Progress Report D6: Definition of metrics and indicators for RRI benefits

Monitoring the Evolution and Benefits of Responsible Research and Innovation (MoRRI)

Development of metrics and indicators for RRI benefits

December 2016

This report is one of a series of documents produced as part of the European Commission's service contract RTD-B6-PP-00964-2013," Monitoring the evolution and benefits of responsible research and innovation". The following deliverables have been produced so far:

- **Citizen engagement and participation of societal actors in research and innovation**, Task 2, Analytical report, Deliverable D2.1, April 2015
- **Science literary and scientific education**, Task 2, Analytical report, Deliverable D2.2, April 2015
- **Gender equality**, Task 2, Analytical report, Deliverable D2.3, April 2015
- **Open access**, Task 2, Analytical report, Deliverable D2.4, April 2015
- **Ethics**, Task 2, Analytical report, Deliverable D2.4.1, April 2015
- **Governance**, Task 2, Analytical report, Deliverable D2.4.2, April 2015
- **Synthesis report on existing indicators across RRI dimensions**, Task 3, Progress report, Deliverable D3.1, May 2015
- **Metrics and indicators of Responsible Research and Innovation**, Task 3, Progress report, Deliverable D3.2, September 2015
- **Update of the literature review & Visioning exercise**, Task 6, Progress report, Deliverable D5.1, January 2016
- **In-depth case studies on the benefits of RRI across the scientific disciplines and industrial sectors**, Task 6, Deliverable D5.2, April 2016
- **RRI benefits and economic effects: summary and assessment of empirical data**, Task 6, Deliverable D5.3, December 2016

Authors:
Richard Woolley and Ismael Rafols
Contributors:
Suzanne Bührer, Rodrigo Costas, Kerstin Goos, Erich Griessler, Andrea Leitner, Ralf Lindner, Bea Mahieu, Nikos Maroulis, Ingeborg Meijer, Niels Mejlgaard, Ed Noyons, Viola Peter, Tine Ravn, Jack Stilgoe, Andrew Stirling, Larissa Talmon-Gros, Thomas Teichler, Angela Wroblewski, Milena Wuketich.

Executive Summary

This deliverable is the Report for Task 7 of the MoRRI project. The objective of Task 7 is to define metrics and indicators for RRI benefits. Methodologically Task 7 was designed to build on the outcomes of Task 6 and the Visioning Workshop.

The first part of D.6 (Chapter 2) summarises the outcomes of the identification of RRI benefits conducted in Task 6. It also summarises the RRI benefits proposed by stakeholders participating in the Visioning Workshop. The identification of democratic, economic and societal benefits of RRI dimensions also highlights existing data gaps, for which the development of primary data based metrics would be required.

The second part of the report (Chapter 3) describes conceptual modelling of the impact processes leading to the RRI benefits for each dimension. The discussion of impact processes builds on the concept of 'productive interactions' to analyse processes enabling the attribution of benefits to RRI. This part includes insights developed in the MoRRI Project Workshop held in Vienna 17-19 May 2016.

The third part of the Report (Chapter 4) identifies potential indicators of RRI benefit. Following on from the conceptual modelling of impact processes three types of indicators are proposed as part of an ongoing developmental framework for monitoring RRI benefits: intermediate indicators; conceptually modelled indicators; and applied indicators.

The final part of the report (Chapter 5) specifies a list of eleven potential indicators of RRI benefits by RRI dimension. Data fiches are compiled for each of these indicators.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

CS	Citizen Science
EC	European Commission
ETH	Ethics
FP	Framework Programme
GE	Gender Equality
GOV	Governance
OA	Open Access
PE	Public Engagement
RFO	Research Funding Organisation
RPO	Research Performing Organisation
RRI	Responsible Research and Innovation
SLSE	Science Literacy and Scientific Education

1 Introduction

The aim of the European Commission funded MoRRI project is to develop an approach to monitoring the evolution and benefits of Responsible Research and Innovation (RRI). Task 7 of MoRRI specifically focuses on the definition of metrics and indicators for RRI benefits. This deliverable constitutes the Report of Task 7.

Three main sources provided input for this report. First, Deliverable D.3.2 (European Commission 2015a) provided a core set of metrics and indicators of RRI (Appendix 1). Second, Deliverable 5.1 (European Commission 2016a) compiled the outcomes of the Visioning Workshop in which experts participated in a range of visioning exercises and proposed potential indicators of RRI benefits. Third, Deliverable 5.3 (European Commission 2016b) provided a final list of possible social, economic and democratic benefits of RRI developed through the MoRRI case study programme conducted in Task 6.

The first section of this report collates all of the inputs to the Task 7 process for each of the RRI dimensions. Preliminary assessment of the feasibility of the list of indicators of RRI benefits developed by Task 6 is included.

The report then develops linkages between indicators of RRI activity and outcomes and the accruing of societal, economic and democratic benefits of RRI. These linkages are conceptualised as impact processes that lead to benefits. The processes that lead to the attribution of benefits to RRI activities and outcomes are conceptualised as a series of impact pathways. These impact pathways are modelled at the level of RRI generally and for each of the RRI dimensions or keys specifically. The productive interactions that underpin the emergence of these pathways are summarised, as are the apparent limitations of these processes.

The following section considers data and metrics options emerging from the MoRRI project process (indicators of RRI and conceptual modelling of RRI benefits) and from other sources. These options are condensed into a set of possible indicators for RRI benefits, by RRI dimension and type of benefit.

In the final section, a number of indicators for RRI benefits are proposed. Data collection fiches are produced for each of the proposed indicators of RRI benefits.

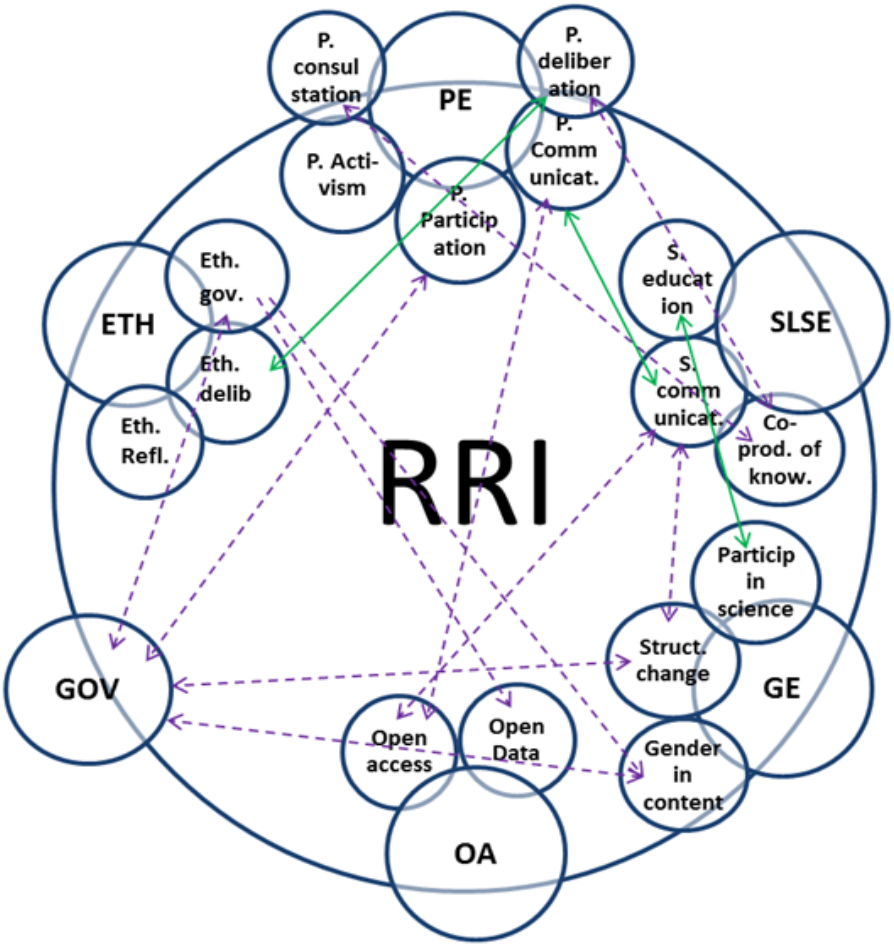
2 Identification of RRI benefits

This section establishes the broad set of potential RRI benefits identified through the MoRRI project process. The potential benefits are classified by RRI dimensions and by type of benefit identified. At the culmination of Task 6, RRI benefits had been identified for the Public Engagement (PE), Science Literacy Scientific Education (SLSE), Gender Equality (GE), Ethics (ETH) and Open Access (OA) dimensions. As part of Task 7, the identification of additional potential indicators for Governance (GOV) was considered in particular in the course of scanning for relevant new indicators emerging during the MoRRI project period (section 4.3), in preparation for selecting a set of potential indicators.

Task 6 of the MoRRI project produced a set of outputs, potential RRI benefits, which were the principal input to Task 7. Task 6 developed a raw list of potential benefits from multiple sources, including project reviews, a series of case studies, and a Visioning Workshop focused on expert opinion. For methodological reasons, related to our preference to be open and inclusive at the outset of our modelling approach (section 3), this extended raw list of potential benefits was used as the input for Task 7. A synthesised, reduced final list of RRI benefits was also specified in Task 6 (European Commission 2016b: 7-9). Unsurprisingly, given the common original source, the list of potential benefits of RRI by RRI dimension produced through the Task 7 modelling approach (Table 4.1) maps quite closely onto the final Task 6 list.

Although potential benefits of RRI have been identified for RRI Dimensions, the emergence of benefits of different types can also be driven and/or reinforced by multiple dimensions. Overlaps and intersections between RRI Dimensions and sub-dimensions, which may be influential in the emergence and nature of RRI benefits, are summarised in Figure 2.1.

Figure 2.1: Existing and potential interlinkages/overlaps between RRI dimensions/sub-dimensions



Source: (European Commission 2015a) MoRRI progress report D3.2, p. 21

2.1 Identification of the RRI benefits of Public Engagement

The Public Engagement dimension of RRI includes five categories:

- Public communication – the aim is to inform and/or educate citizens;
- Public activism – the aim is to inform decision-makers and create awareness to influence decision-making processes;
- Public consultation – the aim is to inform decision-makers about public opinions on certain topics;
- Public deliberation – the aim is to facilitate group deliberation on policy issues, where the outcome may impact decision-making; and
- Public participation – the aim is to assign partly or full decision-making-power to citizens on policy issues.

These categories include both horizontal culture-oriented activities and vertical policy-oriented activities within the remit of PE. There are also overlaps and intersections

between types of PE and other RRI dimensions. For example, public communications shares objectives and features with the dimension of SLSE. Public activism, public deliberation and public participation interrelate with participatory forms of the Governance (GOV) dimension of RRI.

From a RRI benefits perspective, Public Engagement is defined as a complex dimension, that is characterised by 1) the opening up of information flows between different parts of the R&I system and the public at large, 2) the better understanding of the positions and opinions of other stakeholders in the R&I system, and 3) the democratisation of decision-making processes regarding R&I regulation and policy.

Table 2.1 summarises the potential RRI benefits for the PE dimension identified in the Task 6 case studies report, along with further benefits proposed in the Visioning Workshop.

Table 2.1: Potential RRI benefits of Public Engagement, by type of benefit*

Democratic	Economic	Societal
- Increases and deepens citizen participation in the political decision making process - More informed choices by broadening the basis for political decision-making - Empowerment of citizens and local citizens by participatory methods - Knowledge of citizens and locals can be taken into account - Increases citizens' political awareness and understanding of political matters - Institutional learning towards public engagement in policy-making - Researchers learn about public engagement and increase their skills in participatory methods - Unreflective public engagement closes down vital debates in contentious areas - *Increase of trust of society in policy-making* - *Increasing number of productive interactions in R&I policy-making* - *Increase of interest in/attractiveness of R&I policies*	- New and different outcomes which would not be possible without PE - Positive effects (e.g. on sustainability) because of new procedures - Previously unavailable data becomes accessible to researchers because of participatory methods - Cost-effective data collection because of citizen involvement** - Other actors can use open source data*** - Mobilising funding from third actors - Farmers develop greater awareness regarding their land and therefore check it for certain characteristics - New research topics emerging from community needs	- Changes the scientific community's approach to the risks, uncertainties and wider social implications of new and emerging technologies - Citizens and locals gain competences on certain issues - Stimulation of public debate on certain issues - Increased knowledge about certain topics - New networks and network coalitions on certain issues - Facilitation of communication between actors and actor groups - Trust building between actors - Insights into citizen science - Support of citizen science as a concept - Change of awareness for certain topic and behaviours - Outreach to disadvantaged groups and communities - Improvement of curricula - Higher openness in society towards certain topic - New research on topics addressing RRI aspects - *Increasing interest in science*

Source: (European Commission 2016b) MoRRI progress report D5.3, p. Appendix 4. *Visioning Workshop suggestions in italics.

** This potential benefit was considered more properly part of SLSE, sub-dimension co-production of knowledge, see Table 3.5.

*** This potential benefit was considered more properly part of OA, sub-dimension open access, see Table 3.13.

The potential benefits of PE identified in case studies represent empirical evidence of RRI benefits for this dimension. It is apparent from this evidence that the key mechanism for the diffusion of RRI-related impacts is through networks, notably actor coalitions involved in science and relevant policy domains (e.g. environment, agriculture, innovation, etc.). These actor coalitions are vehicles for information exchanges, accessing resources, reducing costs and provision of mutual support. These activities build a broader scope of understanding and in the medium-term the development of trust. This can lead to a democratic benefit whereby actors better understand and increasingly accept their interests as being interdependent. The R&I system becomes institutionalised as a system of interdependent actors when members of diverse actor coalitions cease to advocate or act simply from the perspective of their individual interest. A societal dividend can be expected due to better policy coordination regarding RRI issues.

There is a need for constant reflection and reflexivity regarding this process. Engagement activities which simply seek to monitor the interests of other stakeholders or seek to enrol them to another's perspective can restrict or reduce the benefits of PE. The democratic benefits associated with participatory PE processes can be devolved in instances of capture by powerful groups, for example. Likewise, public or scientific institutions which are running PE processes must be open to feedback, otherwise bottlenecks can occur.

2.2 Identification of the RRI benefits of Science Literacy, Scientific Education

The Science Literacy, Scientific Education dimension of RRI includes three categories:

- Science education - aims at educating (especially young) citizens about scientific facts (textbook knowledge), the norms of science and the way science is 'done';
- Science communication - the aim is to educate citizens of all ages about science, generate awareness of science-related issues and a positive image of/attitude towards science; and
- Co-production of knowledge – is characterised by the co-creation of knowledge through cooperation between scientific experts and non-experts, e.g. citizen science.

SLSE activities thus aim to provide citizens with a deeper understanding of science, to shape their attitudes towards science and to develop their abilities to contribute to science and science-related policy-making (EC 2015 D3.2). There are some clear linkages to the PE dimension of RRI, with many mechanisms for engaging with the public also providing opportunities for the co-production of knowledge, for example.

From a RRI benefits perspective, SLSE is defined as 1) deepening the quality of information flows involving the R&I system and citizens; and 2) promoting a positive socio-cultural attitude toward learning about, and participating in, science.

Table 2 summarises the potential RRI benefits for the SLSE dimension identified in the Task 6 case studies report, along with further benefits proposed in the Visioning Workshop.

Table 2.2: Potential RRI benefits of SLSE, by type of benefit*

Democratic	Economic	Societal
- Well-informed citizens and policy-makers might make better choices - An informed public might be a public that is more engaged in certain topics - Supports students with different abilities and increases their knowledge	- More information might lead to higher acceptance of R&I - Knowledge and information are a prerequisite for open innovation and citizen science which again might lead to broader acceptance, higher market share and competitiveness	- Creates awareness of the impact of science and technology on society - Increased understanding, interest and motivation for a certain topic - Potential increase in students and science-trained labour force - Potentially increased image of science by better information - *More lifelong learning*

Source: (European Commission 2016b) MoRRI progress report D5.3, p. Appendix 4. *Visioning Workshop suggestions in italics.

The potential benefits of SLSE identified in case studies represent empirical evidence of RRI benefits for this dimension. The provision and diffusion of better quality information by stakeholders in the R&I system is foreseen as having a broad range of potential benefits. The quality of information is also linked to a socio-cultural sphere in which attitudes and motivations regarding the R&I system are open and generally positive. Linkages between quality of information, positive outlook and the PE dimension of RRI are also apparent.

2.3 Identification of the RRI benefits of Gender Equality

The Gender Equality (GE) dimension of RRI includes three categories:

- The horizontal and vertical participation of women in research – participation in research and promotion to leadership roles;
- Structural change in institutions – revising existing organisational arrangements to eliminate barriers impeding women's participation and advancement;
- Gender in research content.

The GE dimension of RRI aims to reconstitute the R&I system as one that is free of gender bias. The three elements of GE do not focus solely on achieving equality of opportunity and outcomes in the professional labour markets for researchers. This does not necessarily guarantee attention to the gender dimension of research content. Institutionalizing gender analysis in the design and conduct of R&I aims to improve the validity and reliability of scientific results and to ensure the needs of women are met by the outputs of the R&I system.

