NEXTGEN PROTEINS

Bioconversion of Underutilized Resources into Next Generation Proteins for Food and Feed

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1 Executive Summary

In this deliverable, the RRI framework for the NextGenProteins project is established. First, the objects and impacts of the NextGenProteins project are placed in relation to the concept of RRI. This is done by elaborating on the global grand challenges related to alternative proteins and the ethical, responsibility and sustainability dimensions therein. Next, a matrix consisting of the conceptual dimensions of the RRI framework for the project is rolled out. Finally, the process, actions and interactions that constitute the RRI framework in practice are presented.

The RRI framework of the project is summarised and explained in the conceptual matrix. The dimensions of the matrix relate to the process, product, purpose and people of the research and innovation activities, whereas the components of the matrix consist of anticipation & analysis, reflection & reason, engagement & inclusion and act & responsiveness. Furthermore, the *Societal Readiness Thinking Tool*[1], developed in the New HoRRIzon project[2], is applied to the R&I process of the NextGenProteins project.

RRI approaches inform the project in various ways, for example through regular and ad hoc meetings with the executive board and work packages. The RRI framework is further discussed via webinars and workshops organised during the project. In addition to the internal RRI processes of the project, the responsibility issues related to alternative proteins are discussed together with societal stakeholders. Finally, the RRI framework also covers the developmental evaluations of the R&I processes in the middle of the project and in the end of the project.

In summation, the process of applying the RRI framework in the NextGenProteins project is envisioned to be highly co-creative process between the project actors and the societal stakeholders. The aim of the process is to develop and ensure high quality R&I project and outcomes, which will be acceptable and desirable for the society and environment.

[1] https://www.thinkingtool.eu/
[2] https://newhorrizon.eu/

2 Introduction

NextGenProteins project aims to optimise and validate the production of three alternative proteins through resource efficient bioconversion processes and demonstrate their suitability in an industrially relevant environment as addition to, or substitute of, traditional protein sources by verifying their use in various feed and food applications, in order to meet customers' needs and ensure consumer acceptance. The project will contribute to strengthening EU's food security, sustainability and self-sufficiency of EU protein production by demonstrating the suitability and economic viability of next-generation proteins as part of food and feed value chains; with less strain on natural resources and reduced environmental impacts. Specifically, the project aims to contribute to the overall goals of The EU's Bioeconomy Strategy 2012; to the framework of Food 2030 SWD; and to the EU action plan for the Circular Economy. Furthermore, the project is aligned with selected UN Sustainable Development Goals.

Work Package 7 aims to increase consumer trust and acceptability for alternative protein sources. This is achieved through engagement activities with companies, communities and associations. The basis for these activities is the RRI framework. The RRI framework brings together researchers, policymakers, businesses and other societal actors to facilitate consumer acceptance, effectively disseminate project results and ensure their exploitation.

Task 7.1 of the NextGenProteins project will co-create with all the partners an effective and applicable Responsible Research and Innovation (RRI) framework for the use of all Work Packages. The task will evaluate the implementation of the framework midterm and at the end of the project and provide feedback for the development of responsible, sustainable and ethical approaches. Aspects of the RRI framework cover both internal communications related to development, exploitation and dissemination of results as well as external communication with relevant stakeholders and citizen groups. This task will also support Tasks 7.2 and 7.3 through RRI-guided outreach methods.

In this deliverable, we address first the specific objects and goals set for the project, for this work package and for this deliverable. Secondly, we elaborate on the "big picture" of the project by introducing the concept of RRI, exploring food & feed ethics and addressing global grand challenges related to alternative proteins. Thirdly, we present the conceptual RRI framework matrix for the purposes of this project as well as the aims and methods of this framework. Fourthly, we conduct a step-by-step introduction to the co-creation approach for the project, which consists of developmental evaluations, various tools and interactions.

3 Information, Insight & Impact: Introduction to RRI

3.1 Why RRI? The Aims of Responsible Research and Innovation

The origins of Responsible Research and Innovation (RRI) can be viewed from the point of view of the controversies around scientific breakthroughs throughout history. Science and technology have increased the quality of life for many people, but they have also created controversial innovations and unintended consequences. The most apparent example of unintended consequences is climate change, which is driven by human activities. In addition, innovations such as genetically modified organisms, nuclear energy and web-algorithms have created heated public debate as well as outright resistance.[3]

Despite these controversies, the human appetite for innovations continues to shape our societies and our world. Moreover, addressing global challenges such as climate change or food security requires the application of science and technology. Importantly however, controversies have demonstrated a need for new responsibility frameworks in order to better align research and innovation (R&I) activities with broader societal needs and expectations. As response to this need, RRI has been designed to function as a *"strategy of stakeholders to become mutual responsive to each other and anticipate research and innovation outcomes underpinning the 'grand challenges' of our time for which they share responsibility"*.[4]

In addition to solving problems, research needs to be in line with the ethical values and needs of society. This in turn, requires reflection and the involvement of wider society through open and transparent processes. RRI aims to do just that by engaging a broad range of stakeholders in deliberation and debate on the ways and means of how science and technology can create a desirable future for all.[5] Accordingly, RRI specifically emphasizes responsibilities towards the future. The aim is to engage researchers and innovators to the process of ensuring the social desirability and acceptability of R&I activities and outcomes. According to Stilgoe et al. RRI is about *"taking care of the future through collective stewardship of science and innovation in the present"*.[6]

The simultaneous challenge and imperative for this future oriented approach lies in the complexity and unpredictability of future. The potential and possible societal impacts of scientific and technological innovations are hard to foresee because of the gap between the actual occurrence of inventions and their eventual market entry in a product form. It is telling that some of the societally most impactful innovations, such as the almost universally widespread use of the internet, have emerged as a surprise for the experts.[7]

Innovation thus presents us with dilemma of control: regulatory control is often weak in the early phases of innovation whereas by the time the negative impacts have materialized, the innovation can already be "locked-in". Furthermore, regulatory approaches and ethical assessments that aim to control the impacts of innovations usually have a narrow focus, as they tend to focus on the protection against harm. Regulation is a valuable, but a limited tool:

[3] Thinking Tool 2018, 6; RRI Tools 2016, 7.
[4] Von Schomberg 2013, 11-12, 20-21; Owen et al. 2013, 30-31.
[5] Thinking Tool 2018, 6; RRI Tools 2016, 7.
[6] Stilgoe et al. 2013, 1570.
[7] Von Schomberg 2013, 19-20; Owen et al. 2012, 752.

