

■ ENSURING SOCIETAL READINESS ■ A THINKING TOOL

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Table of contents

Abstract.....	3
1. Introduction.....	4
2. What is RRI?.....	6
3. Thinking Tool.....	10
4. Operationalization.....	12
5. Methods and resources for ensuring societal readiness.....	18
References.....	20
Appendix.....	23

List of Figures and Tables

Figure 1. RRI-related publications in Web of Science.....	6
Figure 2. Conditions and ingredients of RRI.....	8
Figure 3. Thinking Tool.....	11
Figure A1. Flow diagram of article inclusion and exclusion.....	23
Table 1. Conditions of RRI.....	9
Table 2. Ingredients of RRI.....	9
Table 3. Gate 1 – Research Design and Problem Formulation.....	14
Table 4. Gate 2 – Implementation, Data Collection & Testing.....	15
Table 5. Gate 3 – Data analysis and evaluation.....	16
Table 6. Gate 4 – Launching and dissemination.....	17

Abstract

Scientists and policy makers increasingly recognize responsible research and innovation (RRI) as a key priority in European research and innovation. Yet, the research and policy literature on RRI still lacks practical methods for implementation. How can theoretical and policy-based ideas about RRI be applied in the real world? How can procedural RRI-dimensions such as *anticipation*, *reflexivity*, *inclusion* and *responsiveness* be meaningfully translated into research and innovation practices? In this deliverable (6.1), we take a first stab at developing a Thinking Tool that offers practical guidance on how to mature the societal readiness of research projects. The proposed Thinking Tool adopts a stage-gating inspired processual focus. It carves out a generic methodology allowing researchers to reflect on the societal appropriateness of their work at critical stages in the project life-cycle. Insights derived from the RRI literature guide the specific reflection points raised at each project stage. The thinking tool is dynamic by design and open for ongoing adjustments and refinements. During the next 12 months, the relevance of the Thinking Tool will be tested in close collaboration with project participants from Horizon 2020's different funding streams. This will help to ensure that the tool is useful in different research and innovation contexts. A refined version of the Thinking Tool, co-produced with participants in the New Horizon Social Labs, will be published as Deliverable 6.2 in April 2019. In Deliverable 6.2, we also plan to extend the content of the Thinking Tool to include a section with brief descriptions of existing methods and resources for improving the societal readiness of research projects. Deliverable 6.2 will also provide real-world examples of how existing research projects have benefitted from using these methods and resources. In the document at hand, we briefly outline what such descriptions and examples may look like.

Keywords: Responsible research and innovation, implementation, H2020, Societal-Readiness Level, Thinking Tool

1. Introduction

Responsible research and innovation (RRI) has become a key concern in European Research and Innovation policy. RRI is integrated as a crosscutting objective in the Horizon 2020 funding programme (H2020) and the European Commission (EC) highlights its potential for tackling grand societal challenges related to health, food security, clean energy, transport, climate, social inclusion and privacy rights (Geoghegan-Quinn 2012). The concept of RRI is also gaining prominence in the academic literature. Since the late 2000s, we have seen a rapid increase in the number of publications addressing RRI (see Figure 1). Indeed, a peer-reviewed journal specifically devoted to RRI was recently established (i.e. Journal of Responsible Innovation).

Despite these developments, we still lack methods for implementing RRI into practice (Blok and Lemmens 2015; Burget et al. 2017). In this deliverable, we take a first stab at developing a Thinking Tool that offers practical guidance for scientists and engineers who wish to mature the societal readiness of their research projects. Developing an RRI Thinking Tool, of course, requires a flexible set-up that acknowledges the versatile and pluralistic nature of EC-funded research and innovation. The Thinking Tool should be detailed enough to stimulate appropriate reflection and action, and general enough to be applicable in different research and innovation contexts (Owen 2014). It goes without saying that this is not an easy task. To ensure flexibility, we propose that the Thinking Tool is conceived of as a dynamic instrument, and we welcome continuous context- and field-specific adjustments and refinements.

Recent RRI studies raise concerns about the tendency to “squeeze” research, development and commercialization activities into the same RRI framework (Blok and Lemmens 2015; Lubberink et al. 2017). Here, we acknowledge this concern, and limit our focus to academically-driven research and innovation projects. Questions about the commercialization of business-based innovations and how to integrate RRI into such activities are therefore not covered by our Thinking Tool. We have made this decision to allow for a deeper and more careful exploration of the specific RRI-related questions and concerns arising in research-based project activities. In the future, the Thinking Tool may be adapted for use in business-based innovation contexts as well; but this will require involvement of experts and stakeholders from the industry-sector with in-depth knowledge about the particular characteristics of innovation processes in this sector. Here, it is also relevant so note that several existing EC-funded projects including PRISMA (Grant Agreement No. 710059) and COMPASS (Grant Agreement No. 710543) are developing business-oriented RRI tools (see e.g. Blok and Lemmens 2015; Van de Poel et al. 2017; Auer and Jarmai 2017).

The preliminary sketch of the Thinking Tool presented in this deliverable adopts a stage-gating inspired design that allows participants in research projects to reflect on the societal appropriateness of their work at critical stages in the project life-cycle. Drawing on insights from the existing RRI literature, we have proposed of a tentative set of generic “questions for reflection” to be addressed at each project stage. These questions have primarily been developed to spur general reflexivity about how RRI may be integrated into different stages of the research process – from the ideation phase, where new ideas for discovery are conceptualized, to the launching of project outcomes, where results are disseminated to relevant stakeholders, researchers and public audiences.