From a RRI benefits perspective, GE is defined as eliminating gender bias in science, research and innovation. The elimination of gender bias can be understood as an intrinsic democratic and societal benefit that can take numerous forms.

Table 3 summarises the potential RRI benefits for the GE dimension identified in the Task 6 case studies report, along with further benefits proposed in the Visioning Workshop.

Table 2.3: Potential RRI benefits of Gender Equality, by type of benefit*

Democratic	Economic	Societal
- Increase of female researchers is an intrinsic democratic benefit - Including untapped human resources - Needs of 50% of the population are considered - Potential effects on policy-making - Effects not limited to national level, but also on European level via European projects	- Integrating methods of sex and gender analysis into research produces excellence in science, health and medicine, engineering research, policy, and practice - Higher individual and collective performance might lead to higher output, company performance, to higher economic revenue in the end - Greater involvement of women can increase the quality of research projects (better targeted products) and strengthen the competitiveness of the company and the region - Improved (better matching) medication, therapies, information - Increased life expectancy because of improved models, methods, diagnostics, drug development, and evidence based therapies - Cost-saving - *Potentially increased job satisfaction/ motivation (policy-makers, innovators, researchers) in academia & industry*	- Increase of female researchers is an intrinsic societal benefit - Excellence in science, health and medicine, engineering research, policy, and practice - Ensures excellence and quality in outcomes, and enhances sustainability, adds value to society by making research more responsive to social needs and to business by developing new ideas, patents, and technology - Contributes to excellent research by the diversity it brings to research teams and through the analysis of research content by gender - Develops a more diverse science and engineering workforce - Improves corporate financial performance - Improves diagnosis and treatment of female patients - Positive effects on professional education, health, quality of life, prevention

Source: (European Commission 2016b) MoRRI progress report D5.3, Appendix 4. *Visioning Workshop suggestions in italics.

The potential benefits of GE identified in case studies represent empirical evidence of RRI benefits for this dimension. The inclusion of women in the R&I system is seen to

provide clear democratic, economic and societal benefits in terms of the better utilisation of resources (human capital, creativity, methods) for a broader diversity of purposes. This change in collective thinking and approaches to problems leads to outputs from the R&I system that are of better quality, not least due to better design scoping and broader targeting of these outputs.

A direct benefit of eliminating gender bias for the R&I system is more diverse workplaces, in which workers enjoy increased motivation and satisfaction levels overall. This creates flow-on economic benefits in terms of more productive organisations and societal benefits in terms of health and quality of life.

2.4 Identification of the RRI benefits of Ethics

The Ethics dimension of RRI includes three categories:

- Ethical governance - institutionalising ethics debate in terms of the implementation of standards;
- Ethical deliberation - institutionalising ethics debate that raises issues in science and technological development, e.g. technological forecasting; and
- Ethical reflection - institutionalising ethics debate that supports critical reflection, including on social justice issues.

The Ethics dimension of RRI thus aims to build a culture of anticipation and reflection within the R&I system, coupled with foresight regarding impacts of R&I outputs on the public. This cultural context is also linked to procedural elements that can formalise the application of ethical concerns. Strong linkages therefore exist between Ethics and the Governance dimension of RRI. The institutionalising of processes for reflection on societal impacts also links to the PE dimension of RRI.

From an RRI benefits perspective, the Ethics dimension is defined as creating both a thoughtful climate and procedural guidance, that can have democratic benefits in terms of developing an R&I system that is not prejudicial to the interests of society, whilst also having more immediate benefits for the conduct of science itself. Broad economic and societal benefits are also accrued if there is a reduction in the number of inappropriate R&I outputs leading to negative consequences (e.g. pollution of the natural environment), which may be costly to redress or unwind.

Table 4 summarises the potential RRI benefits for the Ethics dimension identified in the Task 6 case studies report, along with further benefits proposed in the Visioning Workshop.

Table 2.4: Potential RRI benefits of Ethics, by type of benefit*

Democratic	Economic	Societal
- *Reduction of R&I related conflicts*	- Saved litigation costs because research misconduct is reduced and conflicts mediated - Reputational gain for research organisations and therefore increased chances for funding - Increased focus by firms on corporate social responsibility (CSR), leading to increased value of goodwill accruing to CSR activities -	- Awareness for research integrity and ethics on a daily basis and clarification of these issues - New institutional practices - Fair science might lead to institutional change and greater attractiveness of science for students - Decrease in scientific misconduct - Increased confidence in science - *More companies receiving rewards for responsible conduct (e.g. environmental, social, ethical)*

Source: (European Commission 2016b) MoRRI progress report D5.3, Appendix 4. *Visioning Workshop suggestions in italics.

The potential benefits of Ethics identified in case studies represent empirical evidence of RRI benefits for this dimension. The promotion of a culture of reflection and anticipation has preventative benefits, in terms of reducing misconduct, conflict and costs, but also positive benefits in terms of building trust and goodwill on the part of the public toward RPOs.

2.5 Identification of the RRI benefits of Open Access

The Open Access dimension of RRI includes two categories:

- Open access - the idea of making research results freely available to anyone that wants to access and re-use them; and
- Open data - free access to the research data that underpins publications or research projects.

The Open Access dimension of RRI aims to open up the products and underlying inputs of the R&I system, encouraging their re-use for replication, exploration and the extension of research results.

From an RRI benefits perspective, the Open Access dimension is defined as a space in which the processes and products of (publicly) funded research are accessible, whether as inputs to further research or as knowledge relevant and useful to end-users. The quality of openness, when applied to the R&I system, can thus be understood as a more efficient way to use valuable resources, both for upstream and downstream purposes.

Table 5 summarises the potential RRI benefits for the Open Access dimension identified in the Task 6 case studies report, along with further benefits proposed in the Visioning Workshop.

Table 2.5: Potential RRI benefits of Open Access, by type of benefit*

Democratic	Economic	Societal
	- Uptake of open data enables to establish a latent value, to stimulate innovation and to increase transparency - Firms could use data they obtained from OA activities - Share of R&D activities that depend on OA - *Potentially increased effectiveness of public investment in R&I*	- Advances/stimulates diffusion of knowledge - Fast sharing of results - Authors get more visibility and recognition as authors and scientists

Source: (European Commission 2016b) MoRRI progress report D5.3, Appendix 4. *Visioning Workshop suggestions in italics.

The potential benefits of Open Access identified in case studies represent empirical evidence of RRI benefits for this dimension. A societal benefit that is apparent relates to the speed of knowledge diffusion through OA. The implicit benefit of this stimulation of faster diffusion mechanisms is a more responsive R&I system. The responsiveness of R&I systems to global challenges such as the *ebola* and *zika* viruses constitutes a societal benefit that OA can be expected to enhance. Creating a relatively frictionless access to a scientific knowledge base can also stimulate innovation, leading to the production of economic benefits with reduced costs of capital investment for private actors.

2.6 Identification of RRI benefits for science

The identification of the democratic, economic and societal benefits of RRI in Task 6 included the identification of a number of 'first order effects' that, in addition to their contribution to the eventual emergence of RRI benefits, are also directly beneficial for science itself. Benefits of RRI for science were identified for five RRI dimensions (Table 2.6). Developing indicators of the benefits of RRI for science was beyond the scope of Task 7 and this Report. Nevertheless, it can be observed that several of the benefits identified may have potential for development as indicators relevant to a monitoring system for the evolution and benefits of RRI.

Table 2.6: Benefits of RRI for science, by RRI dimension

Public Engagement	Science Literacy Science Education	Gender Equality	Ethics	Open Access
Researchers acquire new skills by public engagement methods. New and different research questions and outcomes by addressing societal needs and RRI aspects. Increases sciences' direct and indirect contribution to and exchange with society. Access to previously unavailable data through participatory methods (e.g. Citizen Science). Improvement of science education curricula.	Makes aware of the impact of science and technology on society. Better information potentially improves science's image in society and objectifies public debates on science. Potential increase in numbers of competent students and researchers able to conduct science.	Diverse and inclusive workforce in science as benefit itself. Inclusion and diversity of researchers, research teams and organisations, research topics, and analysis lead to higher quality and excellence of research. Increased and more inclusive funding opportunities. Development of new gender-aware curricula.	Reputational gain and increase in trust into science and research. Increased funding chances because of improved reputation of scientific institutions and new funding opportunities. Change in scientific culture and new institutional processes. Early-career researchers benefit from more open and transparent scientific culture.	Sharing results, data, and knowledge can advance research and innovation. Higher visibility and recognition of scientists as authors and new publication opportunities. New patents. Open Access to data and knowledge benefits early-career researchers and young scientists.

Source: (European Commission 2016b) MoRRI progress report D5.3, p. 7-9.

2.7 Preliminary assessment of the feasibility of metrics and indicators for RRI benefits

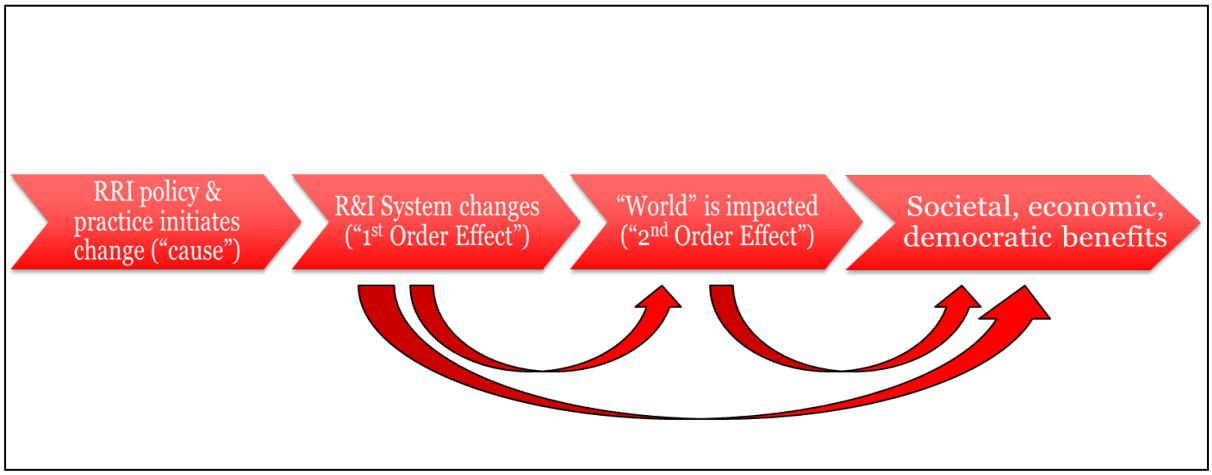
This section contains a preliminary assessment of the feasibility of developing metrics and indicators for the RRI benefits identified. A first point to note is that potential metrics and indicators are not evenly distributed across RRI dimensions. The Public Engagement, Gender Equality and, to a lesser extent, Science Literacy & Science Education dimensions contain substantial numbers of potential benefits. A relatively small number of benefits were identified for Ethics and OA, whilst none were identified for Governance through the case study and Visioning Workshop phases. Second, benefits are not distributed evenly by type. Economic benefits were less readily

identifiable for the PE and SLSE dimensions. Democratic benefits were lacking in the Ethics and OA dimensions.

The character of the benefits identified varies considerably. Many RRI benefits identified were of a very general character, which is logical when considering benefits at a societal scale. The problem of attribution of very general benefits to RRI processes and outcomes is a significant one in such cases.

The more narrow benefits identified were often focused mainly on the R&I system itself. Whilst these 'first order' benefits to the R&I system are important in themselves, it is likely that transformations in the R&I system will take time to translate into 'second order' benefits at a societal scale. This creates a problem of time-lag between observed changes in the R&I system, which might be monitored through indicators of RRI outcomes, and flow-on or emergent benefits to society at large.

Figure 2.2: First and second order effects leading to RRI benefits



Both the attribution and temporal lag problems were foreseen in the MoRRI project design. However, despite mitigation strategies for dealing with these technical problems, assigning causal links between RRI activities and impacts and societal scale benefits remains problematic. This is obviously a difficulty confronting research in general, but which has particular measurement theory challenges in the field of indicator development. Conceptualising RRI benefits as the outcome of both first order and second order impacts reflects both the temporal and the scope/scale issues related to the identification and attribution of different types of benefits.

Overall, this provisional assessment would tend to indicate that the feasibility of metrics and indicators will vary depending on: a) the RRI dimension; b) the type of RRI benefit; and c) whether first or second order effects are being linked to RRI benefits for that dimension.

The democratic and societal benefits identified that relate to socio-cultural transformations are diffuse. In terms of metrics, assessing perceptions of socio-cultural climate or of the experience of changes in perceptions or attitudes appear feasible at first glance. Quantifying societal transformations in material or processual terms seems less feasible.

In terms of economic benefits, very few are identified that could be quantified in monetary terms. Most economic benefits were conceptualised in terms of reduction in costs. Economic benefits based on the creation of value were less in evidence. Whilst

monetizing the benefits of RRI appears to have low feasibility, metrics focused on material or processual changes that have an assumed economic value may offer greater potential.

One outcome of this preliminary assessment of the feasibility of metrics and indicators for RRI benefits is the apparent weakness of empirical links between RRI policy and practice and the specification and attribution of RRI benefits. The following section attempts to redress this situation by building conceptual bridges between RRI outcomes, impact processes and the identification of RRI impacts.

3 Impact pathways and the generation of RRI benefits

This section develops linkages between indicators of RRI activity, their outcomes and the accruing of social, economic and democratic benefits of RRI. These linkages are conceptualised as impact processes that lead to benefits. The processes that lead to the attribution of benefits to RRI activities and outcomes are conceptualised as a series of impact pathways. These impact pathways are modelled at the level of RRI generally and for each of the RRI dimensions specifically. The productive interactions that underpin the emergence of these pathways are summarised, as are the apparent limitations of these processes.

3.1 A preliminary definition of pathways to RRI impacts

Establishing a systematic approach to the linkages between RRI outcomes and benefits at the societal scale requires a straightforward conceptual framework. The aim is to develop theory-based modelling of processes enabling the attribution of benefits to RRI activities. The framework proposed thus posits a set of relations through which the impacts achieved by RRI measures can be said to promote broader benefits. The concept at the core of the MoRRI model of RRI benefits is 'impact pathways' (or interchangeably, 'pathways to impact').

In the evaluation community, all impact assessments start from a logic or programme model that constitutes an explicit model of how a project or programme will (or is expected to) achieve impact. Such a model includes a step-wise or sequential chain of outcomes which are marked by a number of milestones and intermediate goals that are a precondition for the next phase (Douthwaite et al. 2003). At each stage of this sequence different actors will become involved and provide capabilities that *contribute* to the achievement of both intermediate outputs and longer-term impacts. The process of moving from the delivery of planned outputs to the eventual accrual of broad aggregate impacts, some of which may be unforeseen, is understood in the MoRRI project as a pathway to impact.

The MoRRI model draws on elements of existing impact assessment frameworks. The Payback Framework (Donovan & Hanney 2011) highlights the necessary stages of knowledge production and use that progressively and cumulatively move toward benefits (for the healthcare sector). The SIAMPI model rests on the existence of 'productive interactions' between researchers and external stakeholders as the condition of impact creation (Molas-Gallart & Tang 2011; Spaapen & Van Drooge 2011). The ASIRPA approach to assessing the societal impact of public sector research organisations defines research impact as 1) multi-dimensional; 2) based on the involvement of networks of actors; 3) at different stages and playing a variety of roles; and 4) over a non-linear impact pathway (Joly et al. 2015).

These elements are all relevant for the understanding of pathways to RRI impact. In addition to these conceptual elements, the evolution of pathways to RRI impact is understood to produce broad aggregate effects. These include societal, democratic and economic benefits, but these effects may also be negative. In terms of developing indicators for broad-based benefits, the problem of attribution switches from a focus on outputs to a focus on the presence of the planned intermediate impacts and the emergence and evolution of conditions favourable to the transmission of benefit.

The pathways to RRI benefit that characterise each of the RRI dimensions are treated as independent, due to the specific normative assumptions that underlie each dimension. However, we model pathways to RRI benefit using 'productive interactions'

as a common basic unit of analysis. Productive interactions have been defined as "exchanges between researchers and stakeholders in which knowledge is produced and valued that is both scientifically robust and socially relevant", with the productive dimension implying "efforts by stakeholders to somehow use or apply research results or practical information or experiences" (Spaapen & Van Drooge 2011: 212). Impact is conceived as more likely to occur when the number and diversity of stakeholders that are committed to such efforts, including researchers, is relatively high. Pathways to RRI impact are thus broadly conceived as based on the existence of 'productive interactions' between the widest possible range of relevant stakeholders.

Impact pathways for each RRI Dimension can then be analysed individually in terms of: 1) the processes and forms of organising productive interactions among relevant stakeholders; and 2) the contributions of stakeholders to these processes. Focusing on the contribution of stakeholders to the emergence and consolidation of pathways to RRI impact has the added advantage of encouraging a reflexive or self-evaluative approach on the behalf of stakeholders. This can help in disseminating a common understanding of RRI impact pathways and the emergence of complementarities between stakeholders' approaches and contributions that are mutually reinforcing. This could create additional benefits that are more than simply summative in nature.