The reach of innovations often times exceeds the grip of regulators, as the fast pace development science and technology tends to "overflow" the boundaries of regulations.[8]

This brings us to the problem of innovation governance. Neither innovation nor the challenges related to them are linear processes. Innovation is complex, collective and dynamic phenomenon. R&I activities face the "problem of many hands" which refers to the reliance of research on a division of labor where activities are split up between many researchers. This creates the potential for "organized irresponsibility", in which nobody feels responsible for the consequences of R&I activities. Irresponsibility is usually an *"emergent consequence of the workings of the innovation ecosystem, rather than the actions of an individual"*. As a result, emphasis needs to be on *co-responsibility* within the ecosystem of innovation.[9]

RRI tries to answer the aforementioned deficiencies in R&I governance. It aims to empower social agency in innovation by steering the research and innovation activities towards *"shared societal objectives such as sustainable economic growth, social justice, gender equality, and protection of human health and environment"*[10]. Responsible innovation is to be understood as an opportunity to redefine and realign the trajectory of innovation. Thus, the key question posed by RRI is the following: how should innovation look different in response to the emergence of new information, reflections and insights.[11]

In conclusion, RRI is a strategy and a process that *"anticipates and assesses potential implications and societal expectations with regard to research and innovation, with the aim to foster the design of inclusive and sustainable research and innovation"*.[12] To put it simply, the aim of RRI is to create high quality science that is more in the public interest.[13]

Box 1. Definition of RRI by Rene von Schomberg[14]

According to EC officer Rene Von Schomberg's definition, RRI is: *"a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view on 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)."*

Box 2. Definition of RRI by Bernd C. Stahl[15]

Bernd C. Stahl has defined RRI as *"a higher-level responsibility or a meta-responsibility that aims to shape, maintain develop, coordinate and align existing and novel research and innovation-related processes, actors and responsibilities with a view to ensuring desirable and acceptable outcomes*".

[8] Owen 2012, 4-5; Owen et al. 2013, 32; Hoes et al. 2019, 16.
[9] Owen 2012, 4; Owen et al. 2013, 33.
[10] Von Schomberg 2014, 34-36
[11] Owen 2013, 34-35; Owen 2012, 3-4.
[12] https://ec.europa.eu/programmes/horizon2020/en/h2020-section/responsible-research-innovation
[13] RRI Tools 2016, 8.
[14] Von Schomberg 2011, 9.
[15] Stahl 2013, 5.

Box 3. The aims of RRI[16]

- ◊ RRI seeks to prevent irresponsible research and innovations by intervening early on into the R&I process.
- ◊ RRI aims to align innovations with grand challenges and societal issues by addressing major contemporary problems.
- ◊ Societal preferences arising from public deliberations and debates are included, and framed by ethical principles, as well as normative frameworks.
- ◊ The development of technologies is aligned with societal values and expectations through participatory processes.

[16] Bogner & Torgesen 2018, 4-5.

3.2 Ethics as a basis for the RRI framework

The starting point for an RRI approach to food production is to consider eating as an ethical act. According to the Food and Agricultural Organization of the United Nations (FAO), food and agriculture "*are means to ends that are inherently ethical in nature*"[17]. This means that humans are more than just passive consumers; food is a crucial part of human life and food choices are intertwined with our beliefs and values as well as with the globalized world.[18]

One of the main ethical issues related to food is the gap between food production and food consumption. The fact that most consumers are not aware of how their food is produced, serves as a starting point for ethical approaches to food.[19] Furthermore, only a few people are aware of the feed that the production animals are consuming. This lack of knowledge about food and feed production, resulting from ignorance or obstacles to information, is problematic because the right to food choice is central to food ethics. The consumers have a right to be informed honestly about food they eat, because food choices tend to involve trade-offs between the various values and preferences of the actors. Food choice also involves factors such as costs, availability, taste, socio-cultural aspects, and familiarity.[20]

Traditionally in Western cultures, meat and dairy have been valued and consumed in great quantities. This has created a particular culture of food production: The focus has been *"on producing large amounts of good-quality food that should be available to everyone at low cost"*[21]. As result however, values such as animal integrity and welfare have historically been neglected. Moreover, the increasing application of technology into food production in order to increase profitability has raised questions related to responsibility, ethics and sustainability. Indeed, recent criticisms have emphasized that plants and animals need to be seen as more than just mere instruments of production.[22]

Majority of food ethics focuses on the human consumption of food. However, there is also the issue of animal feed, the choice of a feed type, how it is produced and how feed choice affects the welfare of animals. Another pressing question of food ethics is related to land use, whether it should be used for plant-based human food, animal feed, or even for non-fossil fuel production. In addition, the question of food security involves concerns over genetically modified organisms, such as genetically modified soya, which is often used for animal feed.[23]

Despite of the increasing demand for a more responsible approach to food, there are many context-specific challenges in the application of RRI into food production. Contrary to traditional artefacts, organisms related to food production have a double ethical status, *"they are both subjects and objects of the innovation process"*[24]. For example in agriculture, the "distinction between production, process and product", is ambiguous. The specific contextual factors in the application of RRI raise many questions related to animal-, agriculture- and food

[17] FAO 2000.
[18] Fanzo 2015, 15-19.
[19] Korthals 2014, 2; Bruce & Bruce 2019, 783, 786.
[20] FAO 2000; Korthals 2014, 7.
[21] Bruijnis et al. 2015, 954;
[22] Gremmen et al. 2019, 673-674; Fanzo 2015, 22.
[23] Henning 2015; Vinnari & Vinnari 2019; Kasanen et al. 2010.
[24] Gremmen et al. 2019, 675-677

ethics. There is no simple way to reconcile the different and competing ethical demands related to food and its production.[25]

3.2.1 Presenting the Food Ethics Framework Matrix

In order to make sense of the different and often incommensurate ethical demands related food, we apply an ethical framework matrix as a basis to our RRI-framework. The food ethics framework matrix[26], devised by Ben Mepham, helps to organize discussion on the relative merits of different ethical perspectives for different stakeholders by facilitating deliberation and decision-making on ethics. Mepham describes the purpose of the framework matrix:

"The framework gives guidance on contentious issues by employing a strategy which assesses how far ethical ideals are met by proposed changes and sometimes discovering an 'overlapping consensus' despite marked differences in people's moral values."[27]

Respect for	WELLBEING (Health & Welfare)	AUTONOMY (Freedom & Choice)	JUSTICE (Fairness)
PEOPLE IN THE FOOD INDUSTRY	Income and working conditions	Freedom of action	Fair trade laws & practice
CITIZENS	Food safety & quality of life	Democratic informed choice	Availability of affordable food
FARM ANIMALS	Animal welfare	Behavioural freedom	Intrinsic value
THE LIVING ENVIRONMENT	Conservation	Maintenance of biodiversity	Sustainability

Figure 1. Food Ethics Matrix by Ben Mepham[28]

Mepham's framework can be used to facilitate reflection on the possible alternative courses of action in the case of the alternative protein adoption. This requires the weighting of different ethical aspects such as food security and potential negative effects of alternative protein production and its widespread adoption. Mepham's framework does not in itself point out to a specific course of action but it helps to formulate the questions between different ethical approaches and their merits, such as environmental friendliness or the degree of animal friendliness of food production.[29]

[25] Gremmen et al. 2019, 675-677; Fanzo 2015, 21.
[26] Mepham 2010.
[27] Ibid., 18.
[28] https://www.foodethicscouncil.org/resource/the-ethical-matrix/
[29] Bruijnis et al 2015, 956-957.