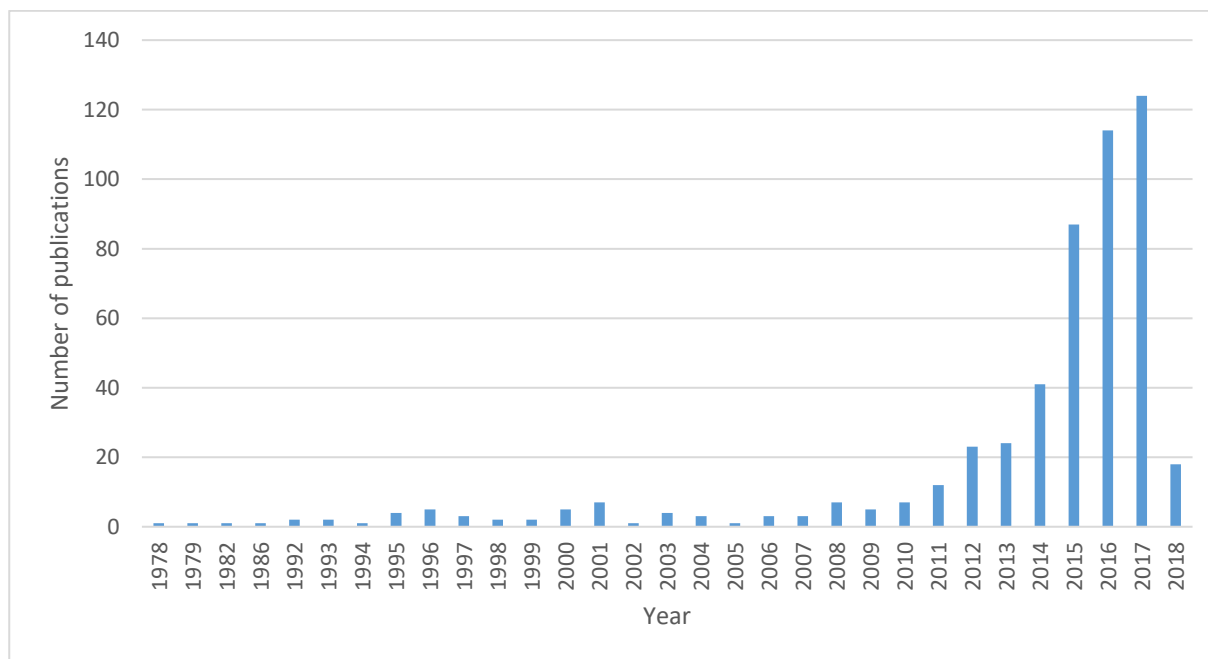
In the course of the next 12 months, the Thinking Tool will be tested in close collaboration with project participants from Horizon 2020’s different funding programmes. The NewHoRRIzon project revolves around 18 Social Labs (SLs), covering all funding modalities under H2020, from the European Research Council to the societal challenges oriented research. Each of the SLs will be used to test the tool in practice. The testing will include a feedback session. Both testing and feedback may give rise to adjustment, refinement, and diversification of the tool. This will help to ensure that the tool is useful in different research and innovation contexts. The deliberations around the Thinking Tool within the SLs will result in a refined version, to be published as Deliverable 6.2 in April 2019.

Further, deliverable 6.2 will extend the content of the Thinking Tool to include a section with brief descriptions of existing methods and resources for improving the societal readiness of research projects. These descriptions will be accompanied by real-world examples of how research projects have benefitted from using existing methods and resources in practice. In the document at hand, we briefly outline what such descriptions may look like. Finally, the second deliverable will offer suggestions on how internal or external evaluators may use the Thinking Tool to monitor the implementation of RRI in research projects.

The literature guiding the initial development of the Thinking Tool and the description of existing RRI-related methods and resources was identified in a comprehensive search in Web of Science, Scopus and CORDIS (see Appendix for specifications on Methodology). The paper proceeds as follows: In Section 2, we briefly summarize common definitions of RRI identified in the existing research and policy literature. Section 3 presents the generic Thinking Tool for integrating RRI into project-based research and innovation activities. Section 4 operationalizes the Thinking Tool by providing concrete examples of RRI-related questions to be addressed at critical stages in the project life. Section 5 briefly demonstrates how we intend to signpost existing methodologies and resources

that have proven useful in strengthening the societal appropriateness of research and innovation activities in Deliverable 6.2. In addition, this section briefly introduces the existing RRI-related support and coordination projects funded by the EC.

Figure 1. RRI-related publications in Web of Science



Note: The search was made on March 21, 2018 and included the following topic-based search terms: "responsible research and innovation", "responsible research & innovation", "responsible research", "responsible innovation". This visualization is inspired by a similar visualization by Genus and Iskandarova (2017).

2. What is RRI?

What do genetically modified crops, nuclear power reactors, genetic testing, self-driving cars and stem cell research have in common? Controversy! Scientific breakthroughs in all of these areas (and many others) have spurred notable public resistance and demonstrated a need for new responsibility frameworks allowing researchers and innovators to better align their activities with broader societal needs and expectations (Pellé and Reber 2015). RRI represents the most recent attempt to develop such a framework. Early ideas about RRI can be traced back to the 1930s (Bernal, 1939; Rose and Rose, 1969; cf. Genus and Iskandarova 2017), but the concept only recently gained prominence in European science-policy discussions. Despite a rapidly growing interest in RRI, there is still little consensus as to what exactly the concept means and what “ingredients” it consists of. In this section, we briefly review the most common definitions of RRI present in the existing literature.

The perhaps most quoted definition of RRI is coined by EC officer Rene Von Schomberg. According to Schomberg (2011, p. 9) 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).

RRI is seen here as a process rather than an outcome (Burget et al. 2017). Ensuring the societal readiness of research and innovation, Schomberg argues, requires careful attention to the social processes through which scientific knowledge and innovations are shaped; and RRI can help steer these processes toward shared societal objectives such as sustainable economic growth, social justice, gender equality, and protection of human health and environment (Schomberg 2014, 34-36).

Bernd C. Stahl (2013, 5) adopts a similar conceptualization and defines RRI as a:

...higher-level responsibility or 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 research outcomes.