3.2 Pathways to impact and the direction of change

Productive interactions among stakeholders provide the mechanism for learning and the transmission of change at the level of R&I system actors (researchers, individuals, groups, organisations). In this sense, an impact pathway is also a vehicle for transformation. The intervention logics associated with RRI dimensions seek to propel change in certain directions. These directions are normatively shaped, in that they pursue a certain understanding of what constitutes a better R&I system and better RRI impacts and outcomes. Altering the normative substrate of research and innovation activities, and influencing the direction of the R&I system overall, depends on the capacity to effect systemic changes.

In this sense, impact pathways have three transformative modalities that apply to the generation of first order effects on R&I system actors[1]:

a) *cognitive transformations* refer to changes in thinking and attitudes;

b) *procedural transformations* refer to changes in the ways things are done; and

c) *competence transformations* refer to systemic changes that effect all relevant actors.

Although these modalities can be separated analytically, they are interwoven in the emergence and institutionalising of impact pathways. Pathways can be shaped by institutional dynamics, such as the introduction of new legislation or regulations, that drive changes in the way things are done (procedural transformation). Equally, the development of improved or safer techniques may emerge at the level of practice (procedural transformation) before being codified in standards or other regulatory principles that can be diffused, impacting on competence and cognitive transformations over time. From a conceptual perspective then, RRI policy and practices set in train processes of transformations linked to actions, outputs, and outcomes that structure pathways to impact through which democratic, economic and societal benefits can be accrued.

[1] The three transformative modalities described here were developed by the MoRRI project team during the project workshop held in Vienna in May 2016.

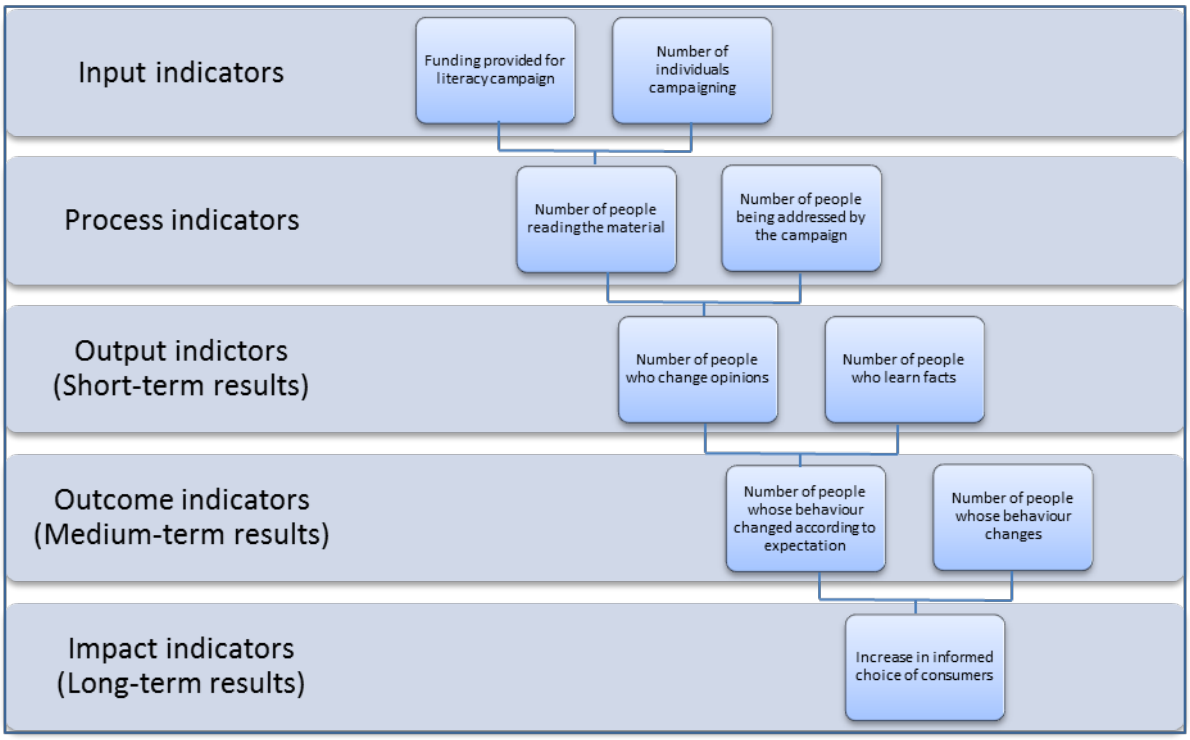
For example, RRI impact pathways toward Gender Equality induce changes in the R&I system (first order effects) and on society/the world at large (second-order effects). In the case of the R&I system, cognitive transformations refer to the proactive and positive attitudes and expectations that researchers and the research community as a whole have toward the process of reducing and eliminating gender bias from R&I. Procedural transformations include reform of existing procedures, or the introduction of new procedures, to reduce and eliminate gender bias from all management and other operational contexts, such as committees. Competence transformations refer to the inculcation of expectations and understandings across the breadth and depth of the R&I system, such that issues related to the Gender Equality dimension of RRI are equally well understood in all parts of the system and can be worked on collectively from a perspective of shared understanding.

The ultimate outcome of these cognitive, procedural and competence transformations should be an R&I system that is free of gender bias. The pathways to impact model then assumes that the scientific outputs and societal impacts produced by an R&I system that is free of gender bias will, in turn, also be free of gender bias.

The final step in the modelling of RRI impacts is the description of how outputs and impacts lead to broader benefits for society. The focus here is on the second order effects of RRI-driven change on wider society and the world at large. How can social, economic and democratic benefits be linked to the impact of RRI-driven changes to the R&I system? What benefits flow from a R&I system that is characterised by Gender Equality that produces outputs and impacts that are free of gender bias, for example? These are not straightforward questions to try and address, as the second order effects of RRI interventions are likely to be diffused throughout society, sometimes in intangible form.

The temporal dimension also introduces uncertainty into the process of developing indicators for assessing social, democratic and economic benefits. A set of indicators of RRI inputs, outputs and outcomes have been developed by the MoRRI project (Annex A). These indicators provide evidence of first and/or second order effects of RRI that can be observed in the short-, medium- and long-term.

Figure 3.1: Result chain of indicators: example of a science literacy campaign



Source: MoRRI Technical Proposal (2014), p.33.

Pathways to impact are more concerned with formulating a vision of longer-term and long-lasting change, both in the R&I system and in society at large. However, some conceptual blurring is evident between those impacts that require time to be observable and the societal, economic and democratic benefits of RRI that can be anticipated to emerge over the *longue durée*. It is thus important, first, to be aware that benefits emerging from RRI interventions may not yet be evident, partially or fully, regardless of the available impact indicators. Second, it is important not to misinterpret available process indicators as evidence of benefits.

RRI interventions are designed to shape both the content of R&I and the direction that the R&I system is moving in. Modelling pathways to RRI impact thus seeks to provide both a description of the direction of change and a plausible explanation of *how* different types of benefits emerge as effects of this change. It also seeks to provide a plausible description of the limitations of an impact pathway, or how this pathway can also be the vehicle for the emergence of negative impacts.

In the following sub-section we take a further step toward modelling RRI benefits by specifying the key processes that characterise the pathways to impact that can help us understand the emergence of RRI benefits for each RRI Dimension.

3.3 Impact pathways and processes

This sub-section clusters the potential benefits identified for each RRI dimension and links these clusters to impact processes that drive changes in the R&I system and wider society. For each type of benefit - democratic, economic and societal – explanation is included of how benefits are expected to occur, along with caveats about limitations and potential risks.

3.3.1 Impact pathways toward benefits of Public Engagement

Pathways to impact emerging from Public Engagement interventions follow a normative logic that suggests improving the amount and quality of connections between actors in the R&I system and the general public will improve outcomes from the R&I system, which in turn will lead to social, economic and democratic benefits. Table 3.1 summarises the Democratic benefits for PE identified by the MoRRI project and the process pathways that lead to their emergence.

Table 3.1: Process pathways toward democratic benefits of PE

Potential democratic benefit	RRI sub-dimension	Process pathways
- Increases and deepens citizen participation in the political decision making process - More informed choices by broadening the basis for political decision-making - Empowerment of citizens and local citizens by participatory methods	Public consultation Public participation	- *Pluralisation* of actors involved in, and bases for, political decisions - *Legitimisation* of decisions at different levels of society
- Increases citizens' political awareness and understanding of R&I matters - Increase of trust of society in policy-making - Increase of interest in/attractiveness of R&I policies	Public communication	- *Legitimisation* of decisions
- Knowledge of citizens and locals can be taken into account	Public activism	- *Pluralisation* of ideas and arguments - *Inclusion* of knowledge from diverse societal sectors
- Institutional learning towards public engagement in policy-making	Public deliberation	- *Inclusion* of public perspective in policy development and design

Pathways to impact linked to the potential democratic benefits of PE are characterised by processes of pluralisation, legitimisation and inclusion. These processes lead to a greater diversity of stakeholders involved in decisions about R&I and more heterogeneous productive interactions between them. These interactions form the

basis for a shared understanding and acceptance of policy- and decision-making procedures and outcomes. An ethos of inclusiveness reflects an active understanding, on the part of all actors involved, that relatively powerless or historically disenfranchised actors should be drawn into impact pathways and their concerns considered if at all possible.

The potential for democratic benefits from PE are not without potential negative consequences. One risk identified by expert participants in the Visioning Workshop was the potential for unreflective PE to close down vital debates in contentious areas. There is also a potential for participatory processes to be captured or to be managed as a means to extend the status quo/limit the degree of change (Stirling 2008). At a certain point productive interactions can become 'counterproductive', for example where processes of public consultation are used to delay decision-making processes in the service of particular interests. It is important therefore not to misinterpret the quantity of interactions associated with PE as being equivalent to a democratic benefit.

Table 3.2: Process pathways toward economic benefits of PE

Potential economic benefits	RRI sub-dimension	Process pathways
- New and different R&I outcomes - Positive effects (e.g. on sustainability) because of new procedures - Previously unavailable data becomes accessible to researchers because of participatory methods (saving resources that would have been devoted to capturing them) - New research topics emerging from interactions that align R&I with community needs	- Public activism	- *Pluralisation* of connections boosts creativity and approaches - *Inclusion* aligns science better with societal and consumer demand
- Mobilising funding from third actors	- Public participation	- *Pluralisation* of connections boosts resources

Pathways to impact linked to the potential economic benefits of PE are characterised by processes of pluralisation and inclusion. These processes lead to a greater diversity of connections among stakeholders and more heterogeneous productive interactions between them. These interactions form the basis for increased levels of creativity and diversity of research approaches that are better aligned with social demand for knowledge. PE that opens up new sources and users of research data also improves the potential returns on investments in R&I. Overlaps with RRI dimensions of Citizen Science and Open Access are evident here. The potential economic benefits of PE appear focused mainly in the category of Public Activism, understood as contributions

emerging from citizens, groups and organisations in their interactions with the R&I system.

Table 3.3: Process pathways toward societal benefits of PE

Potential societal benefits	RRI sub-dimension	Process pathway
- Citizens and locals gain competences on certain issues - Change of awareness for certain topic and behaviours - Outreach to disadvantaged groups and communities diffuses knowledge and information - Increased knowledge about a certain topic enhances awareness and comprehension - Facilitation of communication between actors and actor groups - Stimulation of public debate on a certain issue - Higher openness in society towards certain topic - New networks and network coalitions on a certain issue	- Public communication - Public deliberation	- *Pluralisation* of connections improves awareness and engagement, contributing to build shared understandings
- Changes the scientific community's approach to the risks, uncertainties and wider social implications of new and emerging technologies	- Public activism	- *Inclusion* of non-technical criteria in technology design and development aligns science better with societal concerns
- Trust building between actors - Public insights into citizen science activities - Public support for citizen science as a concept	- Public deliberation - Public communication -	- *Legitimisation* of stakeholder roles and contributions
- Improvement of curricula	- Public communication	- *Adaptation* of education toward citizenry

Pathways to impact linked to the potential societal benefits of PE are characterised by processes of pluralisation, legitimisation and inclusion. These processes lead to a greater diversity of stakeholders involved in shaping R&I and the deepening of shared awareness and models for understanding R&I developments. More targeted interactions between stakeholders regarding concerns about potentially negative consequences of technology helps the R&I system better interpret societal concerns (or fears). The shaping of shared awareness and understanding can thus function to bring science and research closer to societal expectations. Finally, productive interactions in the context of public deliberation, which build on shared understandings and expectations, can help to legitimise the positions and roles of diverse actors in the R&I system, both in the eyes of an engaged public and from the perspectives of other R&I stakeholders.

The productive interactions which allow citizens and stakeholders to make contributions to R&I processes create the conditions for the emergence of RRI benefits from PE. Participation in such processes can open up R&I to greater diversity and include formerly marginalised actors. This can broaden the democratic basis of R&I and aligns science more fully with society. Creating such conditions does not necessarily lead to benefits, or determine the shape such benefits may take. This depends also on whether contributions to participation processes include the capacity to influence or make decisions. It also depends on what the substantive contents of the decisions taken entail, including the extent to which such decisions impact on the R&I system itself (first order effects) and/or on society and the world (second order effects).

3.3.2 Impact pathways toward benefits of Science Literacy, Science Education

Pathways to impact emerging from SLSE interventions follow a normative logic that suggests improving access to, and quality of, the information and education available to actors in the R&I system and the general public will improve outcomes from the R&I system that will lead to social, economic and democratic benefits. Pedagogical methods and techniques are assumed to be important in this context. Table 3.4 summarises the Democratic benefits for SLSE identified by the MoRRI project and the process pathways that lead to their emergence.

Table 3.4: Process pathways toward democratic benefits of SLSE

Potential democratic benefit	RRI sub-dimension	Process pathway
- Aware and informed citizens and policy-makers will make more informed choices - An informed public will be a public that is more engaged in certain topics	- Science communication - (Public participation)	- *Diffusion* of relevant information increases awareness of R&I decisions - *Legitimisation* of R&I choices
- Supports students with different abilities and increases their knowledge	- Science education	- *Inclusion* of student groups with learning or other needs

Pathways to impact linked to the potential democratic benefits of SLSE are characterised by processes of education, legitimisation, inclusion and the diffusion of information. These processes lead to a deepening of awareness about science and informed understanding of R&I developments. This provides the foundation for citizen participation in, and appreciation of, policy choices. Productive interactions in the context of the scientific education of young people can also open a pathway to inclusive impacts where groups with learning or other special needs have access to appropriate pedagogical methods.

Table 3.5: Process pathways toward economic benefits of SLSE

Potential economic benefit	RRI sub-dimension	Process pathways
- More information leads to higher acceptance of R&I and reduced costs of market entry	- Science communication	- *Legitimisation* of R&I choices reduces transaction costs
- Knowledge and information are a prerequisite for open innovation and citizen science which again might lead to broader acceptance, higher market share and competitiveness	- Co-production of knowledge	- *Collaboration* with citizens boosts creativity and innovation. Inbuilt *legitimacy* leads to easier adoption and reduced entry costs
- Cost-effective data collection because of citizen involvement	- (Co-production of knowledge)	- *Pluralisation of data sources improves efficiency of resource use*

Pathways to impact linked to the potential economic benefits of SLSE are characterised by processes of legitimisation and collaboration. These processes can

lead to a deepening of awareness about science and informed understanding of R&I developments. By reducing uncertainty, such a deepening of understanding may have quite direct economic benefits, such as lower marketing and information costs associated with introducing new technologies or innovations. Productive interactions in the context of collaboration on citizen science bring new ideas and creativity to the R&I system. Involving citizens in co-creation processes also increases the likelihood that the outputs and outcomes of collaborative R&I will be adopted relatively straightforwardly by consumers/citizens, again reducing costs.

Table 3.6: Process pathways toward societal benefits of SLSE

Potential societal benefit	RRI sub-dimension	Process pathways
- Creates awareness of the impact of science and technology on society - Increased understanding, interest and motivation for a certain topic - More lifelong learning - Potentially improve the image of science through better quality information	- Science communication - Science education	- *Diffusion* of relevant information increases awareness and understanding of R&I decisions - *Inclusion* of all citizens in education regardless of age improves awareness and understanding of current R&I issues
- Potential increase in students and labour force with relevant skills	- Science education	- *Inclusion* of students boosts their labour market outcomes

Pathways to impact linked to the potential societal benefits of SLSE are characterized by processes of education, diffusion of information and inclusion of young people. These processes lead to a deepening of awareness about science and informed understanding of R&I-related policy and political decisions. Productive interactions in the context of the scientific education of young people can also open a pathway to inclusive impacts where students encounter opportunities that improve their labour market opportunities and outcomes.

3.3.3 Impact pathways toward benefits of Gender Equality

Pathways to impact emerging from Gender Equality interventions follow a normative logic that suggests reducing and eventually eliminating gender bias from the R&I system that will lead to social, economic and democratic benefits. Table 3.7 summarises the Democratic benefits for GE identified by the MoRRI project and the process pathways that lead to their emergence.