Box 4. Relevant topics of food and feed ethics[30]

Current relevant topics of food ethics are:

- Even though there is enough food to feed the whole population of the earth, over one billion people suffer from hunger and malnutrition.
- Whereas many poor people suffer from diseases related to malnutrition, many people in the developed world suffer from the long-term unhealthy effects or the current food system.
- The current food and agricultural system is not sustainable because of the adverse effects it creates for the environment and because of its disproportionate contribution to climate change.
- The question of land use for food, feed or fuel.
- The commodification of food exacerbates the gap between humans and food production.
- The fear of denaturalizing food items through genetic modification creates a distorted relation between scientists and consumers.

Box 5. The five core values in food ethics[31]

According to FAO, there are five core values related to food ethics that need to be taken into account:

i. *The value of food*: Food is essential for humans and their survival; hunger is a result of neglect of every human's universal right for food.
ii. *The value of enhanced well-being*: Human well-being is a core ethical principle; improvements in well-being are accomplished through access to skills, capital, employment, education and opportunities.
iii. *The value of human health*: Human health advances participation in human affairs and contributes to productive and meaningful lives; health is improved through the elimination of hunger and malnutrition.
iv. *The value of natural resources*: Resources should be used in a way that does not undermine their other legitimate uses, current or anticipated; nor should the current use of resources deprive further generations.
v. *The value of nature*: Along with our growing power to modify nature, there is an increasing recognition of "the beauty complexity and integrity of nature", as well as of the limits of human power over nature.

[30] Korthals 2014, 3-5.
[31] FAO 2000.

3.3 Grand Challenges and Societal Issues related to Alternative Proteins

There are many ongoing changes in how the world is producing, distributing, selling and consuming food. Mapping these changes in the food production landscape and especially within the context of alternative proteins is an essential role of the RRI framework. In order to align R&I activities with relevant societal challenges, an engagement with the broader societal transformations, processes and products related to alternative proteins is required.

While protein is a fundamental part of a human and animal diet, the way it is currently produced is quickly depleting natural resources. Furthermore, the demand for protein is growing while the security of supply is at risk. In the next 30 years, the global food system faces a *protein challenge* of "providing up to 10 billion people with enough protein in a way that is healthy, affordable and good for the planet".[32]

The food choices made globally will increasingly reflect the options currently available only in high-income countries. The origins of changing consumer preferences reside in increasing education rates, urbanization, health and sustainability consciousness as well as new technologies. As a result, the global protein demand is projected to increase by over 80 percent when compared to today's levels. The major increase in protein demand in the future decades will require substantial amounts of natural resources, which already under great pressure from the food and feed industry, climate change and bio-fuel production.[33]

From the viewpoint of RRI, there are various ethics, responsibility and sustainability related issues linked to food production. Both animal-based production and vegetal production of proteins create negative impacts such as global greenhouse emissions, excessive cropland and water use, habitat fragmentation and biodiversity loss. Furthermore, the disparities in the access to healthy food between different socio-economic groups are further polarized by rising temperatures, water stress and drought. As a result, the future food production needs to be radically more ethical, responsible and sustainable than it currently is.[34] This is reflected in one of the food related focus areas of Horizon 2020, which states that:

"A transition is needed towards an optimal and renewable use of biological resources and towards sustainable primary production and processing systems. These systems will need to produce more food, fibre and other bio-based products with minimised inputs, environmental impact and greenhouse gas emissions, and with enhanced ecosystem services, zero waste and adequate societal value".[35]

There is a demand for a change in the food production system, food transport and food markets as well as a need for a more broad food base in terms of ingredients. The protein challenge that humanity is facing does not concern only the amount of proteins available for consumption, but also the way in which proteins are produced and consumed in the 21st century. There is a vital need to find sustainable solutions and alternative protein sources.[36]

[32] Forum for the Future 2019, 11; World Economic Forum 2019, 7; Accenture 2017, 21.
[33] World Economic Forum 2019 6-7; Accenture 2017 21.
[34] FAO 2009, 2-4; FAO 2017; World Economic Forum 2019, 20-21.
[35] https://ec.europa.eu/programmes/horizon2020/en/h2020-section/food-security-sustainable-agriculture-and-forestry-marine-maritime-and-inland-water
[36] Forum for the Future 2019; World Economic Forum 2019.

Alternative protein production is also an issue of specific strategic importance for Europe and its food security. The European Union is not self-sufficient in protein production: currently, about 70% of proteins used for animal feed in Europe is imported. This means that EU's protein supply and food security are vulnerable to supply shocks, shortages and restrictions.[37]

One example of a potentially transformative solution are the alternative protein products, developed in this project, such as novel feedstocks such as algae, insects and single cell proteins, which can help to increase the sustainability of land and water usage. The production of these protein alternatives closer to home could also reduce the environmental impacts of shipping, trucking and refrigeration.[38]

According to the World Economic Forum, *"significant technological advances in taste, texture and presentation make modern alternative-protein products considerably more attractive than before"*[39]. These advances have led to the potential commercial exploitation of various alternative proteins. The food industry's increasingly strategic approach towards alternative proteins is highlighted by the increasing investments directed into alternative proteins.[40]

However, the adoption of these types of novel feed innovations is expensive and requires greater structural change in the market to scale. Financial barriers are an inhibiting factor in the wider adoption of new animal feed innovations as many feed companies and producers are operating on very thin margins. Sustainable solutions are often more expensive within the current food production system than the already existing feed products. Systemic change towards a sustainable food system requires political support and collective cost sharing.[41]

3.3.1 Food systems approach

Analyzing the different dimensions of alternative proteins requires us to view the global food system as a complex system with many feedback loops and non-linear effects. This means taking into account the potential negative impacts of alternative proteins for food and feed industry, such as the possibility of reduced livestock and agricultural production. These developments could create unemployment and failed businesses especially in the rural economies. To make matters worse, often times these industries are located in regions, which have restricted possibilities for other employment. In a system view, the effects of alternative proteins and their production for the environment, economy and health are more visible.[42]

Thus, in order to have a responsible perspective on alternative protein production and production, we have to look at food as *"an adaptive system that exhibits complex dynamics"*. The food system involves many parts such as the environment, health, agriculture, economics, culture and politics. This systems view pairs well with RRI, as both their objective is to avoid focusing too much on single issues and narrow solutions.[43]

[37] Van der Aar et al. 2016, 104.
[38] Forum for the Future 2019, 36, 48.
[39] World Economic Forum 2019, 21.
[40] Ibid.
[41] Hoes et al. 2019, 4; Forum for the Future 2019, 39, 42.
[42] World Economic Forum 2019, 10, 20-21.
[43] Hoes et al. 2019, 8.