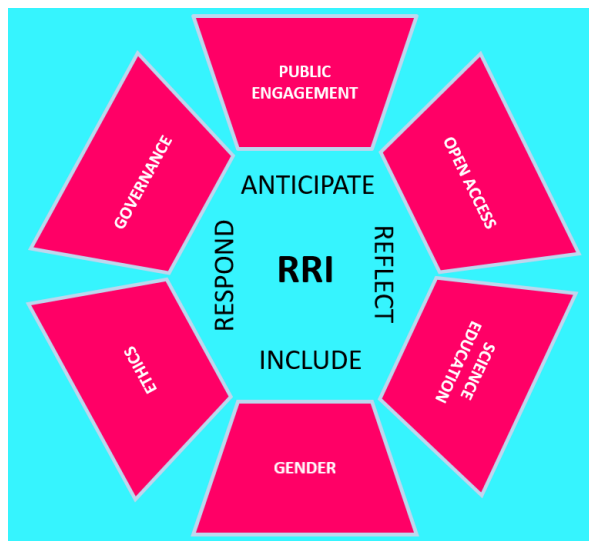
As reflected in both quotes, the “responsibilities” covered by RRI are primarily directed towards the future. The purpose, it seems, is to commit researchers and innovators to engage more actively in ensuring the social desirability and acceptability of their work – both in the short and long run. As Stilgoe and colleagues (2013, p. 1570) put it, RRI is about “taking care of the future through collective stewardship of science and innovation in the present”. RRI therefore also extends beyond conventional scientific responsibilities such as research integrity, ethical reviews and codes of conduct (Owen et al. 2012). It confers new responsibilities on scientists and innovators by committing them to “bring society in” to the research and innovation process at an early stage.

Conditions and ingredients of RRI

In making sense of the existing RRI literature, Pellé and Reber (2015) draws a useful distinction between two main approaches: the procedural approach, which seeks to specify the necessary conditions for ensuring responsibility in research and innovation processes; and the pillars approach which carves out the key ingredients of RRI projects (Figure 2). The first approach primarily pertains to the

academic literature (for a literature review, see e.g. Burget et al. 2017), while the latter has gained prominence in the EC’s policy framework.

Figure 2. Conditions and ingredients of RRI



Conditions

A recent review of more than 200 RRI articles identifies four common conditions frequently discussed in the existing literature: anticipation, reflexivity, inclusion and responsiveness (Table 1) (Burget et al. 2017).¹ The four conditions can be seen as necessary devices for reflection that will give shape to the research and innovation process by cultivating a forward-looking approach to responsibility. They offer a basic framework for reflecting on the intended and possible unintended outcomes and applications of research and innovation in a societal perspective (anticipation). They encourage researchers, innovators, funders and science-policy makers to raise questions about what voices and interest should be taken into account in the design and development process (inclusion), about the underlying motivations, assumptions and world-views driving the work (reflection), and about how to respond to the new knowledge arising through such reflections (Foley and Wiek 2017; Stilgoe et al. 2013).

Ingredients

The RRI ingredients proposed by the EC are more tangible in their characteristics (Pellé and Reber 2015) (Table 2). They represent an attempt to specify the core pillars of the responsible EC-funded project. Each ingredient constitute a thematic element with its own distinct potential for cultivating responsible processes and outcomes in European research and innovation (Rip 2016; RRI Tools

¹ These four dimensions were originally developed by Stilgoe et al. (2013).

2014). The RRI ingredients promoted by the EC consist of six keys (public engagement, open access, science education, gender, ethics and governance) and three Os (open innovation, open science, open to the world).

Table 1. Conditions of RRI

Anticipation is about carefully examining both the intended and possible unintended consequences arising from research and innovation activities, including environmental, health-related, economic and social impacts. Anticipatory processes prompt “what if...?” questions that allow researchers and innovators to prepare for and respond to the various uncertainties and dilemmas built into their work.

Reflexivity is about reflecting on the underlying motivations, assumptions and commitments driving research and innovation. It commits researchers and innovators to inquire and challenge the taken-for-granted assumptions structuring their work and makes them attentive to alternative ways of framing the value and societal impact of their ideas, methods and proposed solutions.

Inclusion is closely related to public engagement and stakeholder involvement. It is about involving relevant societal actors in research and innovation activities from an early stage, and ensuring continuous, open dialogue about desirable and undesirable outcomes throughout the project. Inclusion serves to broaden the ideas, perspectives and world-views guiding research and innovation activities.

Responsiveness is about aligning research and innovation activities with the new perspectives, insights and values emerging through anticipatory, reflexive and inclusion-based RRI processes. Responsiveness presupposes a will to learn from practical experience and a capacity to translate this learning into better, more responsible research and innovation solutions.

Sources: Owen et al. 2012; Stilgoe et al. 2013; Foley and Wiek 2017; RRI Tools (2014)

Table 2. Ingredients of RRI

SIX KEYS

Public engagement is about engaging a broad range of societal actors in the research and innovation process, including researchers, industry, policy-makers and civil society actors.

Open access is about making research and innovation activities more transparent and easily accessible to the public, e.g. through open data and free access to publications.

Science education is about increasing society’s general science literacy, e.g. by boosting children’s interest in science and technology, and by equipping civil society actors with the necessary skills to more actively take part in the research and innovation process.

Gender is about promoting women’s participation as researchers and integrating a gender dimension into research and innovation content.

Ethics is about fostering research and innovation activities of high societal relevance, that comply to the highest ethical standards.

Governance is about the legal and policy frameworks in place to support responsible research and innovation.

THREE Os

Open innovation is about making the innovation processes more open and attentive to the needs and expectations of different societal actors.

Open science is about ensuring openness, cooperation and transparency in scientific knowledge making and encouraging citizen science.

Open to the world is about allowing research and innovation to circulate more quickly and free across national boundaries and ensuring that European research contributes to global agendas.

Sources: Geoghegan-Quinn (2012), EC (2016)

3. Thinking tool

Few would disagree with the general objective of making research and innovation activities more responsible. However, translating the conditions and ingredients of RRI into practice is easier said than done (Blok and Lemmens 2015; Burget et al. 2017, Felt et al. 2017). As noted by Stahl and colleagues (2015, 2) it is not always clear to researchers and innovators “what it would mean to act responsibly or which responsibilities are ascribed to them”. Practical tools and methods for implementing RRI into practice are therefore needed.