Table 3.7: Process pathways toward democratic benefits of GE

Potential democratic benefit	RRI sub-dimension	Process pathways
- Increase of female researchers toward equality is an intrinsic democratic benefit Inclusion of untapped human resources in R&I - Needs of 50% of the population are considered - Potential effects on policy-making	- Participation of women in research - Gender in research content	- *Inclusion* of women in R&I reduces bias
- Effects not limited to national level, but also on European level via European projects	- Participation of women in R&I - Gender dimension in research content	- *Diffusion* of best practice through R&I collaboration

Pathways to impact linked to the potential democratic benefits of GE are characterised by processes of inclusion and international diffusion. These processes lead to a reduction of gender bias in the R&I system. Productive interactions in the context of R&I collaborations at the international level can diffuse good practices that can reduce bias in partner groups and organisations.

Table 3.8: Process pathways toward economic benefits of GE

Potential economic benefit	RRI sub-dimension	Process pathways
- Integrating methods of sex and gender analysis into research produces excellence in relevant science, health and medicine, engineering research, policy, and practice - Higher individual and collective performance leads to higher output, company performance, to higher economic revenue in the end - Greater involvement of women increases the quality of research projects (better targeted products) and strengthen the competitiveness of the company and the region	- Participation of women in research - Gender in research content	- *Inclusion* of women in the design and development of R&I improves quality of scientific outputs
- Improved (better matching) medication, therapies, information - Increased life expectancy/well-being because of improved models, methods, diagnostics, drug development, and evidence based therapies	- Gender content of research	- *Pluralisation* of research topics and approaches moves science closer to social needs and responds to market demand more effectively
- Cost-savings due to lower morbidity - Increased job satisfaction/ motivation (policy-makers, innovators, researchers) in academia & industry	- Structural change in institutions	- *Inclusion* of women in labour market increases supply, improves job satisfaction, reduces turnover and exit costs

Pathways to impact linked to the potential economic benefits of GE are characterised by processes of inclusion, pluralisation and reform of institutions. These processes lead to an improvement in the outputs and outcomes of the R&I system in terms of (re-)modelling and designing products with women as the target user/consumer and aligns the R&I system better with social needs and market demand. Productive

interactions in the context of RPOs and other organisations in which bias in access to professional and other positions has been reduced can improve job satisfaction leading to reduced turnover and human resource management costs.

Table 3.9: Process pathways toward societal benefits of GE

Potential societal benefit	RRI sub-dimension	Process pathways
- Increase of female researchers is an intrinsic societal benefit - Contributes to excellent research by the diversity it brings to research teams and through the analysis of research content by gender - Develops a more diverse science and engineering workforce -	- Participation of women in research - Gender content of research	- *Inclusion* of women in the design and development of R&I improves quality of scientific outputs
- Quality in science, health and medicine, engineering research, policy, and practice - Ensures excellence and quality in outcomes, and enhances sustainability, adds value to society by making research more responsive to social needs and to business by developing new ideas, patents, and technology - Improves diagnosis and treatment of female patients -	- Participation of women in research - Gender content of research	- *Pluralisation* of research topics and approaches in R&I improves relevance of scientific outputs
- Positive effects on professional education, health, quality of life, prevention	- Participation of women in research - Structural change in institutions	- *Inclusio*n of women in professional fields reduces gender bias in social institutions

Pathways to impact linked to the potential economic benefits of GE are characterised by processes of inclusion, pluralisation and reform of institutions. These processes lead to an improvement in the outputs and outcomes of the R&I system in terms of (re-)modelling and designing products with women as the target user/consumer and aligns the R&I system better with social needs and market demand. Productive interactions in the context of RPOs and other organisations in which bias in access to professional and other positions has been reduced can improve job satisfaction leading to reduced turnover and human resource management costs.

3.3.4 Impact pathways toward benefits of Ethics

Pathways to impact emerging from Ethics interventions follow a normative logic which suggests that institutionalising debate about ethical issues and ethical research standards will shape the R&I system in desirable ways. An ethical R&I system shapes the social, economic and democratic benefits that emerge from it. Table 3.10 summarises the Democratic benefits for Ethics identified by the MoRRI project and the process pathways that lead to their emergence.

Table 3.10: Process pathways toward democratic benefits of Ethics

Potential democratic benefits	RRI sub-dimension	Process pathways
- Reduction and/or better management of R&I related conflicts	- Ethical reflection	- *Recognition* of ethical debate about social issues related to R&I - *Inclusion* of societal actors in debate

Pathways to impact linked to the potential democratic benefits of Ethics are characterised by processes of institutionalisation and inclusion. These processes lead to a consideration of ethical issues confronting the R&I system in terms of their broad impact on social justice. Productive interactions in the context of ethical debate can help build consensus about the appropriateness of R&I activities from this perspective, both within the R&I system and the broader society.

Table 3.11: Process pathways toward economic benefits of Ethics

Potential economic benefits	RRI sub-dimension	Process pathways
- Saved litigation costs because research misconduct might be prevented and conflicts mediated - Gain of reputation for research organisations and therefore increased chances for funding - Few attempts in firms to measure the economic impact of CSR; CSR is good in itself and does not need justification	- Ethical governance	- *Legitimisation* of R&I in terms of perceptions of socially desirable and appropriate values, reduces transaction costs and increases goodwill

Pathways to impact linked to the potential economic benefits of Ethics are characterised by the process of legitimisation. This process can lead to an appreciation of actors in the R&I system as being honest and holding values that are aligned with the expectations of citizens. Productive interactions in the context of ethics debates

can contribute to the development and acceptance of standards of conduct and governance that are reflective of societal expectations. Societal confidence in the conduct of R&I can reduce market entry costs and encourage investment.

Table 3.12: Process pathways toward societal benefits of Ethics

Potential societal benefits	RRI sub-dimension	Process pathways
- Awareness of research integrity and ethics on a daily basis and clarification of these issues - More companies receiving rewards for responsible conduct (e.g. environmental, social, ethical)	- Ethical deliberation	- *Recognition* of ethical basis of R&I developments, strategies and choices, and the link to societal challenges
- New institutional practices such as ethics committees, ethical impact assessments - Decrease in scientific misconduct	- Ethical governance	- *Adaptation* of R&I practices to higher standards
- Fair science will lead to institutional change and greater attractiveness of science for students - Increased confidence in science	- Ethical governance - Ethical reflection	- *Legitimisation* of R&I in terms of socially desirable and appropriate values, improves image and attractiveness of science careers

Pathways to impact linked to the potential societal benefits of Ethics are characterised by processes of recognition, adaptation and legitimisation. These processes can lead to an appreciation of the role of the R&I system in socio-economic development and the ethical questions underpinning societal level responses to grand challenges. Productive interactions in the context of ethics debates can contribute to the adopting of new practices and standards of conduct that are reflective of societal expectations. Societal confidence in the conduct of R&I can improve the chances that young generations will hold a respectful regard for science and consider research to be a worthy career choice.

3.3.5 Impact pathways toward benefits of Open Access

Pathways to impact emerging from OA interventions follow a normative logic which suggests that increased access to and availability of knowledge resources will shape the R&I system in desirable ways. Table 3.13 summarises the Democratic benefits for OA identified by the MoRRI project and the process pathways that lead to their emergence.

Table 3.13: Process pathways toward economic benefits of Open Access

Potential economic benefits	RRI sub-dimension	Process pathways
- Uptake of open data enables establishment of latent value, to stimulate innovation and to increase transparency - Firms could use data they obtained from OA activities - New patents - Increased share of economic activities that depend on OA resources - Potentially increased effectiveness of public investment in R&I	- Open data - Open access	- *Pluralisation* of R&I actors utilising valuable knowledge resources - *Exploitation* of scientific research data stimulates creativity and avenues for innovation, more effective use of knowledge inputs/outputs and more efficient use of public resources
- Other actors can use open source data	- Open access - Open data	- *Pluralisation* of data users improves efficiency of resource use

Pathways to impact linked to the potential economic benefits of OA are characterised by the process of pluralisation and exploitation. The involvement of a greater number of researchers, groups and organisations in the exploitation of data and results represents an increase in the effectiveness and efficiency of the R&I system in terms of providing returns on public investments in knowledge production and stimulating private innovation.

Table 3.14: Process pathways toward societal benefits of Open Access

Potential societal benefits	RRI sub-dimension	Process pathways
- Advances/stimulates diffusion of knowledge - Fast sharing of results Authors get more visibility and recognition as authors and scientists	- Open access - Open data	- *Diffusion* of research results stimulates avenues for social innovation addressing local problems, increases awareness of scientific contributors.

Pathways to impact linked to the potential societal benefits of OA are characterised by the process of diffusion. Knowledge circulates more easily and in a more useable form. This can stimulate a second order effect of boosting creativity in terms of social innovation and the application of knowledge to problems or local/regional contexts.

Open access to data and results can also improve the (first order) responsiveness of R&I system to emergent societal challenges, for example emerging disease pandemic.

3.4 Summary of the conceptual modelling approach

Section 3 has laid out a simple conceptual model to help explain the generation of RRI benefits. RRI interventions in policy and practice can be understood as causes that lead to certain effects. This provides the rationale for a conceptual model, which can provide a framework for defining, identifying and explaining the nature and direction of these effects.

The advantage of the approach modelled is that it allows progress to be made in developing a framework for monitoring RRI benefits even whilst precise definitions of these benefits remain elusive. In addition, the modelling approach should also contribute toward building a clearer understanding of the relationships between the impacts, outcomes and benefits of RRI.

In the impact pathways model developed in the MoRRI project, RRI interventions are understood to have transformative effects on actors in the RRI system and in society. Three types of transformations are included in the model – cognitive, procedural and competence transformations. R&I actors who are involved in an impact pathway encounter other actors in specific contexts in which the RRI intervention is occurring. In our model the concept of 'productive interactions' is used to describe the mechanism through which learning, negotiating and cooperating occurs in these contexts.

For example, a research group or CSO may develop a knowledge co-production dimension in a research project in collaboration with a local citizen science (CS) group. The CS group may have links to other CS groups in other localities or regions. This enlarges the number of actors involved in the collaboration and the scope of the data collection. This CS project may become a pathway to research questions that were not previously identified by the R&I system, or to better appreciated questions that had been undervalued to date away from the local context of their emergence. New avenues for research can thus emerge, which bring the R&I system closer to society and in which citizens feel more engaged. Our pathways model assumes that the mechanism of productive interactions, which binds actors and through which they make their contributions, will lead to transformations in the way these actors think about CS, in how they do CS, how they consider the role of CS in their own portfolio of research activities, and in the attributes and expectations they bring to future CS activities. These individual and group level transformations constitute a cultural change, institutionalising attitudes and processes and shaping contexts in ways which are assumed to be conducive to the emergence of benefits from RRI. Pathways are also assumed to be shaped at the institutional level, where the introduction of new legislation, for example, will drive changes in the way things are done (procedural transformations). Institutional changes such as new regulations are also assumed to emerge as a result or consolidation of cultural and practical changes in attitudes and approaches to R&I.

The impact pathways model developed in the MoRRI project also understands impact pathways as being process driven. Building on the logic of productive interactions, RRI pathways to impact are assumed to drive change in certain directions by inspiring and reinforcing collective processes. A number of key processes have been conceptualised in Section 3.3 of this Report, emerging from interpretation of the potential RRI benefits identified in the MoRRI project. We call these process pathways, reflecting their role in effecting change. However, it should be stressed that in this report the process pathways described are products of the conceptual modelling project carried

out. The identity of actual RRI process pathways is an empirical question that must always be linked to the context of productive interactions themselves. The degree to which the process pathways modelled in this Report and empirical evidence coincide remains to be investigated. The process pathways modelled in Section 3.3 are summarised in Table 3.15.

Table 3.15: Process pathways and effects modelled, by RRI dimension for three types of RRI benefit (summary of Tables 3.1 – 3.14)

Process pathway	Modelled effect	RRI dimension	Type of benefit
Adaptation	- *Educational curriculum adapts to needs of citizenry*	- PE	- Societal
	- *R&I system adopts and conforms to ethical standards*	- Ethics	- Societal
Collaboration	- *CS leads to new research questions & applications*	- SLSE	- Economic
Diffusion	- *Of relevant information improves awareness & understanding of R&I decisions*	- SLSE	- Democratic
	- *Of good practices to project partners promotes change in R&I organisations*	- GE	- Democratic
	- *Of research results stimulates social innovation and situated problem-solving*	- OA	- Societal
Exploitation	- *Of research data stimulates creativity and innovation, facilitates more efficient use of resources*	- OA	- Economic
Inclusion	- *Of knowledge from diverse sources in R&I*	- PE	- Democratic
	- *Of citizens' perspective in R&I policymaking*	- PE	- Democratic
	- *Of citizens' contributions aligns R&I better with consumer demand*	- PE	- Economic
	- *Of citizens' perspective aligns R&I better with societal expectations*	- PE	- Societal
	- *Brings science and students with special needs together*	- SLSE	- Democratic
	- *Of students improves labour market outcomes*	- SLSE	- Societal
	- *Reduces bias against women (in R&I, society)*	- GE	- Democratic
	- *Of women in research design & development improves quality of scientific outputs*	- GE	- Economic
Legitimisation	- *Increases understanding & grounds acceptance of R&I decisions DEM*	- PE	- Democratic

Process pathway	Modelled effect	RRI dimension	Type of benefit
	- *Increases understanding & grounds acceptance of stakeholder roles & contributions*	- PE	- Societal
	- *Increases understanding of R&I choices & decisions*	- SLSE	- Democratic
	- *Reduces costs of justifying R&I choices*	- SLSE	- Economic
	- *Reduces costs of market entry & adoption*	- SLSE	- Economic
	- *Perceptions of social appropriateness reduces market entry costs & increases goodwill*	- Ethics	- Economic
	- *Perceptions of social appropriateness improves image & attractiveness of R&I careers*	- Ethics	- Societal
Pluralisation	- *Of actors involved in R&I decisions*	- PE	- Democratic
	- *Of ideas and arguments considered in R&I decisions*	- PE	- Democratic
	- *Of connections between actors, fostering creativity*	- PE	- Economic
	- *Of data sources, improving efficiency of resource use*	- PE	- Economic
	- *Of data users, improving efficiency of resource use*	- PE	- Economic
	- *Of potential research funders, boosting resources*	- PE	- Economic
	- *Of connections between stakeholders, improving awareness and shared understanding*	- PE	- Societal
	- *Of research topics and approaches, moving R&I toward society & market*	- GE	- Economic
	- *Of research topics and approaches, improving relevance of R&I outputs*	- GE	- Societal
	- *Of actors capitalising on knowledge resources*	- OA	- Economic
Recognition	- *Of debates on social issues related to R&I*	- Ethics	- Democratic
	- *Of ethical basis of R&I choices and addressing societal challenges*	- Ethics	- Societal

As table 3.15 shows, pluralisation, inclusion and legitimisation are the most prevalent pathway processes in our modelling of pathways toward RRI benefits. Pluralisation opens up processes to more a more diverse array of actors and the opportunity for connections between these actors. Linked to this is the enriching of the space of ideas and debates with new ideas and a greater diversity of perspectives. The R&I system comes to be more reflective of the inspirations and needs of the broader society. Such

effects are reinforced by processes of inclusion that draw in more marginal actors and the R&I system starts to take account of their perspective. The cumulative effect of greater openness and inclusion is an increased legitimacy of the R&I system and R&I related processes within the broader society. As our modelling suggests, these processes can be expected to lead to the emergence of democratic, economic and societal benefits.

The outcome of the modelling process suggests that we are able to identify processes that are integral to how change happens. We have also linked these in a plausible way to the potential RRI benefits identified through the MoRRI project process. We need to remain acutely aware that the impact pathways modelled are dependent upon productive interactions and that such interactions are always to some extent context dependent. The processes our model described can thus be understood as facilitating the transmission of impacts that can lead to the type and direction of change from which democratic, economic and societal benefits of RRI emerge. Understanding the precise way in which impact pathways succeed or fail to create these conditions for remains a largely empirical problem.

4 Identification of indicators of RRI benefits

The previous section established linkages between the list of potential RRI benefits identified in the MoRRI project process and a series of pathways to impact that model an explanation for how RRI interventions can induce changes that can lead to the emergence of these benefits. This section moves on to develop a selection of potential indicators of the benefits of RRI emerging from the MoRRI project process. It also considers potential indicators of RRI benefits drawn from other sources.

The outcomes of the modelling process leads toward three potential strategies for designing metrics and indicators for RRI benefits. The first approach is to develop metrics and indicators of RRI benefits for each RRI dimension. This approach envisages distinct benefit indicators for each of the RRI keys for each of three different types of benefit (democratic, economic, societal). The second approach is to use existing indicators of RRI outcomes (European Commission 2015a) as proxies for assumed future RRI benefits or existing RRI benefits for which no metric currently exists. The third approach is to develop metrics and indicators of RRI benefits for each type of RRI benefit. This approach envisages distinct benefit indicators for each of the three types of benefit (democratic, economic, societal) as these benefits emerge across the RRI dimensions. The third approach is not pursued further in this report. However, some initial considerations regarding this approach are attached at Appendix 3 for information purposes.