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"*.[44]

The following figure[45] represents, albeit in a simplified form, the functioning of a food system. The food system forms a part of the analytical framework for RRI in our projects, with which it is easier to consider the different interactions between the many actors, perspectives and themes related to the project.

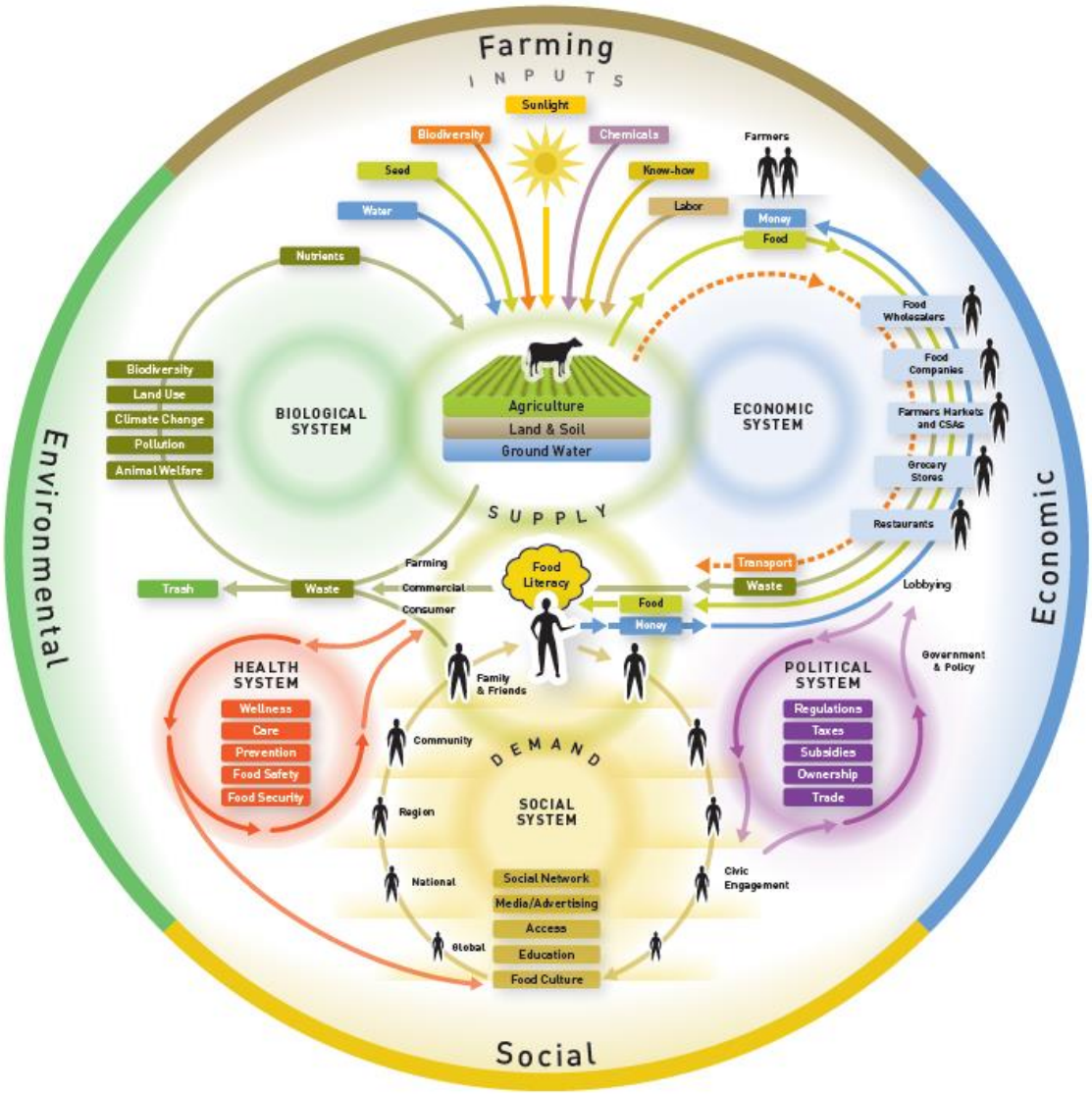

Figure 2. Food Systems diagram[46]

In the food system perspective innovations such as alternative proteins can have a big impact by providing solutions to grand food challenges. Alternative proteins are a novel innovation

[44] HLPE 2017, 23.
[45] https://www.nourishlife.org/teach/food-system-tools/
[46] https://www.nourishlife.org/pdf/Nourish_Food_System_Map_18x24.pdf

that is not (yet) dominant within the food system but might in the future create a transformative change within the food system. In the food system perspective, these small-scale novel innovations are seen from the point of view of their future potential.[47]

Viewed from this food system approach and from a long-term perspective, NextGenProteins impacts the food sector by providing sustainable alternative proteins. Alternative protein production reduces the stress on arable land, generates little GHG emissions compared with current protein sources into food and feed sectors and has little energy and water utilisation. The food sector will have access to more sustainable options in the protein supply chain, leading to reduced risks in sourcing proteins thus allowing for more competitiveness and the availability of diverse sustainable food products for consumers.

Box 6. The Societal Challenges of Horizon 2020[48]

The societal challenges of H2020 are:

- Health, demographic change and wellbeing;
- Food security, sustainable agriculture and forestry, marine and maritime and inland water research, and the Bioeconomy;
- Secure, clean and efficient energy;
- Smart, green and integrated transport;
- Climate action, environment, resource efficiency and raw materials;
- Europe in a changing world - inclusive, innovative and reflective societies;
- Secure societies - protecting freedom and security of Europe and its citizens.

Box 7. The four global grand challenges connected to food production[49]

There are four global grand challenges connected directly to food:

- *Food and population*: Responsibility for current and future generations.
- *Food and climate change*: The global food production is contributing to the acceleration of climate change.
- *Food and natural resources*: We are over-using our natural resources on land and in the sea.
- *Food and global health*: The high living standards in developed countries have come with a price: obesity.

Box 8. Five megatrends linked to food ethics[50]

FAO emphasizes that the following megatrends have a link to questions of food ethics:

- Population growth creates challenges to food production and distribution.
- The rapid degradation of renewable natural resources.
- The large-scale industrialization of agriculture.
- The concentration of global economic power.
- Human induced global emergencies, such as famine, drought and war.

