in the food system, among other national and local food policy and new regulations that stimulate a sustainable and healthy food system. This paper focused on how the food system perspective and R&I can contribute to future-proofing the food system.

A food system perspective is needed to overcome the grand challenges
A food system perspective assists in finding solutions for food-related grand challenges. A food system perspective goes beyond the food chain perspective of production, processing, distribution and consumption and takes into account impacts on, for example, waste, health, environment and societal values. As most 21st century food challenges go beyond the food chain, a broader system perspective is needed to adequately address these complex challenges.[5,6,30]

Current data is insufficient for food system analysis
A benefit of the food system perspective is that it can be used to analyse the problem in more detail. This way root causes and effective points for interventions can be identified, which might be in a very different part of the food system than where the problem is initially identified. Moreover, the system perspective makes it possible to 'model' a proposed solution and forecast possible impacts under different scenarios. Food system analyses are dependent on existing data. At the moment specific and uniform consumer data are missing, which makes it difficult to integrate consumers and public health into food system models in more detail. It is recommended to invest more in gaining high quality data with regard to the functioning of elements of the food system so that impacts, root causes and forecast can be modelled.

The food system perspective takes novel initiatives into account
A system perspective is also applied by researchers, policy makers and innovators who seek to develop and or support promising novel initiatives, such as grassroots innovations, that might, in the long term, become an R&I breakthrough and provide a solution to the grand food challenges. Examples are novel food products such as algae, new lifestyle supports such as personalised nutrition & health, and new production methods such as smart farming. These novel developments are not yet dominant in the food system but might become so if they are able to become an R&I breakthrough and fundamentally change current aspects of the food system. With the food chain perspective, these promising initiatives are undervalued due to their current small market size and therefore small impact on the current food chain. System innovation, on the other hand, highlights that all dominant established techniques, organisations and practices started small and over time grew and replaced or changed earlier dominant techniques, organisations and practices.

5.2 R&I policy to change the food system

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Change R&I system to align with a, newly designed, food policy

A long-term food policy that includes the policy fields of agriculture, health, environment, education, infrastructure, economy, planning and energy is needed to realise the system change ambitions of FOOD 2030. In this respect a promising pathway is to invest more in R&I that:

- goes beyond the topic of improving production and explores topics such as improving health, environment, biodiversity and economic viability (i.e. takes a systems approach).
- collects FAIR (find, access, interoperate and re-use) food data and assesses, monitors and models specific aspects of the food system in order to find drivers and barriers for change.
- is impact oriented and strives for food system change by, among others, supporting societal valuable breakthroughs.
- applies an RRI/multi-actor approach.

Action-oriented RRI for fundamental change

RRI aims to include a variety of stakeholders in a reflection on the value of an innovation for human and animal lives and the environment, during the R&I process. RRI helps to distinguish societal obstacles which may hinder the implementation of the innovation, as well the values that innovation allows to help to bring about. Feeding these insights into the R&I process in a pragmatic and realistic way can contribute to making innovations that are valued and used broadly in society. Furthermore, as RRI involves stakeholders early on in the R&I process, it helps to identify the changes that are needed across the food system (and the various actors responsible for it) in order to make the innovation successful. However, at this moment RRI and other multi-actor approaches are promising developments that have not yet reached their full potential, it will require long-term learning and adaption to achieve this.

More R&I projects that support the breakthrough of promising initiatives

More R&I projects are needed that are targeted at initiating or supporting promising food innovations. Examples of promising food innovations are alternative proteins, bio-based packaging, personalised nutrition and health, and precision agriculture.

Innovation brokers need to stand up to change the R&I system

Moreover, a way to realise change in the R&I system is to change the funding of R&I. It is recommendable for both public and private funding institutions to assess their R&I funding system and to analyse if the incentives, selection criteria and procedures sufficiently contribute to achieving food system change towards FOOD 2030. Funders could take a more involved 'innovation broker' role, making FOOD2030 ambitions more of a collective responsibility. This way funders could also play a role in signalling towards policy, businesses and other sub-systems such as health, which other types of changes are needed to achieve food system change. Examples are adjustments in regulation such as laws, tax instruments, and changes in public advice, communication and education.