The process followed to identify indicators of RRI benefits is as follows:

1. Synthesis and compilation of potential indicators of the benefits of RRI by RRI dimension;
2. Consideration of additional indicators by RRI dimension;
3. Consideration of additional indicators of the benefits of RRI by RRI dimension, using outcome indicators of RRI;
4. Consideration of other indicators of RRI benefits.

4.1 Potential indicators of RRI benefits by RRI dimension

This section condenses the list of potential RRI benefits by RRI dimensions identified in the MoRRI Project process into a small number of indicators. The list is developed by synthesising the benefits summarised in Table 3.15. Each item incorporates the impact pathway and cause-effect direction driven by interventions along a single RRI dimension.

Table 4.1 proposes a list of 26 potential indicators of RRI benefits. This includes 9 potential indicators for PE, 4 indicators for SLSE, 5 indicators for GE, 5 indicators for Ethics and 3 indicators for OA. Originally 29 potential indicators were identified in the MoRRI project process. Some of these were very closely related or overlapping and were merged.

Table 4.1: Reduced list of potential indicators of RRI benefits by RRI dimension*

No.	Description	Potential data type/source
PE-DEM1	*Citizen's knowledge features in R&I*	
PE-DEM2	*Citizen's perspective features in R&I policymaking*	*Perceptions, survey*
PE-DEM3	*Citizens understand & accept S&T policy decisions*	*Perceptions, qualitative*
PE-ECON1	*R&I outputs match consumer demand*	*Perceptions, stakeholder surveys*
PE-ECON2	*Expanded scientific and social capital networks boost creativity*	
PE-ECON3	*More efficient data production and utilisation*	
PE-ECON4	*More Research Funding Organisations (RFOs)*	*Survey RPOs*
PE-SOC1	*Educational curriculum matches citizen's needs*	*Document analysis, qualitative*
PE-SOC2	*Broadens shared understandings and expectations of S&T trajectories*	
SLSE-DEM1	*Citizens are aware of and understand S&T choices and policy decisions*	*Perceptions, survey, qualitative*
SLSE-DEM2	*Better science education for students with special learning requirements*	*Secondary, survey*
SLSE-ECON1	*New research questions & applications emerge from citizen science*	
SLSE-ECON2	*Reduction in cost of introducing S&T innovations*	*Survey - firms*
GE-DEM1	*Diffusion of good gender practices*	
GE-DEM2	*Reduction in bias against women (in R&I and society)*	*Secondary – intermediate proxies*
GE-ECON1	*Better quality scientific outputs*	
GE-ECON2	*R&I better reflects societal and consumer demands*	*Perceptions, stakeholders surveys*
GE-SOC1	*R&I outputs are more relevant*	
ETH-DEM1	*Debate on social issues and S&T*	*Perceptions*
ETH-ECON1	*Social appropriateness of R&I*	*Perceptions*
ETH-SOC1	*R&I system adapts to ethical standards*	*Secondary-intermediate proxies*
ETH-SOC2	*Social appropriateness of R&I improves image & attractiveness of R&I careers*	*Perceptions, survey students*
ETH-SOC3	*Recognition of ethical basis of R&I choices to address societal challenges*	*Perceptions*
OA-ECON1	*Increases efficiency of knowledge and resource use*	*Log data, user surveys, latent value calculations*
OA-ECON2	*More actors capitalising on knowledge resources*	*Subscriber data, surveys*
OA-SOC1	*Increased social innovation and localised problem-solving*	

* Initial full list is contained at Appendix 2

4.1.1 Prospects of additional indicators of RRI benefits by RRI dimension

A major gap that can be identified in the list of potential indicators of RRI benefits is the absence of identified benefits for the Governance dimension (Section 2). Deliverable 5.3 from Task 6 did not identify any potential social, economic or democratic benefits for GOV. Likewise neither were such types of benefits identified in Deliverable 5.1 about experts' contributions via the Visioning Workshop. This does not mean that such benefits of RRI GOV do not exist, but simply that they have not yet been identified.

One avenue for potential additional benefit indicators for the GOV dimension could be the metrics and indicators of RRI developed for the GOV dimension in Deliverable 3.2 of MoRRI. There are three indicators for GOV proposed there:

- GOV1: Composite indicator of RRI governance;
- GOV2: Existence of formal governance structures for RRI within RFOs and RPOs; and
- GOV3: Share of research funding and performing organisations promoting RRI.

All of the proposed metrics and indicators are at the input level of the MoRRI logic model and, as such, do not provide potential insights into the effects that might extend from GOV interventions or how such effects may shape certain types of benefits. At this stage it seems prudent to leave the development of additional indicators of RRI benefits for the GOV dimension aside.

4.2 Potential intermediate indicators of RRI benefits using indicators of RRI

The modelling of pathways to RRI benefits provides a plausible explanatory framework for assuming that the likelihood of emergent RRI benefits is increased where RRI outcomes can be observed. A potential opportunity for developing additional indicators of RRI benefit might therefore extend from the outcome indicators already developed in the context of the MoRRI project (European Commission 2015a). Outcome indicators can be considered as addressing the analytical level that corresponds roughly to medium-term temporal effects of RRI interventions. These indicators can thus be considered more likely to capture evidence of first or second order effects that are the outcomes of transformative processes that take some time to become observable. Such indicators can in this sense be considered plausible proxies for future RRI benefits.

Five outcome indicators have been developed for the GE dimension and one for the OA dimension (Table 4.2).

Table 4.2: Outcome indicators and characteristics

No.	Indicator full name	Primary/ secondary data	Time series	Potential time series	Analytical level	Linkage	Data collection method
GE1	Share of RPOs with gender equality plans	Primary data	No	Yes	Input, outcome	GOV	RPO-survey
GE2	Share of female researchers by sector	Secondary data	Yes	Yes	Input, output, outcome	-	-
GE5	Share of RPOs with policies to promote gender in research content	Primary data	No	Yes	Input, outcome	-	RPO-survey
GE6	Glass ceiling index	Secondary data	Yes	Yes	Input, output, outcome	-	-
GE8	Share of female heads of research performance organisations	Primary data	No	Yes	Input, outcome	-	RPO-survey
OA3	Social media outreach/take up of Open Access Literature and open research data	Primary data	Yes	Yes	Outcome	PE	Register data

Source: (European Commission 2015a) MoRRI progress report D3.2, p. 33

The GE dimension is the most developed in terms of outcome indicators for RRI. The five GE outcome indicators listed all focus on first-order effects of RRI interventions, namely effects on the R&I system itself. For example, each of the GE outcome indicators could be considered a proxy for ultimate benefits of some type. Compiling these proxies in a composite indicator made up of GE2, GE5, GE6 and GE8 could provide be a metric that allows insights into whether young women are well enough prepared and motivated to enter and succeed in science/R&I careers. Such a composite indicator, by compiled diverse metrics on the participation of women in R&I, could capture one aspect of the democratic benefit of eliminating gender bias.

OA3 seems relevant as an indicator of a communication channel that can contribute to knowledge diffusion and potentially economic benefits. It could plausibly be part of a more all-encompassing composite indicator for benefits from OA in the future.

Outcome indicators for the PE dimension have not been developed through the MoRRI project process. However, a number of input and output indicators have been developed for PE (European Commission 2015a: 33). These indicators focus on both first- and second-order effects (Figure 2.1). Benefits from the PE dimension have been modelled as strongly associated with pluralisation and inclusion pathways to impact (see Table 3.15). Pluralisation pathways lead to the diversification of actors involved in R&I networks and processes, while inclusion pathways bring formerly marginalised actors into these contexts. As such these pathways are closely linked to the 'participation' sub-dimension of PE. The potential thus exists to utilise indicators for the PE sub-dimension 'participation' to compile a composite intermediate indicator of the democratic benefits of RRI.

Table 4.3: Public Engagement participation indicators and characteristics

No.	Indicator full name	Primary/ secondary data	Time series	Potential time series	Analytical level	Linkage	Data collection method
PE1	Models of public involvement in S&T decision making	Secondary data	No	Yes	Input	GOV	-
PE2	Policy-oriented engagement with science	Secondary data	Yes	Yes	Output	GOV	-
PE9	R&I democratisation index	Primary data	No	Yes	Input	GOV	SiS actor survey
PE10	National infrastructure for involvement of citizens and societal actors in research and innovation	Primary data	No	Yes	Input	GOV	SiS actor survey

Source: (European Commission 2015a) MoRRI progress report D3.2, p. 33

Table 4.3 summarises four indicators of RRI for the sub-dimension of 'participation'. Each of the individual indicators is based on a metric that captures a specific element of PE participation. A composite indicator that compiles these diverse metrics could capture overall progress toward a more participatory R&I system. Such an indicator, by compiling diverse metrics on participation in R&I and R&I governance, could be interpreted as an intermediate indicator of the democratic benefits that are assumed to flow from the R&I system becoming more closely aligned with citizens' expectations. PE1 is based on a one-off project data collection (MASIS) that would be relatively labour intensive to reproduce as it is based on collecting and coding qualitative data to construct a matrix classification. The other three indicators are based on survey data collections and are more suitable for inclusion in a composite metric that can be used to construct time-series for monitoring purposes. PE1 (Table 4.3) is excluded from the proposed composite indicator on grounds of feasibility.

Table 4.4: Additional potential composite indicators of RRI benefits

No.	Description	RRI linkages	Potential data type/ source
GE-DEM1	Reduction in bias against women's participation (in R&I and society)	GE, SLSE	Secondary
PE-PART	Increased participation of citizens in the research and innovation system	GOV	Primary

DEM = democratic benefit. PART = participation.

In summary, two additional indicators (Table 4.4) could be proposed which use multiple GE outcome indicators and PE input/output indicators respectively to build composite metrics. The GE metric simply treats increased participation of women at all levels of the R&I system as a set of intermediate proxies for reduced gender bias - which is a direct democratic benefit of RRI. In terms of linkages to other RRI dimensions, the foundational importance of SLSE to the participation of women in R&I and therefore to the expected benefits should not be overlooked. The PE metric simply treats increased participation of citizens in S&T processes and decision-making fora as intermediate proxies for more representative social institutions – which is also a direct democratic benefit of RRI. In terms of linkages to other RRI dimensions, the participation of citizens in R&I has very direct linkages with the GOV dimension of RRI.

4.3 Other potential indicators of RRI benefits

A short secondary review of potential indicators for RRI benefits was conducted that a) looked at new indicator development in RRI linked areas such as gender equality, focusing on the period since the initial development of a list of RRI indicators in the MoRRI project; b) looked at other existing indicators in use or development that have the potential to be relevant (modified or applied) to monitoring RRI benefits.

4.3.1 New linked indicators

The She Figures 2015 report (European Commission 2016c: 173) includes a new indicator 'Gender dimension in research content' (GDRC). A second new indicator provides the compound annual growth rate (CAGR) of GDRC (European Commission 2016c: 175). Both indicators are output and outcome indicators. The two indicators close a gap in the proposed selection of RRI indicators regarding 'gender in research content' (European Commission 2015a).

Table 4.5: Indicators of gender dimension in R&I

No.	Indicator full name	Primary/ secondary data	Time series	Analytical level	Source	Data collection method
GERC1	Proportion of a country's research output integrating a gender dimension in its research content (GDRC)	Secondary data – scientific articles	Yes	output, outcome	*She Figures 2015*	-
GERC1-CAGR	Compound annual growth rate (CAGR) of the proportion of a country's research outputs integrating a GDRC	Secondary data – scientific articles	Yes	output, outcome	*She Figures 2015*	-
GE2-CAGR	Compound annual growth rate of share of female researchers by sector	Secondary data	Yes	Input, output, outcome	*Eurostat R&D Statistics*	-

(Source: European Commission 2016d, *She Figures Handbook*, pp. 105-107)

GDRC could be interpreted as an indicator of RRI. It could also potentially be part of a composite indicator that uses RRI indicators as proxies for assumed RRI benefits. For example, GDRC could potentially be included with outcome indicators of RRI for GE (Table 4.2) in a composite indicator for the democratic benefits of GE (Table 4.4).

CAGR of GDRC could also be interpreted as an indicator of RRI. Once again, it could also potentially be part of a composite indicator, included with outcome indicators of RRI for GE (Table 4.2) in a composite indicator for the democratic benefits of GE (Table 4.4).

The GDRC indicators appear to have high relevance for monitoring the benefits of RRI. However, consideration of the methodological approach also opens a possible avenue for further fine-tuning the metric for monitoring RRI benefits. The starting point for the methodology for creating a GDRC dataset centres on research about gender. 'The first step in identifying scientific publications relevant to the gender dimension in research content was to identify the field(s) or subfield(s) related to gender research' (Science-Metrix and ICF International 2015: 57). The GDRC metrics are thus indicative of the proportion of research that is about gender, including gender as the object of the research.

In the context of RRI it might be interesting in the future to consider a metric with a slightly different emphasis – on gender content *of* research, rather than *in* research – to try and monitor the extent to which all research considers the gender dimension. The cultural change required to gain acceptance of the need to study gender issues has advanced substantially over past decades – albeit unevenly. In contrast, the cultural change promoted by RRI to ensure the contents of research - from design, to execution, to results, to products or other outputs based on research – take into account and address gender issues, is in a relatively earlier stage of development. Designing a methodology for a metric with this focus on the gender content of research, (whether using bibliometric or other data), could lead to an indicator with improved relevance for monitoring RRI.

The compound annual growth rate of the share of female researchers (GE2-CAGR) tracks the relative rate of increase of women's and men's participation in R&D employment. It would be calculated from the same data source as RRI indicator GE2 (European Commission 2015a: 33, see Table 4.2 above). GE2-CAGR is proposed as an inclusion in GE-DEM1 (Table 4.4) to further strengthen this composite metric by including a rate of change dimension.

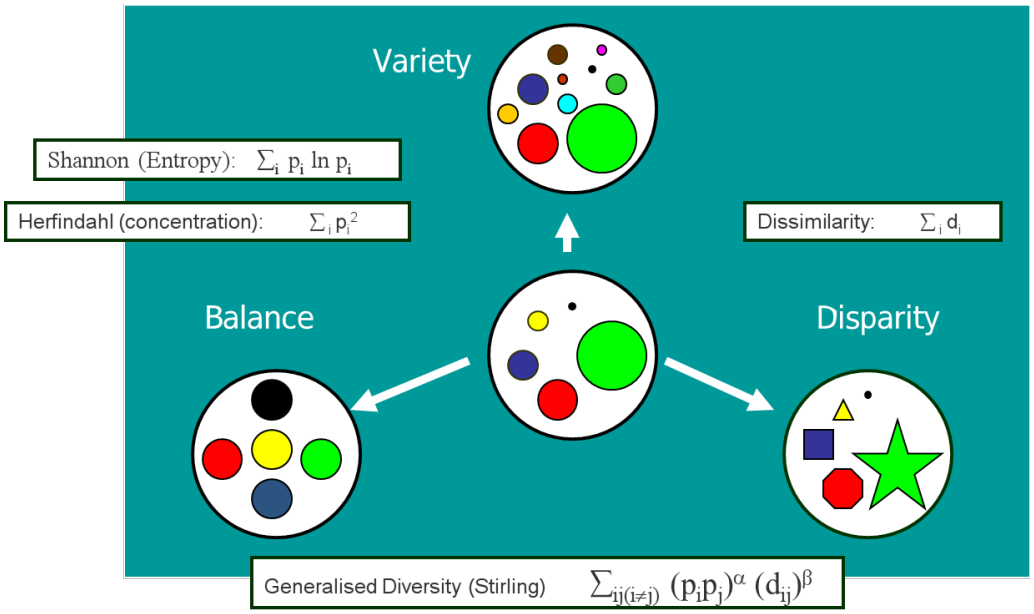
4.3.2 Indicators with potential relevance for monitoring RRI benefits

Section 3 modelled pathways to RRI benefits in which productive interactions among stakeholders in the R&I system and society are the vehicle for transformations in certain directions. Two of the pathways modelled were pluralisation, the opening up of R&I related practices and processes to more participants, and inclusion, the drawing of previously excluded or marginalised stakeholders into R&I practices and processes. These pathways can be seen to promote both an increase in the *diversity* of the R&I system itself and of its inter-linkages with society, in terms of practices, processes and participation.

Diversity is an irreducible property of a system, which is composed of the variety, balance and disparity of the elements of that system (Stirling 2007). Variety refers to the number of different types of elements in the system, balance refers to how much of each element make up the system, while disparity refers to how different from each other the elements of the system are (Stirling 2007). Holding everything else equal, more variety or a more even balance or greater disparity, will each increase system diversity (Stirling 2007: 709). Indicators of the degree of diversity thus offer intuitively interesting possibilities for monitoring pluralisation or inclusion pathways toward RRI benefits.

Reasons for fostering diversity in science and research include fostering innovation, hedging against ignorance, mitigating lock-in and accommodating plural perspectives (Stirling 2007). All four of these reasons are consistent with RRI, with mitigating against lock-in and accommodating plural perspectives particularly relevant to RRI principles.