[47] Hoes et al. 2019, 24.
[48] https://ec.europa.eu/programmes/horizon2020/en/h2020-section/societal-challenges
[49] Kaiser & Algers 2016, 3-5.
[50] FAO 2001.

Box 9. The UN SDGs[51] aligned with the NextGenProteins project

The NextGenProteins project aligns itself with the following United Nations Sustainable Development Goals (SDGs):

Goal 2 (Zero hunger)

According to the UN, 815 million people are now suffering from hunger, and another 2 billion people are expected to be undernourished by 2050. In order to meet the future demand for food, (especially for proteins), and to decrease world hunger, identification and adoption of new sources of sustainably produced proteins and improved sustainability in production of existing sources, is desperately needed. NextGenProteins will contribute to at least three of five targets under SDG 2 (2.1, 2.3, 2.4).

Goal 9 (Industry, innovation and infrastructure)

Technological progress is, and will continue to be, a big driver to improve sustainability of the food and feed industries, including for improved resource use and circularity, energy efficiency, GHG emissions, land and water use, etc. Development of and investment in new, sustainable and resilient food and protein production processes and infrastructures is therefore crucial to future proof both food and feed value chains and create more sustainable food choices. NextGenProteins will contribute to at least three of five targets under SDG 9 (9.1, 9.4, 9.5).

Goal 12 (Responsible consumption and production)

Promoting resource and energy efficiency, supporting innovation towards sustainability in the food/feed sectors, and providing access to affordable, sustainable, safe, nutritious alternative proteins that meet consumers' needs and expectations, are all factors that will encourage and contribute to future responsible consumption and production. NextGenProteins contributes to at least six of eight targets under SDG 12.

Goal 13 (Climate Action)

The current pressure that global food and feed production is putting on the world's natural resources (soils, freshwater, oceans, forests and biodiversity) is further accelerated with added pressure from climate change, which is now affecting every continent, with the most severe consequences for the vulnerable and poorest people. NextGenProteins contributes to SDG 13 in numerous ways, by offering opportunities that strengthen both the adaptation and mitigation within the food and feed sectors, thus strengthening the resilience of the sectors and contributes to reducing the existing pressure on existing natural resources. NextGenProteins will contribute to at least two of three targets under SDG 13 (13.1 and 13.3).

Goal 15 (Life on land)

With NextGenProteins bioconversion processes that turn waste into value, the project will provide positive impacts in terms of reduced pressure on terrestrial resources, such as freshwater (through less water use), agricultural land and soil (through less land use) and forests (by utilising forest waste streams and contributing to improved management of European forests). By focusing Europe's attention (policy makers, producers, markets and consumers) towards alternative protein sources, NextGenProteins will contribute to at least four of nine targets under SDG 13 (Targets 15.1, 15.2, 15.5, 15.8).

[51] https://www.un.org/sustainabledevelopment/sustainable-development-goals/

4 Research, Reflect & Respond: Conceptual framework matrix for RRI

4.1 Introduction to the framework matrix

The basis of the RRI framework matrix for NextGenProteins is in the concept of Responsible Research and Innovation (RRI). The framework matrix itself, the insights, tools and questions embedded within the framework are based on various studies and research on RRI. The sources to which our framework is most heavily indebted to are the AREA-framework prepared by the UK Engineering and Physical Science Research Council (EPSRC)[52], Orbit RRI framework[53], Food ethics Matrix by Ben Mepham[54], developments of Stilgoe et al.[55], the RRI framework of Stahl & Coeckelbergh[56] and the framework for Responsible Innovation devised by Owen et al.[57]. In particular, the NextGenProteins RRI framework is based on the framework of Orbit AREA 4P Framework and the work of Stahl & Coeckelbergh.

RRI represents a valuable tool for assessing the social, environmental and ethical implications of alternative proteins. The aim of RRI is to create a socially desirable outcome through interactive and mutually responsive process. In practice, this means giving non-experts a voice and the ability to influence the R&I process and its outcomes. RRI works as a two-way street, by which scientists and innovators become more accountable, but also more interactive towards the society.[58]

The two-way process of accountability and interaction requires reflecting on what we, as a society, want innovations to do. Thus, RRI asks the following questions: What sort of futures do we aim for with the help of science and technology? Are these futures democratic in nature? What values underline the research? What kind of challenges will these innovations help to tackle? The questions also relate to the underlining purpose of research: Why do it? Who might benefit and how? Will the benefits be equitable? Do we as society want it?[59]

Naturally, the answers to these questions are not simple, straightforward nor static. However, the different principles, dimensions, components and keys of the RRI framework are designed to help. The different aspects and parts of the framework are illustrated in the matrix below. The actual size conceptual framework matrix for application and use in the project can be found in Annex I.

[52] https://epsrc.ukri.org/research/framework/
[53] https://www.orbit-rri.org/about/area-4p-framework/#1491212432193-984afde8-5394
[54] Mepham 2010.
[55] Stilgoe et al. 2013.
[56] Stahl & Coeckelbergh 2016.
[57] Owen et al. 2013.
[58] Hoes 2019, 17-18.
[59] Owen et al. 2013, 34-35.

Dimensions ➡ / Components ⬇	Process: How could you approach it differently?	Product: What are you working on?	Purpose: Why are you working on it?	People: Who might be affected in the future?
Anticipate & Analyze Opportunities **Tools & Techniques:** Foresight Horizon Scanning Scenarios	Is the planned research methodology acceptable? How do we know we are right? **Project Challenges** Paradigms Assumptions Theories Methodology	Will the products be socially desirable? What impacts can we anticipate? **Project Challenges** Ethical issues Regulation Product properties Animal welfare Food & Feed safety Property rights	Why should this research be undertaken? What are the challenges and goals addressed? **Project Challenges** Protein challenge Malnutrition Sustainability Climate change Business impact	Who matters? Who might care? How are the stakeholders affected? **Project Challenges** Open access Transparency Acceptance & desirability Variety of people & views
Reflect & Reason Considerations **Tools & Techniques:** Ethical Assessment Multidisciplinary Collaboration Codes of Conduct	How should risks and benefits be measured? How should standards be drawn up and applied? **Project Practices** Data security Gender balance Risk assessment Fair trade laws and practices	How will the risks and benefits be distributed? How might the risks and benefits change over time? **Project Practices** Welfare of people and animals Conservation Food & Feed quality	Are these motivations transparent and in the public interest? How could the challenges and goals of the research change? **Project Practices** Maintenance of biodiversity Availability of affordable food Intrinsic value of people and animals Quality of life	Have we included the right stakeholders? Who else could be included? **Project Practices** Variety of stakeholders Behavioural freedom Democratic informed choice Freedom of action Income and working conditions
Engage & Include Alternatives **Tools & Techniques:** Open Innovation Focus Groups Citizen Panels	Who is in control? Who is taking part? **Project Enablers** Researchers People in the food industry	How can we embed the stakeholder perspectives? What are the viewpoints of stakeholders? **Project Enablers** Stakeholders Animals and insects	Who will benefit? What are they going to gain? **Project Enablers** Stakeholder groups The society The living environment	Who is affected? Who else could be affected? **Project Enablers** Citizens
Act & Respond Capacities **Tools & Techniques:** Regulation & Standards Societal Challenges oriented research Value-sensitive design	How can responsibilities be shared? How can your research structure become flexible? **Project Barriers** Issues with data security Discriminatory practices Gender problems Field testing problems	What needs to be done to ensure social desirability? How can we increase awareness on the impacts? **Project Barriers** Regulation Animal welfare Misuse	How do we ensure that the implied future is desirable? What are the alternative futures? **Project Barriers** System level problems Unpredictability of innovations Environmental issues Ethical dilemmas and problems Productions costs	Who prioritizes research? How could this influence diffused more widely? **Project Barriers** Cultural and religious barriers Dishonesty Ignorance Discrimination