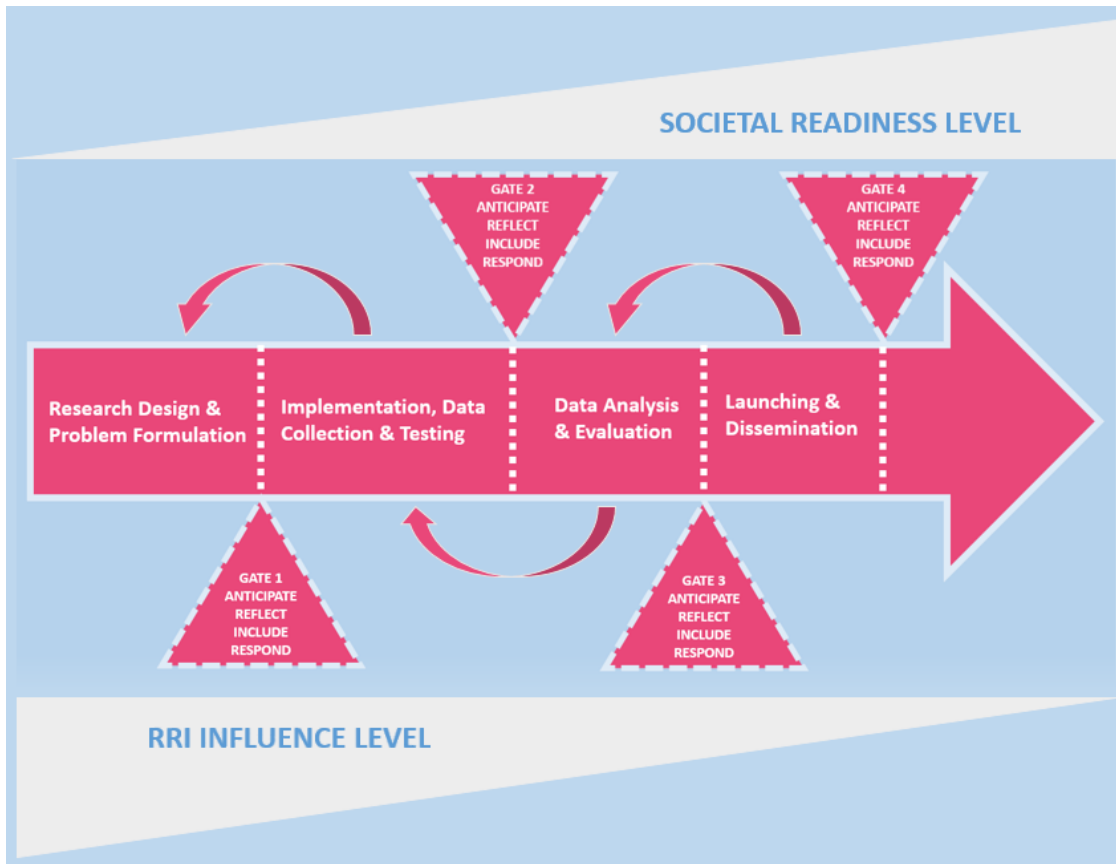
Here we propose a generic Thinking Tool for researchers and innovators who wish to mature the societal readiness of their projects. The Thinking Tool adopts a stage-gating inspired approach. Stage-gating is widely used in business-based product development (Cooper, 1990)². It divides the development process into discrete stages punctuated by decision gates. At each decision gate, the product will be subjected to certain assessment criteria (typically aimed at minimizing costs and increasing the likelihood of market success), and progression to the next development stage will be contingent on formal or informal approval (Nathan 2015; Stilgoe et al. 2013). Our Thinking Tool integrates considerations about RRI in the stage-gating architecture. It asks researchers and innovators to pause and reflect on the societal appropriateness of their work at critical stages in the project life (Figure 3).

Our Thinking Tool distinguishes four discrete phases common to most research-driven projects (Figure 3):

- Phase 1 captures the ideation process, where new ideas for discovery are conceptualized, research problems are formulated and appropriate procedures for data collection and experimentation are planned.
- Phase 2 covers activities related to implementation, data collection and experimental testing.
- Phase 3 encompasses data analysis, evaluation and interpretation of results.
- Phase 4 covers the launching of project outcomes (primarily in technology-focused projects) and the dissemination of results to relevant stakeholders, researchers and public audiences.

² Stilgoe and colleagues (2013) have demonstrated the relevance of using the stage-gating approach to promote the societal readiness of research and innovation activities.

Figure 3. Thinking Tool



Note: Some elements in this figure are inspired by Figure 9.1 in Lettice et al. (2017)

Here, it is important to acknowledge the limitations of the linear account of research and innovation. In reality, these phases are not always consecutive. As Geoff Mulgan (2006, p. 155) observes:

Sometimes action precedes understanding. Sometimes doing things catalyses new ideas. Feedback loops also exist between every stage, which make real innovations more like multiple spirals than straight lines.

To add to this, EC-funded projects are typically organized in large-scale consortiums with multiple closely connected research agendas bringing together partners from all over Europe and beyond. This implies that several interacting research processes may be at play in the same project, which in turn makes the linear account problematic. In practice, iterating between phases will therefore be necessary.

As demonstrated by the upper and lower triangles in Figure 3, the largest opportunities for cultivating RRI typically occur in the early phases of the project (Lettice et al. 2017). Put simply, researchers and innovators that invest considerable efforts in RRI early in the project will be more likely to ensure high levels of societal readiness when the project ends.

In this respect, any research and innovation project faces a paradox of control, known as the “Collingridge dilemma”: “when change is easy, the need for it cannot be foreseen, when the need for change is apparent, change has become expensive, difficult and time consuming (Collingridge 1980, p. 11). In an RRI perspective this implies that in the early project phases, where the research and innovation objectives are still malleable and the costs of choosing a different direction are limited, it is difficult to clearly foresee the possible risks and social impacts. In the later project phases where the possible risks and social impacts are more apparent, it becomes increasingly challenging and costly to choose a new course for the project (van de Poel et al. 2017). Resolving this dilemma requires a well-developed “sociological imagination” (Mills 1959). It calls for critical and sometimes abstract thinking about the complex paths through which the planned project may influence (and be influenced by) wider society.