Figure 4.1: A heuristics of diversity, following Stirling 1998, 2007.



Source: Rafols et al. 2013.

There are several existing metrics and indicators of non-parametric diversity, which can also be combined into a general heuristic of diversity (Stirling 2007) (Figure 4.1). The purpose of such a heuristic is to provide a model for understanding diversity in systems or subsystems, which can be user-defined. For example, Benhamou and Peltier (2010) use such an approach to assess the cultural diversity of the cinema industry.

Wallace and Rafols (2015) use the concept of 'research portfolio' to describe the mix and diversity of research relevant to societal challenges where high levels of uncertainty exist regarding outcomes and likelihoods. They advocate the use of a system-level portfolio approach to understand and monitor the alignment between research supplied by public institutions and demand for knowledge addressing desired and/or expected outcomes. The degree of diversity of a defined research portfolio should correspond broadly to the degree of uncertainty associated with a particular challenge and to the degree of complexity (for example, the extent of interdisciplinary research) required to address this challenge.

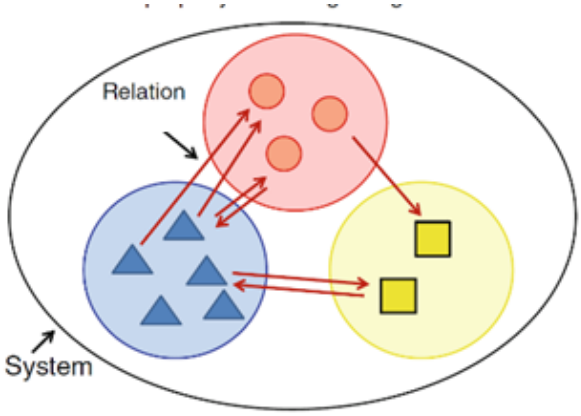
Two specific measures appear most suitable for this process. First, the Shannon entropy measure, which is favoured over the Herfindhal measure due to its sensitivity to small contributions. Second, the Rao-Stirling diversity measure, which includes cognitive disparity within it design.

Developing metrics of diversity for the purposes of monitoring RRI benefits appears to be a potentially promising approach for monitoring the Governance dimension of RRI. This could help to overcome the gap in available outcome indicators for the GOV dimension (see section 4.1.1). The Expert Group on Policy Indicators for RRI noted that "there is a need for indicators that fit into interactive approaches that do justice to the contributions of the relevant stakeholders in the network" (2015: 19). Understanding the diversity of the stakeholders composing networks could conceivably form a basis that captures important qualities of the context in which stakeholder contributions are to be made. Combining diversity indexes with metrics based in qualitative data collection techniques may also be an effective approach. The diversity

index approach could be useful at different levels of aggregation of R&I Governance including projects and programmes. There are also likely to be potential avenues for constructing metrics for other RRI dimensions using a diversity index.

Pluralisation and inclusion pathways imply the involvement of more actors and, therefore, more productive interactions between these actors. A methodological approach to the assessment of translational research initiatives (projects, programmes) suggests a way to understand not just the diversity of a network system such as a translational research project, but the degree of *coherence* of this network. Coherence can be defined as the extent to which interactions are created, and how these connections bridge the distance between diverse elements of the sub-system. These linkages and their qualities (coherence) are the key factor in the generation of societal impacts and outcomes from research translation.

Figure 4.2: Index of coherence, illustration



Source: Lang et al. 2016.

The coherence index captures the relationship between two elements of a system on three dimensions, the number of connections, the intensity (frequency) of interactions and the distance bridged by the interactions. Distance can be measured in terms of cognitive proximity, organisational position, social network location, institutional context and norms, and geographic location. In this way the contributions of each node in the network is incorporated in the index.

The coherence index has been trialled as an assessment tool at the level of intermediate R&I sub-systems of significant scale (large projects, centres). Data collection is primarily qualitative based in semi-structure interviews and, as such, is relatively labour intensive. The data collection process leads to the development of the quantitative metric.

The coherence index thus appears to be a potential metric for developing an indicator of benefits for the Governance dimension. For example, a diverse project network involved in the co-creation of knowledge, public diffusion activities or involving citizen science contributions could generate social benefits in terms of improved cohesion between actors and sectors of society through such RRI activities. It is possible that the index could also be applied to the generation of RRI benefits across other RRI dimensions.

Finally, among other methodologies, standard social network analysis (SNA) techniques may offer one consolidated approach to developing indicators of benefit stemming from the pluralisation of network contributors. SNA analysis could be used

to develop metrics regarding the way contributions to network interactions can build trust and other interpersonal qualities among participants. Once again this appears to be well suited to developing indicators for the RRI governance dimension. Experimental methods, such as those utilised in experimental economics and other social sciences may also offer possibilities. For example, the potential may exist to develop an experimental metric to measure the impact of PE or ETH initiatives, which raise trust in science, on citizen concerns about scientific fraud and corruption.

This section has identified some potential metrics and indicators for RRI benefits by RRI dimensions. For discussion purposes, it also considered potential indicators of RRI benefit by type of benefit, as these accrue as synthesis of the effects of actions associated with different RRI dimensions. It has also identified three approaches to metrics (intermediate, modelled, applied) that could contribute to a framework for further developing these and other metrics and indicators for inclusion in a monitoring system for RRI benefits. The following section briefly summarises this possible framework. It then focuses on the selection of indicators of RRI benefit by RRI dimension and on defining a data fiche structure detailing each proposed indicator, rationales for its inclusion and its interpretation, along with comments on potential source data availability and limitations.

5 Indicators of RRI benefits

This section proposes a selection of indicators of RRI benefit by RRI dimension. It also defines a data fiche structure detailing each of the proposed indicators. The section proceeds as follows:

1. Consideration of measurement issues;
2. Selection of indicators;
3. Feasibility and a framework for moving forward; and
4. Data fiches.

A final sub-section summarises linkages with other tasks, including primary data collection to be carried out within subsequent Task 8 of the MoRRI project. Collecting these data may allow initial assessment of the feasibility and quality of proposed indicators.

5.1 Methodological issues

This section considers methodological issues pertinent to the development of metrics that can be used to build specific indicators from the list of potential indicators of RRI benefits. The process of development of the potential indicators of RRI benefit carries with it several methodological problems and/or *caveats*. The two major issues relate to general measurement theory and to the use of proxy items to stand in for emergent benefits.

In the conceptual modelling process (Section 3), pathways to impact were described as learning and transformation processes that are carried in certain directions by productive interactions between actors. This process assumes that even in seemingly non-interactive cases productive interactions can be linked to emergent, observable impacts – impact cannot be created in a vacuum. However, productive interactions are a specific type of connection/relationship between entities that presents a serious challenge to underlying measurement theory. Whilst 'productive interactions' may be a necessary condition for the process pathways that lead to impact and RRI benefits, it is not necessarily the case that 'more' productive interactions is 'better' in terms of the emergence of impact and benefits. It is therefore not sufficient to simply count the volume of interactions or number of dialogue partners as proxies for impact.

The conceptualisation of impact pathways also implicitly assumes that the benefits of productive interactions outweigh possible negative consequences. In relation to public engagement, for example, interactions fostering communication, participatory formats and mutual learning are assumed to outweigh risks of introducing extra red tape or the capture of obligatory participatory processes by powerful interests. Attention therefore needs to be paid to the context of productive interactions. Insofar as benefit cannot be automatically inferred on the basis of the existence of productive interactions, the burden falls on empirical investigation to trace the emergence of benefits of different types.

As neither documenting changes in processes nor counting interactions are valid proxies for the emergence of impacts and types of RRI benefits, other approaches to designing metrics are required. One possibility is the creation of primary data on perceptions, which can be designed to monitor and interpret changes in citizens' views. One advantage of developing perceptions-based metrics is that these can be more easily translated to other contexts in the interests of extending coverage for

monitoring tasks. Perceptions can also be investigated using multiple data collection methods, such as questionnaires, focus groups and interviews, allowing the triangulation of data and the validity testing of results.

The limitation of perceptions-based metrics is that data may not reflect real changes in attitudes, behaviour and performance in the direction of responsibility. In the case of RRI interventions, it may remain unclear whether perceptions reflect the creation of actual desired impacts or just the appearance of compliance (European Commission 2015b: 14). Perceptions indicators have been foreseen as very useful for tracking R&I linked to controversial topics (European Commission 2015b: 17). This may point toward another avenue for understanding whether citizens or other stakeholders consider R&I has become more 'responsible' or not – namely by tracking perceptions about different S&T controversies or conflicts over time, including the roles and perceived appropriateness of key actors' contributions in these conflicts.

Metrics for RRI benefits by dimension may also confront very different problems in trying to capture the benefits for RRI dimensions that are quite targeted, such as OA, and those that are very broad, such as Ethics. For this reason, it is not realistic to expect much consistency between metrics for benefits associated to the different keys. Rather, indicators of benefit will likely need to be flexible and adapted to include at least four factors: 1) the RRI dimension; 2) the context of the RRI intervention; 3) the type of benefit assumed; and 4) the main beneficiaries (first or second order impacts or both), in different combinations.

A general limitation regarding indicators for RRI benefit is the unevenness of the temporal periods that may be required for benefits of different types to emerge. For example, creating an open access database may create quite direct economic results in terms of new applications of knowledge, but this does not necessarily mean that this outcome will lead directly to societal benefits, which may take much longer to accrue. Even more complicated is that these economic benefits may, over time, be seen to have led to negative societal or democratic impacts. For more diffuse RRI dimensions, such as Ethics and GOV, these problems may be even more complex to discern and complicated to monitor.

An alternative can be to use intermediate indicators as proxies for the expected benefits along a particular dimension. Ideally these proxies would be taken from late in the temporal model of emerging impacts from RRI interventions. Outcome indicators, which seek to capture medium-term impacts (see Figure 3.1) could be suitable for this purpose. As discussed in Section 4, a potentially good case for taking this approach is for the GE dimension where a number of valid and reliable output indicators based on secondary data are available. A composite indicator of democratic benefit could be built on these output measures as a proxy for defined democratic benefits.

In prospect it could be useful to consider whether such opportunities to use output indicators as intermediate proxies for assumed or anticipated benefits exist along other RRI dimensions. However, it is also the case the GE dimension is particularly well populated with reliable outcome indicators for RRI. In addition, the inclusion of women in the R&I system can be considered a direct democratic benefit.

An initial scan of other RRI dimensions for instances where solid outcome evidence of a direct RRI benefit is available did not reveal other cases that were so well consolidated. However, for the dimension of OA it does appear that reliable data on open data access may be available relatively soon. Such data, when consolidated into outcome indicators, may well provide the basis for a composite indicator that could be an intermediate proxy for emerging RRI benefits (most probably economic or societal benefits).

5.2 Selection of indicators and scoping of feasibility

This section contains a selection of indicators of RRI benefits. A set of eleven indicators of RRI benefits and some descriptive characteristics are summarised in Table 5.1. Indicators were chosen principally on the basis of RRI dimension and to provide a mix of three types of indicators according to the proposed development of a monitoring framework (Table 5.2).

Table 5.1: Indicators of RRI benefit

No.	Indicator full name	Data type	Composite	Time series	Avail-ability	Formerly	Data collection methods
PE-DEM1	Citizens' participation in research and innovation	Primary data	PE2*, PE9*, PE10*	Poten-tial	EU Member States	PE-PART (Tables 4.3, 4.4)	Surveys, interviews
PE-DEM2	Citizens' perspectives feature in R&I policy making	Primary data	No	Poten-tial	-	PE-DEM2 (Table 4.1)	Surveys, qualitative
PE-SOC1	Training of researchers in public communication	Primary & secondary data	No	No	EU Member States	PE-SOC1 (Table 4.1)	HEI survey, document analysis
SLSE-DEM1	Citizens' awareness and understanding of S&T choices and policy decisions	Primary data	No	Poten-tial	-	SLSE-DEM1 (Table 4.1)	Survey, qualitative
GE-DEM1	Reduction in bias against women's participation in R&I	Secondary data	GE2*, GE6* GE2-CAGR	Yes	EU Member States	GE-DEM1 (Tables 4.4, 4.5)	Statistical agencies
GE-DEM2	Proportion of research that includes a gender dimension	Biblio-metric	GERC1 GERC1-CAGR	Yes	EU Member States +	GERC1, GERC1-CAGR (Table 4.5)	Bibliometric/ content analysis
GE-ECON1	Gender relevance of R&I outputs	Primary data	No	No	-	GE-ECON2 (Table 4.1)	Stakeholder survey(s)
ETH-SOC1	Image and attractiveness of R&I careers	Primary data	No	No	EU Member States	ETH-SOC2 (Table 4.1)	Student survey(s)
OA-ECON1	Access and utilisation of open data	Primary & secondary data	No	Poten-tial	-	OA-ECON1 (Table 4.1)	User surveys, log data
GOV-DEM1	Degree of diversity in R&I networks	Index	No	Before/ interim /after	-	- Sec 4.3.2	Network analyses
GOV-SOC1	Degree of coherence in R&I networks	Index	No	Before/ interim /after	-	- Sec 4.3.2	Network analyses

DEM = democratic benefit, ECON = economic benefit, SOC = societal benefit.

* Source: European Commission (2015a) MoRRI Progress Report D3.2, Metrics and Indicators of RRI.

Two benefit indicators are proposed for Public Engagement, one for democratic benefits and the other for societal benefits. A single Science Literacy, Science Education indicator is proposed for democratic benefits. Three benefit indicators are proposed for Gender Equality, two for democratic benefits and the other for economic benefits. One Ethics indicator is proposed for societal benefits and one Open Access indicator for economic benefits. Two Governance indicators are proposed, one for democratic benefits and the other for societal benefits.

PE-DEM1 is designed to capture the extent to which citizens participate in science and technology decision-making processes and avail themselves of full or part decision-making power. The metric proposed is a composite of three metrics of RRI: PE2 (policy-oriented engagement with science); PE9 (R&I democratisation index); and PE10 (national infrastructure for involvement of citizens and societal actors in research and innovation). These three metrics compile an intermediate indicator of the achievement of the democratic benefit of increasing citizen representation and decision-making in R&I and society. Data for PE2 have already been collected as part of a Eurobarometer survey respectively and could be collected again at periodic intervals. PE9 and PE10 are new indicators, for which data will be collected via surveys as part of Task 8 of the MoRRI project. These data could be collected on an annual/bi-annual basis. Coverage across all MS is conceivable at the national level.

PE-DEM2 captures the inclusion of the perspectives of the citizenry in R&I policymaking. The focus of metric development for this indicator is likely to be surveys of policymaking agencies and stakeholder groups at all levels. A metric such as the percentage of agencies which observe beneficial impacts emerging, over time, from their undertaking of certain processes or steps to incorporate public opinion and interests in decision-making could underpin this indicator, for example. Perceptions questions could also be a possibility. In addition, it is desirable that qualitative research tools be utilised to ascertain the extent to which these processes are aligned with desirable principles of democratic participation such as transparency, accessibility and responsiveness. Methodologies such as focus groups in which stakeholder opinions are available for contest and qualification could strengthen the reliability of this approach. This indicator would be reasonably labour intensive. Nevertheless, the potential for an intermittent time-series (every three to five years, for example) could produce useful time-series information. In terms of coverage, this indicator would be contextually sensitive and could be targeted at localised (town, city), regional or national levels of analysis and focus on specific controversies or on overall perceptions of the S&T polity.

PE-SOC1 captures the extent to which the provision of education to science and engineering professionals also prepares them to communicate with citizens to inform and/or educate them as part of their professional communication activities. This reflects the responsiveness of the R&I training system to the interests of the citizenry in terms of the appropriateness of public communication of S&T work, impacts and knowledge. Two metrics would be combined in PE-SOC1. The first metric proposed is the percentage of HEIs that provide/have a strategy for science communication training for S&T postgraduates. A second metric proposed is the percentage of science and engineering postgraduates that receive units/hours of training in science communication and other public engagement activities such as public seminars, science/museum days and media appearances. A survey to higher education institutions (research direction or department units) would be the principle data source. This would be backed by document analysis of degree course curricula and unit outlines or postgraduate professional coursework. This indicator is relatively labour intensive and could be repeated every three to five years to produce a time-series. A voluntary method of collating the introduction of new hours/units/courses of complementary training in science communication for science and technology could be

envisaged as a mechanism to reduce the labour intensiveness of the indicator. This indicator has the potential to be developed with full EU MS coverage.