Figure 3. The NextGenProteins RRI framework (based on the Orbit AREA 4P Framework.[60]).

[60] https://www.orbit-rri.org/about/area-4p-framework/#1491212432193-984afde8-5394

4.2 Dimensions, Components and Keys of the Framework

The framework for RRI needs to consider the whole spectrum of R&I activities: the actual *products*, their *purposes*, the *process* of creating them and the *people* involved and/or affected. Thus, our framework is divided into four dimensions: the **process** of the research; the resulting **product**; the **purpose** of the research; and the **people** related to the research.

Process refers to the activities related to research, data collection and analysis. **Product** refers to the outcomes and outputs of research, both products and services. **Purpose** is about questioning the motivations and reasons for undertaking research. **People** refers to the fact that people are at the center of the research process and the outcomes of the process.

The more specific aim of our framework is to build *anticipatory*, *reflexive*, *deliberative* and *responsive* capacity for the researchers and into the R&I process. According to an interpretation made by Bruijnis et al., research and innovation process should:

*"***anticipate** *intended and potentially unintended future impacts of their innovations,* **reflect** *on the purposes, motivation and potential impact of their innovations,* **deliberate** *with multiple stakeholders about norms and future trajectories of their innovations, and finally* **respond** *to societal needs through participatory and anticipatory governance*." [61]

These four aforementioned components are applied into our framework. Below is a more in depth analysis of the rationales and actions within each of these components:

Anticipate & Analyze: considering, describing and analyzing the possible impacts that might arise from the R&I process. Anticipation supports an exploration on the possible impacts and implications that may otherwise remain outside of discussion. Anticipation is about increasing engagement with scientific imaginaries and futures thinking rather than prediction. [62]

Reflect & Reason: reflecting on the purposes, motivations and assumptions of the R&I process. Reflection requires reasoning with the possible uncertainties, biases and framings that play a role in shaping the R&I activities. In practice, reflection is about challenging the various assumptions related to knowledge and about rethinking the moral division of labor. [63]

Engage & Include: engaging and involving the public and relevant stakeholders into discussion. The purpose of this public engagement is to open up new visions of the future through inclusive deliberation, dialogue and debate. The idea behind inclusion is to increase the capacity for analysis and reflection by broadening the pool of ideas and perspectives. [64]

Act & Respond: aligning the R&I process and activities with new information and insights emerging from experience and learning. Responsiveness is about acting on the basis of the reflections created through the previous principles, in order to influence the trajectory of the R&I activities, through "an iterative, inclusive and open process of adaptive learning". [65]

[61] Bruijnis 2015, 956.
[62] Owen et al 2013, 38; Von Schomberg 2013, 21.
[63] Ibid.
[64] Ibid.
[65] Ibid.

The RRI framework also deals with four themes within the different dimensions and components: the multiple **challenges** present in the four dimensions, the current **practices** in dealing with these challenges, and the expected **enablers** and **barriers** in dealing with these challenges. These **challenges**, **practices**, **enablers** and **barriers** were identified together with the work package leaders of the NextGenProteins project.

4.2.1 European Commission's Six Keys

In addition to the presented dimensions and components, we also apply the RRI framework of the European Commission and its specific *keys*. A set of six keys and their interrelation are at the core of EC's RRI framework: **Ethics**, **Open Access**, **Gender**, **Engagement**, **Governance** and **Science Education**.[66] The RRI *keys* specify the core ingredients of responsibility in R&I projects.

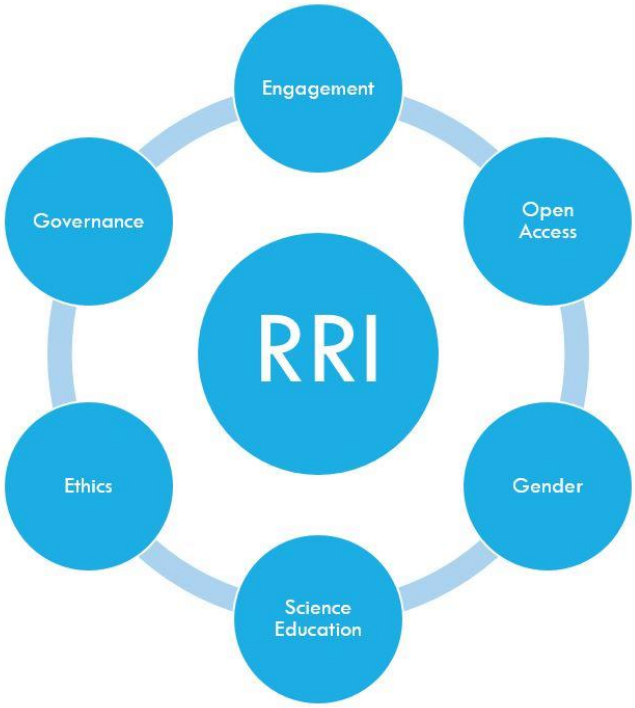

Figure 4. EC's RRI-Keys

Engagement aims at framing the societal challenges based on social, economic and ethical concerns. Engagement is about engaging a broad range of societal actors in the research and innovation process, including industry, policymakers and civil society.[67]

Open Access focuses on the transparency of scientific results of research and innovation. Open access is about making research and innovation activities more transparent and easily accessible to the public.[68]

[66] https://ec.europa.eu/programmes/horizon2020/en/h2020-section/responsible-research-innovation
[67] RRI Tools 2016, 11; Thinking Tool 2018, 9; Gianni 2013, 26-28.
[68] ibid.