Here it is also important to acknowledge the EC’s crucial role in paving the way for RRI. As should be evident to anyone familiar with the H2020 funding scheme, most of its calls and topics are tailored to address the grand societal challenges defined in the Europe 2020 strategy (see introduction). The research agendas, objectives and possible outcomes of EC-funded projects are in this sense (at least to some extent) predefined by the Commission in interplay with the European Parliament and Council. This raises important questions as to how these calls and topics have been developed and to what extent they are based on the ideals of anticipatory, reflexive and inclusive ways of governing research and innovation activities. However, addressing these questions is beyond the scope of this paper.

4. Operationalization

In this section, we make a first attempt to operationalize the Thinking Tool. This operationalization is based on four tables with tentative, generic questions that may aid in fostering RRI at critical phases in the project life. Many of these questions are adopted and adapted from the existing literature (Andersen 2017; Callon et al. 2010; CEN 2017; Jirotko et al. 2017; Kupper et al. 2015a; Kupper et al. 2015b; RRI-Tools 2018; Stahl et al. 2015; Stilgoe et al. 2013). Each table pertains to one of the four “gates” represented by pink triangles in Figure 3. To proceed from one phase to another, project

participants are expected to carefully consider the proposed questions in the associated table, and ideally come up with additional questions of specific relevance to their own projects. Obviously, not all questions are equally relevant to all projects, but carefully reflecting on how a question might be relevant, and why it may *not* be relevant at all, is an important part of the exercise.

Each of the four gates and their related questions will be discussed in closer detail during the New HoRRizon project meeting in Berlin, June 2018, and will specifically be targeted in the discussions with the SLs over the next 12 months. The intention is to provide concrete examples that demonstrate how a proposed set of questions pertaining to a given condition and ingredient may be relevant to a given project. In this regard, we will draw on insights from existing EC-funded RRI projects and potentially also on the broader RRI literature. The examples will be made available as part of the reporting of the refined Thinking Tool in deliverable 6.2.

Table 3. Gate 1 – Research Design and Problem Formulation

	Anticipate	Reflect	Include	Respond
Public Engagement	<ul style="list-style-type: none"> - At which phases in the project will stakeholder involvement have the most crucial impact, and why?^b -How early in the project do you plan to involve potential stakeholders?^g -Who will be the primary users/beneficiaries of the project, and could this change? -Who will not benefit from the project? -How will different stakeholders benefit from your project? 	<ul style="list-style-type: none"> -Have you considered alternative definitions of and approaches to the problem at stake?^c -Who have been involved in defining the research problem?^b -Who are the relevant stakeholders of your project?^e 	<ul style="list-style-type: none"> -What actions will be taken to ensure diversity in terms of gender, nationality, ethnicity, class, age, etc. among the involved stakeholders?^c -What actions will be taken to involve all potentially relevant stakeholders including researchers, representatives from industry, policy-makers and civil-society actors in the project?^h 	<ul style="list-style-type: none"> -Would you be able to change the course of work in response to changing stakeholder needs / perceptions / values / perceptions, and how?^c
Open Access	<ul style="list-style-type: none"> -What aspects of the project do you plan to make open access?^b -What can you do to ensure that all project partners comply with your open-access strategy? -Could pre-registration ensure transparency and openness in this project? 	<ul style="list-style-type: none"> -How do the partner organizations involved in the project approach open access?^b -What are the potential barriers to making your data, coding and publications open access? -Do you have valid reasons for not pre-registering you research? 	<ul style="list-style-type: none"> -What can be done to make proceedings and the final results of your project easily accessible and intelligible to a diverse set of stakeholders?^d -With whom do you plan to share the results of your work?^b 	<ul style="list-style-type: none"> - How will you address potential barriers to open access in this project? - How will you align diverging approaches to open access among the project partners?
Science Education	<ul style="list-style-type: none"> -Will the project contribute new knowledge of relevance for science education, and how? -Could your project benefit from involving citizens in data collection and analysis, and how? 	<ul style="list-style-type: none"> -Can RRI perspectives be integrated into the training and supervision of project staff, and how? - What would it take to better accommodate citizens interested in contributing to your work, and how? 	<ul style="list-style-type: none"> - Which stakeholders will take part in the project's education and training activities, and why?^b - Will your education and communication activities be tailored to specific stakeholder groups, and which?^b 	[To be populated]
Gender	<ul style="list-style-type: none"> -How may your project contribute to improve gender balance in academia? -Could the outcomes of this project benefit from incorporating a gender dimension into research content, and how? 	<ul style="list-style-type: none"> - What are the barriers to gender balance among researchers and leaders in this project? - What are the possible gender and sex dimensions of the problem at stake? 	<ul style="list-style-type: none"> -What can be done to ensure gender balance among researchers and leaders in this project? -What can be done to ensure gender diversity among research subjects?^c 	<ul style="list-style-type: none"> -How will you address barriers to gender balance in research and leadership?
Ethics	<ul style="list-style-type: none"> -Why should this project be done?^a -What ethical issues could your project potentially give rise to?^b - To what extent will you be able to predict the long-term societal outcomes of the project?^a 	<ul style="list-style-type: none"> - What actions should be taken to ensure research integrity and compliance with ethical standards in the project?^b - Does your project involve any risks of negative impacts, and which? 	<ul style="list-style-type: none"> -Who will be involved in identifying the ethical issues and possible solutions to these issues in your project, and how?^b - What actions will be taken to ensure diverse perspectives on the potential ethical issues arising in your project? 	<ul style="list-style-type: none"> - Would you be able to change the course of work in response to unforeseen ethical issues arising throughout the project, and how?^c
Governance	<ul style="list-style-type: none"> - Who will be responsible for ensuring the long-term impacts of your project?^b - Who will be responsible for ensuring continuous attention to RRI throughout the project? 	<ul style="list-style-type: none"> What policies, laws and regulations may support or curb the expected societal outcomes and RRI activities of your project? Will you take action to influence legislators and how? 	<ul style="list-style-type: none"> Who will be responsible for ensuring continuous involvement of different stakeholders throughout the project? 	<ul style="list-style-type: none"> -Would you be able to change the course of work in response to contextual changes? (e.g., results by competing projects; judicial changes, organizational rules and regulations)^c

Sources: The following questions were adopted or adapted from existing work. a= Jirotko et al. (2017); b= RRI-Tools (2018); c= Kupper et al. (2015a); d= Andersen (2017); e= Stahl et al. (2015); f= Stilgoe et al. 2013; g= Callon et al. (2010); h= Kupper et al. (2015b); CEN (2017).