Competence development for next generation of researchers and innovators

Last, the food system perspective and RRI approach are not aims in themselves but rather frameworks that better fit the aim of ambitious fundamental change such as FOOD 2030. This paper does not argue that all R&I projects should always follow all RRI principles[30], but an R&I system that addresses the grand challenges effectively will need to be responsible, multi-actor and action-oriented. Such an R&I system may attract the next generation of researchers and innovators that strive towards doing something meaningful and that want to realise social impact with their work. At the same time, it will be crucial to develop the necessary competences such as: anticipation and future-oriented competency, communication, collaboration, creativity, critical thinking, empowerment for transformation and acting as change agents, system thinking, transdisciplinarity, reflexivity and awareness, responsibility and self-regulation. Such an R&I system is not achieved overnight, but promising steps towards it are made.

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No774088

Annex 1: Table with four possible domains of R&I breakthroughs (selection from)[48,p.24-32]

Fortunately, there are already numerous food research and innovation initiatives taking place that contribute to the FOOD 2030 goals. FIT4FOOD2030 identified 22 R&I breakthroughs that were clustered under the four domains:

(1) The new approach of primary food production and distribution (including breeding; new techniques and applications; smart farming; non-conventional production systems; reduction of impact of production; new value systems; new aquaculture).
(2) An engaged and healthy consumer (including empowered consumer; change of dietary habits; new tools to improve nutrition and health; new methods in education).
(3) The tools of a future-proof food system (including logistics - new systems; smart traceability in the food supply chain; a novel approach to biotechnology; information and communication technologies (ICT) applied to Food System; Food Industry 4.0 - novel and efficient food processing; sustainable packaging; diversity on the diet; the global food analysis).
(4) A sustainable and dynamic value-based food system (including circularity in food systems; efficient use of resources; food for society; policy and management within the food system)

An extended table was made in which each breakthrough was explained and linked to the identified trends and cases in FIT4FOOD 2030. Table 1 provides one example for each domain, the full table can be found in report[48].

Table 1. Potential R&I breakthroughs

R&I Break-through	Specific R&I breakthrough topics	Impact	FOOD 2030	Trends aligned (from WP2)	Cases aligned (from WP3)
Smart farming (domain 1)	- Precision farming: Use of local data (e.g. Apps, terrain data, irrigation data, foliar growth). - Use of global data (e.g. Web platforms, forecasts). - Applied mechatronics. - Artificial intelligence applied.	Higher quality, ensured food safety, better traceability, improved productivity, higher efficiency, less fraud, lower costs and more benefits to a new era of higher sustainability of the agricultural ecosystem	Climate & circularity	- Climate change. -Malnutrition. - Demographic change. - Scarcity of natural resources. - New and Game - Changing Digital Technologies in Agriculture. - Changes in farm structures. - Agricultural pollution.	-021 -022 -027 -026 -033 -060 -064 -066 -069 -071
Change of dietary habits (domain 2)	-Awareness of healthy habits - Reduction of targeted ingredients (salt, sugar, trans saturated fats) - Reduction of targeted additives (clean label)	A healthier population with all the consequences this enables: Less communicable diseases, healthier growth and ageing of individuals, a	Nutrition	-Rise of non-communicable diseases. - Demographic changes. - Biofortification. - High/Ultra processed foods. - Clean eating / transparent labels.	-024 -040 -043 -044 -045 -050 -052 -062 -063 -075