Science Education is about increasing society's science literacy by boosting general interest in science and technology, and by equipping civil society actors with the necessary skills to take part in the research and innovation process.[69]

Gender focuses on ensuring that the results of research and innovation are relevant and useful for all citizens. Gender is about integrating a gender dimension and perspective into research and innovation content.[70]

Ethics refers to the moral acceptability of research, its outcomes and its conduct. Ethics is about respecting fundamental rights, fostering research and innovation activities of high societal relevance as well as ensuring social desirability.[71]

Governance aims to prevent harmful outcomes and develop ethical measures for research and innovation. Governance is about the frameworks, which support responsible research and innovation.[72]

4.2.2 The Societal Readiness Thinking Tool

As a part of our RRI framework, we aim to give the researchers practical tools for the implementation of RRI into practice. This is why we recommend the application of RRI-framework with the help of the *Societal Readiness Thinking Tool*.

In the R&D and R&I communities, there is often talk of Technological Readiness Levels (TRLs), which aim at clarifying and classifying the technological maturity of a certain technology. For example, in relation to the TRL scale, the NextGenProteins project aims to mature alternative protein technologies/applications from TRL5 to TRL6, which will help to provide new market opportunities for novel products. In slightly analogous way, the *Thinking Tool* helps to analyze and increase the societal readiness or maturity, of the research processes and outputs.

The *Thinking Tool* asks reflective questions to stimulate thinking about how to integrate ideas about responsible research and innovation into research practice, at different stages in the project life. The *Thinking Tool* is inspired by the stage-gating design, which helps the researchers to reflect and assess the societal readiness and acceptability of their work during different stages of the project's life-cycle, from the launching of the research to the dissemination of project results. The R&I process is divided into four separate phases:

Phase 1: the ideation process, formulation of research problems and research procedures.
Phase 2: the implementation, data collection and testing/experiments.
Phase 3: data analysis, evaluation and interpretation of results.
Phase 4: launch of project outcomes and dissemination.[73]

[69] ibid.
[70] ibid.
[71] ibid.
[72] ibid.
[73] Thinking Tool 2018, 5.

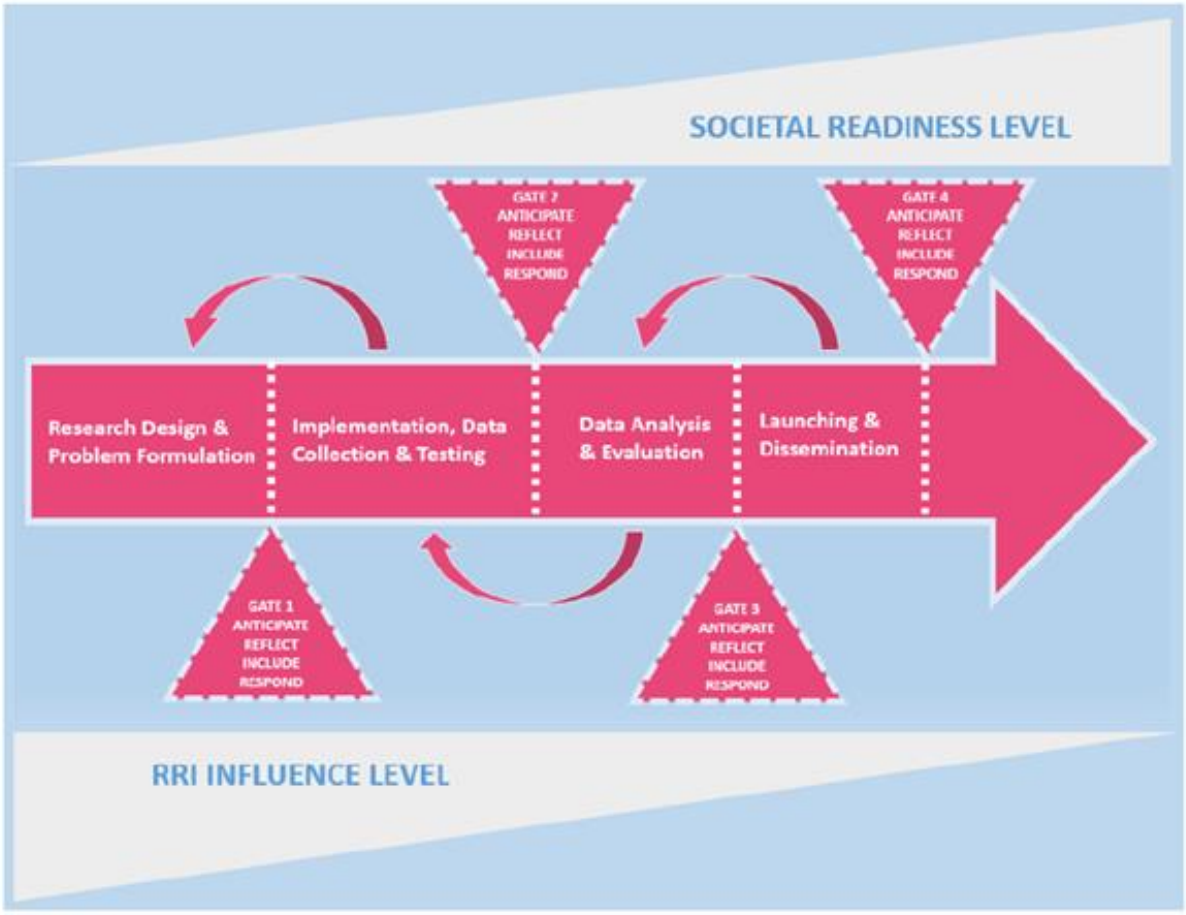

Figure 5. Societal Readiness Level Scale

The R&I activities within the NextGenProteins project consists of multiple interacting research processes. Thus, in practice, research work is about iterating between the different phases and not just a linear process. However, from the point of view of RRI, it is important to note that the different principles of responsibility will have more influence at the beginning of the project pipeline. Thus, researchers should invest substantial efforts in RRI already early in the project in order to ensure high levels of societal readiness when the project ends.[74]

[74] Thinking Tool 2018, 11-12.

5 Interact, Iterate & Implement: RRI process in NextGenProteins

5.1 General

We aim for a co-creative and participative process in implementing the RRI framework in our NextGenProteins project. The co-creation in here means that RRI is a common thing to all work packages in the project, not just WP7 or WP9. Participative manner is understood in two ways: among and between the project partners, and together with various societal stakeholders. In summary, we aim to create Responsible Research and Innovation together with the project partners and with the various stakeholders of the project.

Below is a representation of the different actions and interactions that constitute the NexGenProteins RRI framework and Task 7.1.