Table 4. Gate 2 – Implementation, Data Collection & Testing

	Anticipate	Reflect	Include	Respond
Public Engagement	<ul style="list-style-type: none"> -Will the selected methods for data collection cover the full gamut of expected beneficiaries and end-users? -What potentially relevant beneficiaries and end-users will not be captured by this methodology? -How might the project benefit from involving stakeholders in identifying proper methods for data collection and empirical testing? 	<ul style="list-style-type: none"> - Have you engaged in dialogue with all relevant stakeholders so far, and how? - Who have been involved in designing the data collection / testing? - How has the nature and purpose of the project been communicated to external stakeholders?^f -Did the data collection give rise to new consideration about potentially relevant stakeholders, and which? 	<ul style="list-style-type: none"> -How will you ensure that all stakeholders feel empowered to voice their opinion?^c -What actions will be taken to ensure that all relevant stakeholders have sufficient information to engage in a meaningful dialogue about proper procedures for data collection and testing?^e 	<ul style="list-style-type: none"> -Are methods for incorporating stakeholder feedback being explored and implemented?^c -Is it possible to change the data collection methods in response to stakeholders' viewpoints or suggestions?^c
Open Access	<ul style="list-style-type: none"> -How may the selected methods for data collection and testing best be documented to ensure transparency and allow for replication and knowledge transfer? 	<ul style="list-style-type: none"> -Will you document your methods for data collection / testing in an intelligible and transparent way, and how? -What are the potential barriers to making documentations of data collection and testing publicly accessible (e.g. intellectual property rights, competing interests) 	<ul style="list-style-type: none"> -With whom will you share potential documentations of data collection and testing?^b 	<ul style="list-style-type: none"> -What can be done to overcome the potential barriers to open access?
Science Education	<ul style="list-style-type: none"> -Will the project contribute new methods and techniques of relevance for other researchers and practitioners? -How could this translation be supported through this project? 	<ul style="list-style-type: none"> -Will it be possible for interested citizens to contribute to the collection of data, and how? -How can you ensure that interested stakeholders understand the purpose and approaches of the project? 	<ul style="list-style-type: none"> -Which stakeholders are taking part in your education activities, and why these?^b 	[To be populated]
Gender	<ul style="list-style-type: none"> -Will the selected methods for data-collection / testing, and sample-size allow for nuanced analysis of possible gender- and sex-related differences and similarities? 	<ul style="list-style-type: none"> - Have gender and sex related issues been taken into consideration in the selected methods for data collection and testing, and how? -What is the sex composition of the subjects included in the collected sample? 	<ul style="list-style-type: none"> - How do you plan to identify participants that do not identify as men or women (e.g. non-binary or gender fluid subject) in the data collection? 	<ul style="list-style-type: none"> -Will it be possible to change procedures for data collection and testing to allow for nuanced gender and sex analysis?
Ethics	<ul style="list-style-type: none"> -What future impacts may the methods developed for data collection/testing have, and will they be applicable for other types of research? - Can you imagine possible scenarios of misuse?ⁱ 	<ul style="list-style-type: none"> -Is the planned research methodology ethically acceptable?^a -Does your data collection require informed consent from the participants? - Have the ethical aspects related to data collection and data storage been sufficiently addressed?^c - Does your project involve any risks of breach of confidentiality and what might they be? 	<ul style="list-style-type: none"> -Who have been involved in identifying the ethics-related issues to be considered in the data collection, and why these?^b -Have certain groups of potential participants been excluded from the data collection due to ethical concerns, and how may this limit your analysis? 	<ul style="list-style-type: none"> Is it possible to change procedures for data collection and storage in response to ethical issues arising in this phase?
Governance	[To be populated]	[To be populated]	[To be populated]	[To be populated]

Sources: The following questions were adopted or adapted from existing work. a= Jirotko et al. (2017); b= RRI-Tools (2018); c= Kupper et al. (2015a); d= Andersen (2017); e= Stahl et al. (2015); f= Stilgoe et al. 2013; g= Callon et al. (2010); h= Kupper et al. (2015b); CEN (2017).

Table 5. Gate 3 – Data analysis and evaluation

	Anticipate	Reflect	Include	Respond
Public Engagement	<ul style="list-style-type: none"> - Which stakeholders may benefit from your results, and how?^f - Which stakeholders may not benefit from your results, and why?^f - How may stakeholders benefit from your results?^f 	<ul style="list-style-type: none"> - Who have been involved in data-analysis and evaluation, and why these? - Did the data-analysis and evaluation give rise to new considerations about potentially relevant stakeholders, and which? 	<ul style="list-style-type: none"> - What actions will be taken to ensure that all relevant stakeholders have sufficient information to engage in meaningful dialogue about data analysis and evaluation?^g - Have the results been discussed with different types of stakeholders to allow for alternative interpretations? 	<ul style="list-style-type: none"> - Is it possible to adjust procedures for data analysis in response to stakeholders' viewpoints or suggestions?^c
Open Access	<ul style="list-style-type: none"> - How may the data analysis and evaluation best be documented to ensure transparency and allow for replication and knowledge transfer? 	<ul style="list-style-type: none"> - Did you document your data analysis / evaluation in an intelligible and transparent way, and how? - What are the potential barriers to making code-scripts and documentation of the full analysis publicly accessible (e.g. intellectual property rights, competing interests, confidentiality etc.) 	<ul style="list-style-type: none"> - With whom will you share the documentation of your analysis and evaluation?^b 	<ul style="list-style-type: none"> - Is it possible to adjust procedures for data analysis to strengthen eligibility and transparency?
Science Education	[To be populated]	<ul style="list-style-type: none"> - How may interested citizens contribute to your data analysis? 	<ul style="list-style-type: none"> - What types of training do you provide for citizens to contribute to your data analysis? 	[To be populated]
Gender	<ul style="list-style-type: none"> - How may your findings impact gender norms and gender relations in Europe? 	<ul style="list-style-type: none"> - Has your data analysis focused attention to possible gender- and sex-related differences and similarities, and how? 	<ul style="list-style-type: none"> - Have you analysed possible interactions between gender and sex and other socio-demographic variables such as class, ethnicity, race, nationality and age, and how? 	<ul style="list-style-type: none"> - Is it possible to change procedures for data analysis and evaluation to allow for closer inspection of possible differences by gender and sex?
Ethics	<ul style="list-style-type: none"> - What future impacts extending beyond the focus of this project may your findings have? - Can you imagine possible scenarios of misuse?ⁱ - Could your findings be misinterpreted, and how? 	<ul style="list-style-type: none"> - What ethics-related issues are involved in your data analysis? - Did your analysis devote attention to possible variations across sub-groups of participants, and how? - What types of sensitivity analysis have been used to test the robustness of your methods and results? - Does your analysis ensure full anonymity for the involved research subjects? 	<ul style="list-style-type: none"> - Have you disaggregated the data analysis by socio-demographic categories? 	<ul style="list-style-type: none"> - Is it possible to change procedures for data analysis and evaluation in response to ethical issues arising in this phase?
Governance	[To be populated]	[To be populated]	[To be populated]	[To be populated]