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R&I Break-through	Specific R&I breakthrough topics	Impact	FOOD 2030	Trends aligned (from WP2)	Cases aligned (from WP3)
		sustainable lifestyle.		- Novel foods. - Natural preservatives and milder processing methods. - Alternative protein sources. - Functional foods including pro& prebiotics. - Health and food consciousness. - Responsible consumers. - Special diets like vegetarian, vegan or low carb. - Destabilised consumer trust.- Fast and convenient food.- Low prices, high calories. - 'Free-from' products.- Smart personalised foods. - Globalisation of diets. - Consumer engagement. - Traditions and Do It Yourself. - Social media and food. -Food regulation.	-077 -078
Diversity on the diet (domain 3)	- New sources not fully exploited. - New protein sources (biotechnology). - Full exploitation of algae. - Full exploitation of insects. - Cultured meat.	Exploring new ingredients allows a higher diversity on use of resources, technological applications and health impact on consumers. Always from a sustainable perspective and	Climate, circularity & nutrition	- Malnutrition. - Scarcity of natural resources. - Cultured / in vitro meat. - Novel food. - Alternative protein sources. - Health and food consciousness.	-012 -013 -014 -017 -019 -029 -050 -058 -074 -075 -077 -078

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R&I Break-through	Specific R&I breakthrough topics	Impact	FOOD 2030	Trends aligned (from WP2)	Cases aligned (from WP3)
		environmental impact perspective		- Special diets like vegetarian, vegan or low carb. - Globalisation of diets. - Food regulation.	
Food for society (domain 4)	-Community driven social innovations (City Labs, Community based participatory research, Citizen science, urban cropping, urban beekeeping, rent a tree). - Innovative public procurement (meals in nurseries, schools, residences, senior people's homes). - Social entrepreneurship. - Awareness of waste in social context (homes, schools, restaurants, take waste food at home). - Trade norms (Dismissed fruits by shape or form). - Do It Yourself. - Collaborative production. - The European cultural food heritage (maintaining the local characteristics considering new options of geographic diversity).	How the society interacts with the food system and how there is an overall awareness on the impact of the power of small individual actions and public policies is relevant for a social innovation breakthrough.	Innovation & circularity	- Urbanisation. - Demographic change. - Migration. - Scarcity of natural resources. - Rise in energy consumption. - Economic globalisation. - Urban agriculture / urban farming. - Health and food consciousness. - Responsible consumers. - Destabilised consumer trust. - Consumer engagement. - Traditions and Do It Yourself. - Social media and food. - Food waste recovery up-cycling / waste cooking. - Women's empowerment	-004 -007 -008 -025 -037 -043 -048 -049

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Annex 2: Case study TransForum: lessons learned from transformative R&I programme

From 2004 until 2010, TransForum was an R&I programme in the Netherlands (financed with implementation arrangement Bsik from Ministry of Economic Affairs) that financed over sixty R&I projects. With the R&I projects TransForum aimed to contribute to the sustainable development of agriculture and green space in the Netherlands. By changing 'the existing technology- and supply-driven knowledge infrastructure, into a demand-driven infrastructure which transcends boundaries between disciplines and which has a significantly broader scope than at present' this was needed 'to make the transition from the current, industrialised agriculture to a sustainable and multi-functional agriculture that anticipates the social needs for a responsible food production and a beautiful rural area'.[101] The idea was 'that successful innovation projects may trigger others to innovative which, in turn, may lead to a cascade of technical, practical and cultural changes within the sector. Thus, innovation projects may, in time, result in system innovations that transform the agricultural sector into a more sustainable sector'.[63, p.14]

TransForum made a split between innovation projects in which mainly applied researchers participated and research projects in which mainly PhDs and Postdocs worked. For the innovation project in-kind co-funding from entrepreneurs were a requirement. Also, TransForum decided to start with financing innovation projects, as it was anticipated that research questions would emerge from these projects that could be explored by PhDs and Postdocs in the research projects.[101]