SLSE-DEM1 seeks to capture citizens' awareness and understanding of S&T issues and controversies and the democratic decisions that affect S&T trajectories at particular times. The metric proposed is a series of survey questions designed to capture the democratic benefit of educational foundations that underpin citizens' awareness of S&T issues and of the different sides of debates about these issues. The indicator will capture the percentage of citizens with exposure to societal issues of S&T within educational curricula, particularly exposure to societal perspectives on scientific controversies. This is intended to provide information on the basis of citizens' capacity to consider contemporary S&T issues from a variety of scientific, social and technical perspectives. The indicator would also include metrics for the recognition of current topics of debate in S&T and the capacity to recognise different arguments within these debates. Generational differences would need to be taken into account in survey question design. It would be preferable to back these data with qualitative information that could further explore degrees of scientific citizenship with a small sub-set of survey participants. Again, this is a relatively labour intensive indicator. It is relatively more experimental as the intention would be to add significant nuance to the capture of data regarding the concept of 'understanding' – in such a way as to document the value of educational experiences within forms of attentive S&T citizenship. There would be potential to replicate this indicator to construct time-series information, but this would likely be quite costly. The indicator would also be strongly cultural-context dependent and may not be very useful for comparative purposes. The level of analysis/coverage of SLSE-DEM1 would be contingent on the definition of relevant contextual factors, which could range very widely from local controversies to the impact of national education or targeted literacy/awareness campaigns, for example.

GE-DEM1 captures progress toward the elimination of bias against women in terms of participation at all levels of the R&I system. The metric proposed is a composite of two metrics of RRI, GE2 (Share of female researchers by sector) and GE6 (Glass-ceiling index), and a metric for the rate of change in women's and men's employment in R&D (GE2-CAGR). These three metrics compile an intermediate indicator of the achievement of the democratic benefit of reducing bias against women in R&I and society. Thought could be given to adding other secondary data based metrics to this composite indicator. These could include educational participation in and completion of science courses at undergraduate and postgraduate levels. These data are readily accessible and have increasingly comprehensive and consistent coverage across MS.

GE-DEM2 captures progress toward the inclusion of a gender dimension in research content. The metric proposed is a composite of two indicators, the gender dimension in research GERC1 (Proportion of a country's research output integrating a gender dimension in its research content) and GERC1-CAGR (Compound annual growth rate of GE-RC1). These indicators are assumed to be intermediate proxies for the achievement of the democratic benefit of including a gender dimension in research content. Thought should also be given to adding other metrics to this composite indicator. For example, this could include a metric for the percentage of research projects that include a statement or analysis on the gender content of the research proposed.

GE-ECON1 captures the extent to which R&I is perceived to be aligned with societal expectations as expressed through consumer demand, in particular in providing outputs that relevant to women. The proposed metric would be questions focused on perceptions of the relevance of R&I outputs for women. These questions would be targeted at relevant women's stakeholder and advocacy groups to capture their perceptions of whether R&I outputs are relevant and whether the R&I system is responsive to demands for more relevant outputs. Questions regarding perceptions of

R&I investment priorities are also a possibility, although this would likely require quite specialised knowledge on the part of respondents. In particular, the perceptions of women's health and other advocacy groups would be sought, along with environmental, education and general consumer interest organisations. Coverage and level of analysis would be contingent to some degree on the definition of relevant contextual variables including stakeholder interests and specific community or social needs.

ETH-SOC1 captures the degree to which the R&I system is seen to reflect a principled and ethical image that is aligned with the expectations of young people making decisions about education and careers. The metric proposed will be based on questions posed as part of a survey to incoming science students of HEIs or students existing secondary education. The relevant questions will seek perceptions of professional roles in science and engineering, including whether a career in this field is perceived as offering opportunities to contribute to society in a desirable and appropriate way. This indicator could be produced as a time-series, although the validity of comparisons over time would possibly be compromised by (potentially radical) shifts in the science-society relationship. Coverage of the indicator could be all MS, although the validity of any direct comparability between MS would need to be carefully assessed.

OA-ECON1 captures the number of users of public data repositories and the utilisation of open data resources. There are different possibilities for a metric to underpin this indicator. One approach could be to use user surveys to compile estimates of the value to individual firms or other users of accessing data from OA data repositories, including the estimated cost of having to acquire the data themselves. A second approach could be to use the number of discreet users and log data to assess changes in the rate of data downloads/accesses over time, using specified values for the type/amount of data being transferred to individual users. Initially such a metric could focus on large public data repositories.

GOV-DEM1 is designed to capture the diversity of networks and other sub-systems of R&I and society. The base metrics used are the Shannon entropy and the Rao-Stirling diversity measure. Other metrics of balance and disparity may be considered as additional inclusions in some contexts. Together these metrics compile an Index of Diversity. The indicator could be applied to large research projects and projects or other R&I initiatives in which engagement with multiple participants, stakeholders and publics are expected or desirable. The effects of pathway processes of pluralisation and inclusions can be revealed in changes in the degree of diversity of a defined entity, for example, at the commencement, in the formation, and at the end of a large project.

GOV-SOC1 captures the degree of coherence of networks and other sub-systems of R&I and society. The metric is the index of coherence, which measures the functioning of a set of network relationships in terms of characteristics of intensity and bridging. The bridging of distances between diverse elements of a system are considered as measures of qualities such as trust and coordination that are considered to produce societal benefits in terms of legitimisation and perceived responsiveness of R&I across a range of participating and non-participating stakeholders.

In terms of types of benefits, there are five proposed indicators of democratic benefits, two economic benefits and three of societal benefits. The full rationale for selecting these eleven indicators is primarily to include an appropriate balance of RRI dimensions and benefit types and indicator types, as well as variety in terms of data types and potential collection methods.

The selection nevertheless could appear somewhat arbitrary, reflecting the early stage of development metrics and indicators for RRI benefits. There is little doubt that

further conceptual development will be required in terms of what qualifies as a 'benefit'. The use of intermediate outcome proxies to compile composite metrics as part of a versatile framework for monitoring the emergence of benefits (Table 5.2) is conceptually sound and methodologically viable. The number of indicators proposed at this point could also be expanded to include others from Table 4.1. However, from the point of view of a first stage of trial and error and assessment from the MoRRI project process, this selection should provide a set of information-rich test cases.

5.3 Indicator feasibility and a framework for further development

This section links the feasibility of the indicators described in the previous section with the further development of a framework for monitoring RRI benefits. It makes a preliminary assessment of their feasibility in relation to existing data sources and the potential for new data collection.

Monitoring the evolution and benefits of RRI is constrained to some extent by the state-of-the-art in assessment of societal forms of impact from R&I. The assessment widely regarded as the 'industry leader' in this regard is the UK Research Excellence Framework. Assessment of societal impact proceeds through a peer review of an impact template, describing the approach to achieving impact, and societal impact case studies which must be linked specific to scientific outputs produced by the unit being assessed. This is a relatively labour-intensive approach to assess societal impact, which does not translate easily to a monitoring framework.

The conceptualisation of benefits from R&I also remains a work in progress. Benefits (democratic, social, economic) are conceived in this report as shifts that occur as a consequence of impacts and outcomes of R&I. Benefits are, by definition positive, but this does not necessarily mean they cannot be the consequence of a net positive mix of positive and negative impacts and/or outcomes. Capturing and classifying RRI impacts and outcomes is itself a work in progress. Further work leading to more precision in defining RRI benefits is undoubtedly required.

This report makes a modest contribution to this task. It pursues a strategy of developing diverse approaches to metrics and indicator development. This strategy has involved pursuing both the MoRRI project methodology through successive interconnected stages and scanning for external developments. These approaches are summarised in Table 5.2.

Table 5.2: Framework for developing RRI indicators

Indicator type	Indicator name	Feasibility		
		Relevance	Data	Availability
Intermediate	PE-DEM1	High	Moderate to high comparability	EU27
	GE-DEM1	High	High comparability	EU27
	GE-DEM2	High	High comparability	EU27+
Modelled on pathways from RRI impacts/ outputs to benefits	PE-DEM2, PE-SOC1, SLSE-DEM1, GE-ECON1, ETH-SOC1, OA-ECON1	Moderate to high	Varies	EU27 (PE-SOC1, ETH-SOC1)
Applied	GOV-DEM1	Moderate	Moderate comparability	
	GOV-SOC1	Moderate	Low to moderate comparability	

Table 5.2 outlines a framework for developing indicators for RRI benefits that includes three types of indicators. First, intermediate indicators based on RRI outcomes are taken as proxies for RRI benefits that are assumed on the basis of the changes captured by these intermediate indicators. Second, indicators developed according to a pathways model that interprets RRI benefits as consequences of transformative processes, impacts and outputs of RRI. Third, existing metrics that can be applied to innovative indicator design, but which may need to be quite extensively tested, adapted and developed for use in capturing RRI benefits.

The rationale for this diversified approach is that whilst constraints in terms of conceptualising RRI benefits and the state-of-the-art in impact measurement continue to evolve, progress can still be made in developing a monitoring framework and specific indicators of RRI benefits based on these methodological approaches. This ongoing work then contributes to a better conceptualisation of the forms that RRI benefits take and how these may be captured by metrics, pushing the state-of-the-art forward. The individual data fiches (section 5.4) endeavour to provide links between the conceptualisation of benefits and a data strategy that can both concretise this conceptualisation and provide initial empirical insights.

The feasibility of the proposed indicators varies by type. The proposed intermediate indicators are based on secondary data with full coverage available or possible. Further intermediate indicators that may be developed for RRI benefits would also have these characteristics. The indicators conceptualised using a pathways model vary significantly in terms of their feasibility. Most of the proposed indicators of this type apart are based on primary data collection. These typically rely on standard methodologies. However, these may be combined with more innovative data types, such as log data, and several include qualitative data collection. The question of the level of analysis, or scale of these indicators, has implications for their coverage – and

the appropriate level of analysis will not be clear without significant testing and validation efforts.

PE-SOC1 has high relevance and potential for full coverage. Developing a valid and reliable data collection approach is certainly feasible for this indicator, requiring simply the investment of time, resources and potentially multiple iterations to design and test. Likewise ETH-SOC1 has high relevance and potential for full coverage. Data collection design would need to take full account of the highly varied and continuously evolving socio-cultural and political contexts in which such a student survey would be context. Overall, the final specification of metrics to underpin indicators of the conceptually modelled type requires a considered development approach and strategy.

To conclude, core questions remain in flux in relation to the development of precise indicators for RRI benefits. Aside from the issue of further developing the conceptual understanding of what constitutes the democratic, economic and social benefits of RRI and how such benefits can be identified, there are significant challenges remaining regarding the complexity of quantifying those benefits. Of course, success in constructing metrics and workable indicators also does not guarantee that these indicators turn out to be highly useful for monitoring purposes. At this juncture, however, it is important that progress continues to be made in a systematic and considered way, taking into account the development of the state-of-the-art in indicator development and impact assessment both with regard to RRI and more generally.

5.4 Data collection fiches

This sub-section includes a description of the template for the data collection fiches, followed by compiled fiches for each of the eleven proposed indicators of RRI benefit. The purpose of describing each indicator in a data fiche format is to provide clear guidance on the development of metrics and indicators emerging from this Task. These should not be considered to be final tailored data collection fiches as more clarity, precision and detail will be required in the following stages of indicator development.

5.4.1 Description of the template for data collection fiches

The template for the data collection fiche (Table 5.3) has been designed to provide information on the general character of the indicator, the rationale for its choice, the limitations, the indicator's possible interpretation for the analysis of RRI benefits and its expected source availability.

Table 5.3: Data collection fiche, template

Information item	Description
RRI dimension/type of RRI benefit	Please state the RRI dimension and type of RRI benefit addressed in full
Name of indicator	Please state an informative short name for the indicator
Primary/secondary data	Please state whether this indicator is based on secondary (already existing) data or on primary data that we will need to collect
Need for supplementary data collection	Please state how primary data could be collected. In the case of potential data collection within the MoRRI project specify which.
Description	Please provide as accurate and thorough description of the indicator as possible (what is it an indicator of, how does it capture information about the RRI dimension in question, in which context was the indicator developed (if secondary data) etc.)
Qualitative/Quantitative	Please specify whether the basic data are of quantitative or qualitative. In some cases, the basic data will be qualitative (interview transcripts, national reports or similar) which require coding / categorisation in order to be useful for monitoring purposes. Please specify
Source of data	If indicator is based on secondary data, please state the data sources for the indicator. If possible please provide direct links to the data source in question.
Date	If indicator is based on secondary data, please note in which year data was most recently collected
Time-series	Are time-series data available? Please specify by yes/no and note the actual years for which data are available
Potential time series data/Collection period	Could the indicator be a potential candidate for longitudinal data collection? Please specify
Measurement	Describe the unit of measurement if applicable
Unit of analysis	Please state the basic unit of analysis (e.g. countries, citizens, publications etc.)
Coverage	If the indicator is based on secondary data, please state the specific data coverage.
Further remarks	Additional remarks, caveats or issues can be specified here

5.4.2 Compilation of data collection fiches

In this sub-section data collection fiches for each of the eleven proposed indicators are described. The fiches are not at identical stages of development; they are designed to be filled out and modified as more detail and precision is developed.

Table 5.4: Data collection fiches

Information item	PE-DEM1
RRI dimension/type of RRI benefit	Public Engagement/Democratic benefits
Name of indicator	Citizens' participation in research and innovation
Primary/secondary data	Secondary/Primary
Need for supplementary data collection	-
Description	a) Policy-oriented engagement with science depicts citizens' engagement practices. It uses the 2010 Eurobarometer on 'Europeans, science and technology', specifically the following three items: 1) Do you attend public meetings or debates about science and technology', 2) Do you sign petitions or join street demonstrations on matters of nuclear power, biotechnology or the environment, 3) Do you participate in the activities of a non-governmental organisation dealing with science and technology related issues. An index score (from 0-6) is calculated based on assigning 2 points to 'yes regularly', 1 point to 'yes occasionally' and 0 points to other answers. The mean national score is calculated. b) The R&I democratisation index is based on a stakeholder survey among organisations in the 'science in society' field, 20-30 organisations per country. A series of questions (5 point response scales) assess the extent to which citizens and civil organisations are: informed about R&I developments; are consulted as part of political decision-making processes; can influence political decisions; and are able to shape the R&I agenda. The index is constructed based on these items, and the national mean score is calculated. c) National infrastructure for involvement of citizens and societal actors in research and innovation is based on a stakeholder survey among organisations in the 'science in society' field, 20-30 organisations per country. Two questions (5 point response scales) assess the extent to which citizens and civil organisations: and have easy access to R&I policy-makers; are represented in R&I policy advisory bodies. A third question assesses whether multiple channels for interactions between science and society exist. The indicator summarises the degree of development of the national infrastructure for involvement of citizens and societal actors in R&I. Combined in an intermediate indicator of the participation of citizens in R&I, which is a direct democratic benefit. Reflects processes leading to greater diversity and inclusiveness in the governance of R&I and legitimisation of R&I at the societal level.
Qualitative/Quantitative	Quantitative
Source of data	a) Eurobarometer 340, wave 73.1. b & c) SiS Survey MoRRI project Task 8 (2016)
Date	a) 2010
Time-series	a) No. b & c) No.
Potential time series data/Collection period	a) Could be included in future Eurobarometer surveys. b & c) Yes.
Measurement	Mean national scores (numerical)
Unit of analysis	a) Individuals aggregated at national level. b & c) Organisations aggregated at national level.
Coverage	EU27
Further remarks	Weight the three metrics equally.

Information item	PE-DEM2
RRI dimension/type of RRI benefit	Public Engagement/Democratic benefits
Name of indicator	Citizens' perspective features in R&I policy making
Primary/secondary data	Primary
Need for supplementary data collection	Survey of policy making agencies and science in society actors; focus groups/interviews with citizens and community stakeholders
Description	The existence of documented measures for receiving and incorporating citizens' views indicates institutionalised public engagement processes that produce democratic benefits. A series of survey questions about modes of engagement and whether there is a scope for citizen review of draft policy. This quantitative aspect of the indicator could be considered an outcome level proxy for democratic benefits, where respondents report observing the emergence of democratic benefits over time. Perceptions of accessible, participatory S&T policy processes, on the part of citizens, community groups and other stakeholders, indicate the effective pluralisation of policy processes and the emergence of democratic benefits. Survey question to citizens (likert-type scale): Do you agree with the statement 'S&T policy decisions reflect citizen's perspectives'? Complementary qualitative research to ascertain the democratic quality of the policy processes encountered and perceptions regarding citizen influence on policy (to participants). Reflects processes of pluralisation and inclusion leading to democratic benefits.
Qualitative/Quantitative	Quantitative and qualitative
Source of data	-.
Date	-
Time-series	-
Potential time series data/Collection period	Potential for intermittent collection, every three to five years.
Measurement	Share of policy making organisations. Proportion of citizens. Composite
Unit of analysis	Public agencies, citizens, community groups
Coverage	-
Further remarks	This is an experimental and complex indicator that captures one dimension of the inclusive pathways opened up by public engagement activities. It would be potentially labour intensive to produce. How to weight and integrate the various data components into a consolidated metric would be a significant challenge. However, investing in a significant data collection process would also provide the basis for the potential expansion of the number of indicators. For example, the two elements could be split.