Sources - The following questions were adopted or adapted from existing work: a= Jirotko et al. (2017); b= RRI-Tools (2018); c= Kupper et al. (2015a); d= Andersen (2017); e= Stahl et al. (2015); f= Stilgoe et al. 2013; g= Callon et al. (2010); h= Kupper et al. (2015b); CEN (2017).

Table 6. Gate 4 – Launching and dissemination

	Anticipate	Reflect	Include	Respond
Public Engagement	-What implications may the results and procedures for stakeholder involvement of this project have for different stakeholders' future engagement in research activities in your area?	-To what extent does your dissemination plan address the relevant user and beneficiaries of the project? ^d - Who is responsible for your dissemination strategy?	-Will your dissemination plan be tailored to target the needs and characteristics of specific stakeholder groups? ^b	-Is it possible to adjust or expand your dissemination activities in response to stakeholders' needs and suggestions? ^c
Open Access	-Who will be responsible for maintenance and storage of the open-access information after the project ends, and for how long? -Could the data collected as part of this project be useful for other research purposes, and which? - Could the information made open access be misused, and how?	-Is the open access information accompanied by clear and transparent documentation of data editing, statistical procedures and analytical decisions made through-out the project? - Is the information made open access accompanied by clear specifications on data structure and variable descriptions to allow for replications or new research purposes? - Where will the open access information be stored and who are responsible for maintenance?	-Will all open access information be available in English? -Does use of the information made open access require access to licensed software? -Will publications hidden behind paywalls be accompanied by freely accessible pre-print copies?	[To be populated]
Science Education	-How may your results contribute to the public interest in and understanding of science? - How may the results of this project be used in the education of future generations of researchers and engineers?	-How will your results be communicated to the broader public? -Will you use other communication channels than peer-reviewed journals to communicate your work, and which?	-Will the results of your project be available in other languages than English?	-Is it possible to adjust or expand your dissemination activities in response to public needs and suggestions? ^c
Gender	[To be populated]	-What is the gender balance among the authors on the peer reviewed papers resulting from this project? -Will both women and men be taking roles as leading authors? -Are the results reported by sex and gender in your publications, and how?	[To be populated]	[To be populated]
Ethics	- Can you imagine possible scenarios where the outcomes of the project may be misrepresented or misconstrued in the public debate?	- How will you brief the participating research subjects about the project results?	[To be populated]	-What can be done to ensure that your results are not misrepresented or misinterpreted in the public debate?
Governance	[To be populated]	[To be populated]	[To be populated]	[To be populated]

Sources: The following questions were adopted or adapted from existing work. a= Jirotko et al. (2017); b= RRI-Tools (2018); c= Kupper et al. (2015a); d= Andersen (2017); e= Stahl et al. (2015); f= Stilgoe et al. 2013; g= Callon et al. (2010); h= Kupper et al. (2015b); CEN (2017).

5. Methods and resources for ensuring societal readiness

We propose that the final, consolidated version of the Thinking Tool should provide examples of useful methods and resources for ensuring the societal readiness of research-driven projects. We plan to briefly describe the different methods and resources in information boxes accompanied by concrete examples of how the methods have been used. The information boxes will also offer suggestions for further reading. Relevant methods will be discussed as part of the involvement of the SLs.

A Tentative list of methods and resources to be described in information boxes:

- Value-based design
- Stakeholder mapping
- Midstream modulation
- Constructive Technology Assessment
- Foresight methods
- Fictive scripts
- Prospective impact assessment
- Socio-technical scenarios
- Ethical impact assessment
- Improving Gender balance in research
- Integrating a Gender dimension in research
- Ensuring Public engagement
- Science education

Example:

Box 1 – Value Sensitive Design

Value Sensitive Design (VSD) offers a three-step methodology for embedding values in research and technology design. The first step is a conceptual investigation aimed at identifying direct and indirect stakeholders and values affected by the research/technology. In the second step an empirical investigation is carried out to map how stakeholders understand and prioritize between the identified values. Third, a technical investigation is conducted to illuminate how technical properties of existing technologies support the realization of the human values and how new technology could be proactively designed to do so.

Case example

Azencot et al. (2011) used VSD to develop an application that eases public transit for blind and deaf-blind users. First, they identified the blind and deaf-blind transit riders as direct stakeholders, and bus drivers as key indirect stakeholders. Second, a list of possibly relevant values were proposed, and based on an empirical investigation *safety* and *independence* were identified as key values. Finally, in the technical investigation, the qualities and characteristics of the existing technology “Braille” (a tactile writing system for people who are visually impaired) were assessed to provide the best foundation for developing the application “GoBraille” which supports the key values.

Further reading: Friedman et al., 2006; Davis & Nathan, 2015; Walton & Derenzi 2009, Van den Hoven 2015. Associated “ingredients” and “conditions”: Ethics, Public engagement; Inclusion, Responsiveness, Reflexivity, Anticipation

As a further resource to be included in the final version of the Thinking Tool, a selected list of RRI-related EC-funded projects could be described. These should be chosen with the purpose of inspiring and informing the users of the Thinking Tool.