The programme theory of TransForum has similarities to the Food System perspective and RRI approach, but paid less attention to health issues. With regard to the Food System perspective for example TransForum's director stated that: 'sustainable development is a dynamic process [which] needs system innovation'.[102, p.13-14] Moreover, TransForum formulated a 'set of motivating assumptions' on which participating actors had to agree order to be granted financial support. These principles are: 'system innovation is a non-linear learning process [..and..] requires a multi-stakeholder approach [..which..] implies trans-disciplinary knowledge creation'.[102, p.13-14]

Several requirements of the TransForum approach match the principles of RRI. For example, TransForum working philosophy was that in R&I pioneering entrepreneurs, researchers, policy makers, NGOs and intermediaries had to enter into a process of co-creation – this aligns with the diversity & inclusion principles of RRI, even if TransForum does not have a gender policy. TransForum focused less on openness & transparency, but did require R&I projects to publish results and to give assistance to TransForum in distilling and communicating lessons learned, both on the process of R&I and the learning outcomes. To stimulate anticipation & reflection within the project, each project appointed a process facilitator or learning evaluator who was responsible for assisting project members to reflect upon their intervention strategies.[63] No formal ethical committee was embedded within TransForum, although this is required in an RRI approach. The RRI principles of responsiveness and adaptive change were taken into full account: the TransForum program strived to enable 'the necessary trial and error spaces. […] which enables entrepreneurs to explore yet uncertain opportunities, and learn from them'.[103,p.47]

The intended outcomes of TransForum were focused on achieving sustainability. TransForum noted that not all learning and R&I outcomes could be captured by a single project. Therefore some projects focused more on environmental sustainability while others were more focused on outcomes in the realm of social sustainability. TransForum's philosophy was to support ambitious, radical R&I projects with a few pioneering entrepreneurs to set in motion change rather than incremental innovations or change for the large group of stakeholders. From theory we know that more radical, ambitious innovations usually trigger more ethical debate then incremental change.

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Lessons learned TransForum

In 2015 the staff of TransForum learned that to be able to achieve their ambition they had to obtain a different role than merely funding R&I projects. Table 1 summarises the change in role that TransForum aimed for. In 2006 this ambition was clearly communicated to TransForum's network during TransForum's first scientific conference.[101]

Table 1. Changing role of TransForum (minimally adopted[90,p.172])

From	To
Reactive	Proactive
Funder	Partner
Control	Develop
Neutral in-between	Stakeholder

As a result TransForum changed the proposal submission procedure. Instead of 'cold' acquisition in which proposals were submitted without conversations taking place between the staff of TransForum and the candidates of an R&I project beforehand, TransForum developed a procedure in which candidates first had a meeting with a staff member, next a 1 pager was developed by the candidate which was discussed during a staff meeting of TransForum. If this proposal was indeed perceived as valuable for contributing to the aims of TransForum, the candidate would perceive feedback from the TransForum team that assisted in shaping a full proposal. If this proposals was accepted, budget were given for the first year of the four year project, with the option to stop the project after the first year if it under-performed.

Letting go of 'cold' acquisition does not mean that no selection criteria were present. Practical project proposals were evaluated on aspects such as:

- Triple P contribution
- Participation of entrepreneurs, researchers, policy makers and NGOs or civil society
- Co-funding in terms of time by project participants
- Radical innovations that provide inspirations for others

It was recognised that these criteria were hard to integrate in one project, therefore TransForum was flexible in accepting projects that did not comply to all these criteria, if the reasoning for this was clear and understood by TransForum's programme staff.

Moreover, specific programme staff members of TransForum were appointed to each R&I project that were actively involved in the project, by, for example, joining bi-monthly steering committee meetings. In addition, people were appointed that were responsible for stimulating collective reflection within the project and documented the learning process taking place for the next generation of R&I projects and programmes.[101]

Last, TransForum recognised that the administrative and control aspects of the R&I process still had to be organised as TransForum was financed with public funds which bring a specific type of accountability. The challenge was to organise the control in a way that did not hamper the innovation process of the researchers and entrepreneurs involved. The solution was to split the responsibilities: one programme staff member was made responsible for the control aspect, other programme staff were partners of the R&I projects.

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