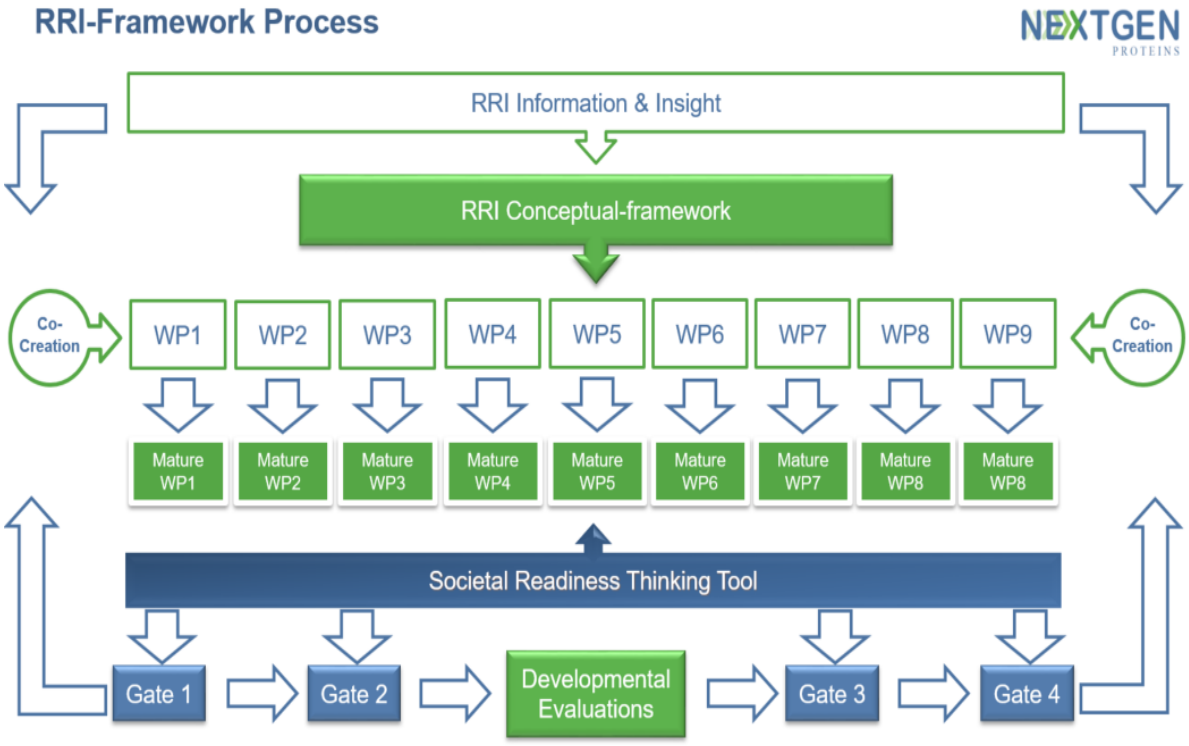

Figure 6. Illustration of the Task 7.1 RRI framework process

5.2 How to do the RRI process in practice?

There will be several concrete ways how to implement the RRI framework in Next Gen Proteins project. The practices are listed in Table 1.

Table 1. Concrete practices how to process RRI issues in Next Gen Proteins project

Practice	When	Who	Method/Tool
Following the RRI framework	During the whole project	All partners, and stakeholders in appropriate stages	Discussing and answering the questions raised in the framework and during the project Thinking Tool (https://newhorrizon.eu/thinking-tool/)
Executive Board meeting	Monthly	WP leaders and RRI representative from VTT	Meeting, agenda
WP progress	Whole project	WP leaders and RRI representative from VTT when needed	Meeting
Webinar	Spring 2020	VTT, Task 7.1 to all project members	Presentation, virtual discussion
Face-to-face RRI workshop	In project annual meetings: Project Month 12 Project Month 24 Project Month 36 Project Month 48	All partners, VTT leads	Workshop, 1 h Facilitation
Bilateral discussions	When needed	All	Discussion
RRI issues together with the stakeholders	Integrated into the WP7 processes, interactions with stakeholders	All	Various participative methods
Interim evaluation	Project Month 24	VTT, Task 7.1	Evaluation Virtual bilateral discussion between WP leader and VTT RRI person
Final evaluation	Project Month 48	VTT, Task 7.1	Evaluation Virtual bilateral discussion between WP leader and VTT RRI person

Overall, the NextGenProteins RRI framework will serve as a frame on how to tackle the RRI related issues and questions in this project. The Societal Readiness Thinking Tool will also give guidance in this task, especially in guiding the integration of the RRI process into the R&I process. The RRI-framework can be used in WP's internal discussions and research processes, especially in planning the processes. The most effective way to apply RRI principles is to consider and reflect them as early as possible in the processes.

The framework will be present in several meetings and other events in the project. VTT's RRI experts will participate in all the project Executive Board meetings. Relevant and acute RRI issues will be discussed monthly. There will also be WP progress meetings in which RRI issues are to be considered. VTT's RRI experts can assist on the topic when needed and bilateral discussions between VTT's experts and the researchers are also possible when found relevant.

VTT, Task 7.1., will organise a webinar in the spring 2020 where the RRI framework is presented to all partners of the project. A virtual workshop will be organised to all partners in the Autumn 2020, and close to the end of the project in late Spring 2022. A face-to-face workshop to the all partners is organised integrated into the project annual meetings as shown in the table. The agenda of the workshops includes presentations and discussions on how each WP has implemented the RRI framework.

The use and implementation of the RRI framework is evaluated by the VTT RRI researchers in the middle of the project and in the end of the project. This evaluation is based on virtual bilateral discussions between VTT and WPs.

6 Conclusions

The RRI framework of the NextGenProteins project consists of different parts aimed at increasing the responsibility, societal readiness and maturity of the project. At a conceptual level the RRI framework consists of a matrix of different dimensions and components. On a more practical level it is about using tools, such as the Thinking Tool, and applying the insights from the RRI related materials and different interactions within the project.

All the various RRI tools and approaches of the framework provide resources to identify and to respond to the different issues and questions arising out of the research and innovation activities within the project and its processes. The framework specifically covers responsibility, sustainability and ethical issues related to food and feed in the case of alternative proteins.

Another part of the RRI framework is the practical process research work and innovation activities. This is done in the NextGenProteins project by identifying the RRI related issues in the executive board meetings, in the work package meetings and in the bilateral discussions together with the WP leaders. Furthermore, an RRI themed webinar and workshop will be arranged around the topic of alternative proteins. RRI issues and insights are also discussed together with various stakeholders through different activities.

Finally, the RRI framework covers the evaluations of the R&I processes in the middle and in the end of the project. Evaluations are made in close cooperation together with the WP leaders. In general, the whole RRI process of the project is envisioned to be a highly co-creative process, not just among the researchers but also together with the stakeholders. The main aim of the RRI framework is to improve R&I in order to ensure high quality research process and outcomes, which will be acceptable and desirable for the society.

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ANNEX I

Conceptual RRI framework matrix (see below)

Dimensions → / Components ↓	**Process:** How could you approach it differently?	**Product:** What are you working on?	**Purpose:** Why are you working on it?	**People:** Who might be affected in the future?
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