A tentative list of projects to be described in information boxes:

- ENGAGE2020
- GREAT
- PREPARES
- PROGRESS
- RES-AGORA
- RESPONSIBILITY
- RRI TOOLS
- HEIRRI
- IRRESISTIBLE
- STARBIOS
- RRI-ICT FORUM
- EnRRICH
- FoTRRIS
- RRI-Practice
- JERRI
- PRISMA
- ENERI
- COMPASS
- OpenUP
- VIRT-EU
- SIENNA
- ENTIRE
- FOSTER PLUS

Example:

Box 2 – HEIRRI (Higher Education Institutions and Responsible Research and Innovation, 2015-2018, Coordination and Support Action)

The key objective of HEIRRI is to support the integration of RRI into the formal and informal education of scientists, engineers and professionals involved in research and innovation activities. Based on insights and examples collected from existing EC-funded RRI projects and the broader RRI literature, the project offers a useful open access inventory of good cases and practices of RRI and RRI learning. As stated on the project website, the inventory includes RRI Training programs and formative materials, equipping students with the necessary “knowledge and skills to develop viable solutions to specific problems related to Research and Innovation”. The teaching programs target students at various education levels (undergraduate, MD and PhD fellows) and are based on a Problem Based Learning Methodology.

Further reading: Mejlgaard et al. 2018.

Associated “ingredients” and “conditions”: Science education

Website: <http://heirri.eu/>

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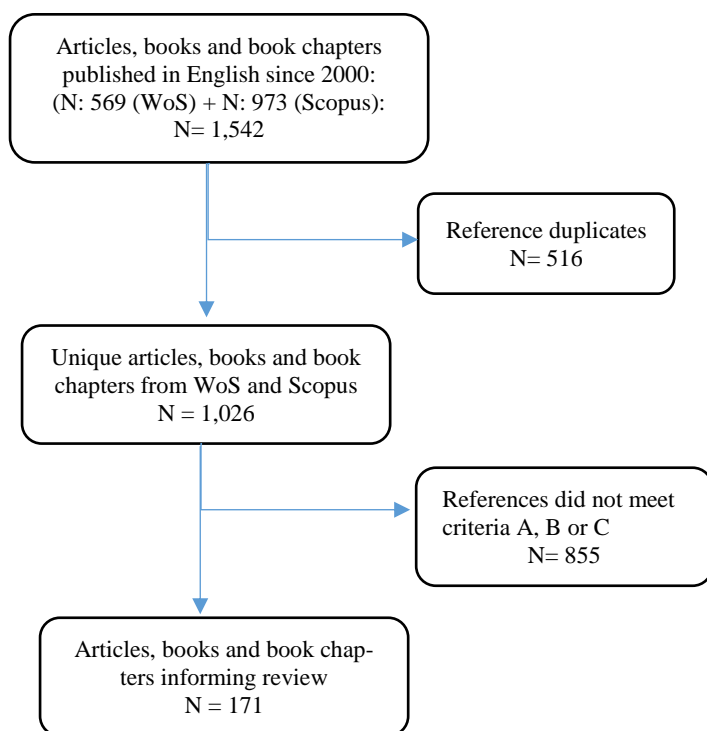
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Appendix

The literature survey of peer-reviewed scholarly papers was carried out using abstract and title-focused searches in Web of Science and Scopus. We searched for articles, books and book-chapters in English published since 2000, using a broad variety of search terms (See Table A1). We read through 1,026 titles and abstracts, ending up with 171 relevant articles (See Figure 1). All articles deemed relevant met at least one of the following selection criteria:

- A) Articles should add to the conceptual clarification of what RRI is, and/or
- B) Articles should provide practical ideas or methods on how to mature the societal readiness of R&I projects
- C) Articles should offer practical case-examples on how to ensure the social appropriateness of R&I activities.

Figure A1. Flow diagram of article inclusion and exclusion



Search string WoS:

(TS= (innovation OR "research and innovation" OR technology) AND TI= ("responsible research" OR "responsible innovation*" OR "Innovation trajector*" OR "responsible research and innovation*" OR "broader impacts criterion" OR "value sensitive design*" OR "value-sensitive design*" OR "technology acceptance" OR "social-technological alignment*" OR "social technological alignment" OR "ethical impact assessment*" OR "ethics assessment" OR "human readiness level*" OR "human-readiness level*" OR "social implications of technolog*" OR "human implications of technolog*" OR "stage-gate system" OR "upstream engagement" OR "system readiness" OR "human factors measur*" OR "human-factors measur*" OR "decision gate proces*" OR RRI OR "human factors readiness level*" OR "human-factor readiness level")) AND LANGUAGE: (English) AND DOCUMENT TYPES: (Article OR Book OR Book Chapter)

Timespan: 2000-2018. **Indexes:** SCI-EXPANDED, SSCI, A&HCI, CPCI-SSH, ESCI.

Search string SCOPUS

TITLE-ABS (innovation OR "research and innovation" OR technology) AND TITLE ("responsible research" OR "responsible innovation*" OR "Innovation trajector*" OR "responsible research and innovation*" OR "broader impacts criterion" OR "value sensitive design*" OR "value-sensitive design*" OR "technology acceptance" OR "Social-technological alignment*" OR "social technological alignment" OR "ethical impact assessment*" OR "ethics assessment" OR "human readiness level*" OR "human-readiness level*" OR "social implications of technolog*" OR "human implications of technolog*" OR "stage-gate system" OR "upstream engagement" OR "system readiness" OR "human factors measur*" OR "human-factors measur*" OR "decision gate proces*" OR rri OR "human factors readiness level*" OR "human-factor readiness level")

Search strategy in CORDIS

We searched for all funded projects mentioning “RRI” or “Responsible Research and Innovation” in the CORDIS abstract database. One-hundred and two FP6, FP7 and FP8 projects were identified using this search strategy. Of these, 23 were considered relevant to the Thinking Tool. The plan is to briefly describe the focus and activities of each of these projects in the “updated” second version of the “Thinking Tool”.