Information item	PE-SOC1
RRI dimension/type of RRI benefit	Public Engagement (Public communication)/Societal benefits
Name of indicator	Training of researchers in public communication
Primary/secondary data	Primary
Need for supplementary data collection	HEI survey, official university course documents
Description	The existence of science communication (or related) courses in science and engineering postgraduate degree courses or professional development courses indicate institutionalised activities designed to

	prepare research professionals for public engagement and the emergence of a societal benefit in terms of broad diffusion of relevant information and knowledge about S&T. This indicator captures the extent to which the professional education and training of scientists and engineers prepares them to inform and/or educate citizens through public communication activities. Consideration could be given to converting PE-SOC1 into a composite indicator that also includes RRI indicators SLSE1 and SLSE2 (European Commission 2015a, MoRRI Progress Report D3.2). These two indicators capture the RRI-related training provided at secondary and university levels in science education. In the context of PE-SOC1 the outcomes of these processes can be considered to prepare the ground for subsequent science communication training and professionalisation of researches, potentially deepening the societal benefit obtainable. Reflects processes of adaptation and inclusion that bring science and society into better alignment.
Qualitative/Quantitative	Qualitative analysis coded into types of training and hours/units allocated.
Source of data	University curricula, subject outlines, professional development courses.
Date	-
Time-series	-
Potential time series data/Collection period	Potential for intermittent collection, every three to five years
Measurement	% of HEIs with science communication plan for S&T PhDs % of PhDs/Masters graduates with science communication training
Unit of analysis	Researchers, HEIs
Coverage	HEIs in 28 EU countries
Further remarks	The adaptation of R&I institutions to the needs of citizens highlights the potential for responsiveness on the part of responsible R&I actors. Voluntary contribution of information by HEIs as part of reporting requirements would provide an updated indicator of societal benefit, i.e. the continued formation of R&I professionals competent to engage with citizens.

Information item	**SLSE-DEM1**
RRI dimension/type of RRI benefit	Science Literacy, Science Education/Democratic benefits
Name of indicator	Awareness and understanding of S&T choices and policy decisions
Primary/secondary data	Primary
Need for supplementary data collection	Survey (e.g. Eurobarometer)
Description	The existence of both awareness and understanding of the S&T choices confronting society and the rationale for policy decisions that make selections among possible alternatives, indicates the emergence of a democratic benefit from RRI interventions. Survey questions would include educational basis for understanding and focus on specific topics or controversies. Reflects processes of diffusion of relevant information and legitimisation of decisions.
Qualitative/Quantitative	Quantitative
Source of data	Survey of citizens
Date	-
Time-series	-

Potential time series data/Collection period	Yes. Question(s) could be included in regular survey to citizens. Stratified population survey to citizens of EU MS, conducted every five years.
Measurement	% receiving education in societal aspects of S&T within educational curricula; % recognising specific S&T debate(s); % recognising different perspectives or arguments within debates.
Unit of analysis	Citizens
Coverage	Flexible
Further remarks	Coverage would be contingent on the local, regional, national or global scope of the issues or controversies. The benefits of SLSE in terms of an enhanced S&T citizenship can be expected to improve the legitimacy of R&I overall.

Information item	**GE-DEM1**
RRI dimension/type of RRI benefit	Gender Equality/Democratic benefits
Name of indicator	Reduction of bias against women's participation in R&I
Primary/secondary data	Secondary data
Need for supplementary data collection	-
Description	a) The percentage of female researchers depicts the representation of women in research. Its differentiation by sectors indicates different opportunities and barriers. b) The relative chance for women, as compared with men, of reaching a top position addresses vertical segregation. It compares the proportion of women in grade A positions to the proportion of women in academia (grades A, B and C) (Glass Ceiling Index). c) The average annual percentage change in the proportion of women and men in the researcher population over a particular period, by all sectors of employment in R&D, highlights the rate of transformation in the horizontal participation of women in all sectors. Combined in an intermediate indicator of the reduction of bias against women's horizontal and vertical participation in R&I workforce, and in society, which is a direct democratic benefit. Reflects processes leading to greater inclusiveness and legitimisation of R&I at the societal level.
Qualitative/Quantitative	Quantitative
Source of data	Eurostat: Statistics on research and development. She Figures 2015.
Date	Most recently collected: 2011 (Eurostat); 2015 (She Figures).
Time-series	Most countries biennial – but data availability differs according to countries (Eurostat) Four editions of She Figures at 3 yearly intervals.
Potential time series data/Collection period	Yes
Measurement	Share of female researchers FTE (interval) Share of women in grade A (top level) in relation to share of women in academia (interval) Compound annual growth rate of share of female and male researchers Composite
Unit of analysis	Country
Coverage	R&D statistics are currently available for EU Member States and Candidate Countries, EFTA Countries, the Russian Federation, China, Japan, the United States and South Korea. Regional R&D statistics are available for EU Member States, Candidate and EFTA countries. Besides national and regional statistics Eurostat calculates and disseminates

	aggregates at the EU-and Euro-area-levels (EU-28, EU-15 and EA-18) but data availability differs over the years (EUROSTAT) 29 countries, EU27 (She Figures)
Further remarks	Weight the three metrics equally. Potential exists to add more intermediate metrics of this quantitative type to the indicator to make it a more robust reflection of the direct democratic benefit of reduced gender bias in R&I (and consequently in society).

Information item	**GE-DEM2**
RRI dimension/type of RRI benefit	Gender Equality/Democratic benefits
Name of indicator	Inclusion of gender dimension in research
Primary/secondary data	Secondary data
Need for supplementary data collection	-
Description	a) The base metric measures the gender content of a country's research output by dividing the number of journal articles which include a gender dimension by the total number of articles produced. b) The rate of change of the proportion of research with a gender dimension highlights whether a particular country is reducing the bias in the research system relatively quickly compared to other countries. Combined in an intermediate indicator of the degree to which the R&I system is responsive to the needs of women, which is a direct democratic benefit. Likely link to societal and economic benefits. Reflects processes leading to greater inclusiveness and legitimisation of R&I at the societal level.
Qualitative/Quantitative	Quantitative
Source of data	Web of Science.
Date	Most recently collected 2015 (She Figures 2015)
Time-series	Four-year moving periods: 2002-2005; 2006-2009; 2010-2013; and so on
Potential time series data/Collection period	-
Measurement	Number of scientific journal articles with a gender dimension in the research content indexed in the Web of Science/Total number of scientific journal articles indexed in the Web of Science Compound annual growth rate of the ratio of number of journal articles with a gender dimension to total number of journal articles
Unit of analysis	Countries
Coverage	Web of Science data is global, including a limited set of scientific journals. EU27+
Further remarks	Weight the two metrics equally. This indicator would ideally be driven by both the production of research *on* gender and by the gender content *of* research (in terms of its design, conduct and outputs). It is possible that the indicator will more easily capture the former aspect, whilst the latter aspect may be submerged to some degree.

Information item	**GE-ECON1**
RRI dimension/type of RRI benefit	Gender Equality/Economic benefits
Name of indicator	Gender relevance of R&I outputs
Primary/secondary data	Primary data
Need for supplementary	Targetted survey of stakeholders, including consumer groups, advocacy

data collection	groups, women's advocacy and community groups.
Description	This indicator provides an assessment of how relevant the outputs and products of the R&I system are and whether a perceived and communicated lack of relevance prompts a response on the part of R&I actors. Possible questions would focus on key public good areas of consumer interest such as health, education and sustainability. Interest groups focused on these and other issues would be the target of questions, including from a gender content of research perspective. Questions regarding the appropriateness of R&I investment priorities may be another option, although this would require specialised knowledge that may need to be drawn from expert stakeholders within and linked to R&I system. Reflects processes of pluralisation of both societal interests and expectations with respect to R&I and the potential proliferation of R&I responses to these demand side forces, in this case in relation to demands for products relevant to women. Reflects processes of inclusion of women's needs in R&D that have led to an improvement inequality and relevance of outputs from the perspective of users and advocates.
Qualitative/Quantitative	Quantitative data
Source of data	-
Date	-
Time-series	-
Potential time series data/Collection period	Yes, periodic.
Measurement	Proportion of stakeholder/advocacy/consumer groups who perceive outputs of R&I to be gender relevant and R&I actors as being responsive to issues of gender relevance.
Unit of analysis	Collective actors at multiple levels (community, regional, national, international)
Coverage	Flexible
Further remarks	Coverage and the level of analysis would be contingent on a range of contextual variables. One key variable could be sector, e.g. health, or more narrowly defined within a sector, e.g. orphan drugs for rare diseases. Another key variable would be interest, e.g. women's health, rare disease patients and their families. Differences between regions, countries, degrees of S&T based consumer culture would likely limit capacity for direct comparisons between different institutional contexts unless specifically matched. For example, direct comparisons amongst Nordic countries may be valid; comparisons between Nordic and Mediterranean countries quite probably would not.

Information item	**ETH-SOC1**
RRI dimension/type of RRI benefit	Ethics/Societal benefits
Name of indicator	Image and attractiveness of R&I careers
Primary/secondary data	Primary data
Need for supplementary data collection	Survey of students
Description	This indicator reflects the degree to which young persons who may be considering S&T careers, especially students, perceive that the R&I system provides a suitable and socially appropriate context in which to pursue a career that can satisfy their desire to make a positive contribution to their society/the world.

	Questions could include perceptions of gender equality in science, the trustworthiness of scientists, the ethical conduct of science (including fraud and manipulation), the regard in which S&T careers are held by family and friends, the capacity of S&T to address local problems in their personal context of life, etc. Reflects processes of legitimisation of R&I as aligned with young peoples aspirations.
Qualitative/Quantitative	Quantitative data
Source of data	-
Date	
Time-series	-
Potential time series data/Collection period	Yes, periodic.
Measurement	Among students considering science, engineering or other R&I system careers, the proportion who have a favourable opinion overall of the R&I system as a vehicle for them to make a positive and appropriate contribution to society.
Unit of analysis	Citizens
Coverage	EU27 +
Further remarks	An additional approach could be to question whether young people/students feel they can build a career in R&I that adheres to their conception of integrity, whilst remaining free from the influence of inappropriate counterforces and/or without endangering their chances of career progress. The legitimacy of S&T from the perspective of younger generations is assumed to be enhanced by high levels of ethical behaviour and integrity (perceived and actual).

Information item	**OA-ECON1**
RRI dimension/type of RRI benefit	Open Access/Economic benefits
Name of indicator	Use Access and utilisation of open data
Primary/secondary data	Primary data
Need for supplementary data collection	Survey of users of open data repositories, compilation of log data
Description	This indicator will showcase the efficiency of infrastructure that allows for the multiplication of uses/users of valuable knowledge resources. a) Compile and profile data on the access and use of open data resources from user survey information, including the numbers of users and their location. b) Compile log data of discrete accesses, searches, enquiries and downloads of data resources. The indicator will also highlight both increases in scale and diversity of these knowledge resources by computing the available base of data available in terms of volume and variety. Reflects processes of pluralisation of actors and (non-excludable) exploitation of valuable knowledge resources.
Qualitative/Quantitative	Quantitative
Source of data	-
Date	-
Time-series	-
Potential time series data/Collection period	Yes

Measurement	Volume of use of data (downloads, users, data requests); per user, per data set, per data type. Volume of users trained in context specific techniques that facilitate use and the exploitation of the commercial value of the information.
Unit of analysis	Public data repositories (for example EMBL-EBI).
Coverage	Public data repositories located in EU MS. Registered users by registered geographic location, by access points (IP addresses), by type (citizen, CSO, SME, University, etc.)
Further remarks	The way this indicator might contribute to monitoring is contingent on whether the metrics are used to describe the distribution and activity of data users, or to capture the value of the data repository. Data repositories are located in particular geographic locations, but data deposited originates from diverse locations. A second indicator might be considered that focuses on this 'upstream' aspect of open data. Qualitative research can also be used to approximate the monetary value (in terms of cost of producing these data independently) to firms who use free public data. Approximations of contributions to profit from applications that include free open data inputs may also become more attractive as methodologies improve. (A number of methods have already appeared that triangulate and create best estimates of value to users and to the economy as a whole.)

Information item	**GOV-DEM1**
RRI dimension/type of RRI benefit	Governance/Democratic benefits
Name of indicator	Diversity of R&I networks
Primary/secondary data	Primary data
Need for supplementary data collection	Interviews, focus groups.
Description	The diversity of R&I networks metric highlights the involvement of sets of research and societal actors in direct relationships. The degree of diversity of any (user-defined) network can be specified as: $$\sum_{i,j(i\neq j)} p_i p_j d_{ij}$$ Where: p is the proportion of elements in a category d is the distance between category i and category j The indicator captures information on the variety, balance and disparity of the set of interconnected bi-lateral relationships which make up a particular network. The indicator enables large project networks, for example, to be measured in terms of their diversity. This indicator is potentially useful for monitoring the diversity of projects and/or programmes specifically designed to draw multiple actors into collaboration or co-creation networks. The unit/level of analysis for applying the metric is flexible. Reflects processes of pluralisation and inclusiveness with regard to the participation of S&T and societal actors in R&I.
Qualitative/Quantitative	Qualitative data collection, principally through interviews, coded into numeric values.
Source of data	-
Date	-
Time-series	-
Potential time series	No.

data/Collection period	
Measurement	Overall degree of diversity of a defined network (0-1).
Unit of analysis	Large projects, research programmes, industry sectors, researcher sub-systems (disciplines/fields).
Coverage	-
Further remarks	The cultural change advanced by RRI promotes diversity in terms of the meaningful involvement of research, industry and societal actors along multiple dimensions, including GE, PE, SLSE, OA and GOV. The use of an index of diversity can be one way to capture evidence of the impact of this cultural change at the level of sizeable research networks. Trial and error approach to fine-tuning the application and interpretation of this indicator.

Information item	**GOV-SOC1**
RRI dimension/type of RRI benefit	Governance/Societal benefits
Name of indicator	Coherence of R&I networks
Primary/secondary data	Primary data
Need for supplementary data collection	Interviews, focus groups.
Description	The coherence of R&I networks highlights the connectedness and interactivity of sets of research and societal actors in direct relationships. The degree of coherence of any (user-defined) network can be specified as: $\sum_{i,j(i\neq j)} i_{ij} d_{ij}$ Where: d is the distance between element i and element j i is the intensity of the link between element I and element j The indicator captures information on the connectedness, intensity and distance bridged by, the set of interconnected bi-lateral relationships which make up a particular network. The indicator enables large project networks, for example, to be measured in terms of the apparent cohesiveness of their functioning. This indicator is potentially useful for monitoring the coherence of projects specifically designed to draw multiple actors into collaboration or co-creation networks. The unit/level of analysis for applying the metric is flexible. Reflects processes of inclusiveness, with regard to the participation of S&T and societal actors in R&I, and legitimisation, with regard to the development of trust and informal coordination, including between research and societal actors.
Qualitative/Quantitative	Qualitative data collection, principally through interviews, coded into numeric values.
Source of data	-
Date	-
Time-series	-
Potential time series data/Collection period	No
Measurement	Overall degree of coherence of a defined network (0-1).
Unit of analysis	Large projects, research programmes.

Coverage	-
Further remarks	The cultural change advanced by RRI promotes pluralisation and legitimisation in terms of the meaningful involvement of research, industry and societal actors along multiple dimensions, including GE, PE, SLSE, OA and GOV. The use of an index of coherence can be one way to capture evidence of the impact of this change, including on networks that cross cognitive, institutional and sector frontiers. Trial and error approach to fine-tuning the application and interpretation of this indicator.

5.5 Task 7 linkages to other MoRRI tasks

Task 7 followed on from the process of identifying benefits of RRI conducted in Task 6. The proposed benefits identified through case study analysis and expert opinion (visioning workshop) provided the basis for the conceptual modelling of indicators conducted in this Report. Task 3 provided the input/output and outcome indicators of RRI which were used as the building blocks for the intermediate-type indicators proposed in this Report.

Task 7 is linked to Task 8 and the survey of FP7 participants (researchers). Researchers will be asked about their observation of benefits emerging from their own RRI practices, or whether it is their expectation that such benefits will accrue in the future. We might expect to see different types of responses from different segments of the researcher population, depending on their predisposition toward societal engagement and contribution.

Task 7 is also linked to the Science in Society (SiS) survey being conducted in Task 8. Questions included in this survey will collect information for testing two indicators of RRI (PE9 and PE10). Both PE9 and PE10 form part of the proposed intermediate indicator for democratic benefits of RRI, PE-DEM1.

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Appendix 1 Overview of 36 RRI indicators and selected characteristics

No.	Indicator full name	Primary/ secondary data	Time series	Potential time series	Analytical level	Linkage	Data collection method
GE1	Share of RPOs with gender equality plans	Primary data	No	Yes	Input, outcome	GOV	RPO-survey
GE2	Share of female researchers by sector	Secondary data	Yes	Yes	Input, output, outcome	-	-
GE3	Share of RFOs promoting gender content in research	Primary data	No	Yes	Input, output	GOV	RFO-survey
GE4	Dissimilarity index	Secondary data	Yes	Yes	Output	-	-
GE5	Share of RPOs with policies to promote gender in research content	Primary data	No	Yes	Input, outcome	-	RPO-survey
GE6	Glass ceiling index	Secondary data	Yes	Yes	Input, output, outcome	-	-
GE7	Gender wage gap	Secondary data	Yes	Yes	Output	-	-
GE8	Share of female heads of research performance organisations	Primary data	No	Yes	Input, outcome	-	RPO-survey
GE9	Share of gender-balanced recruitment committees at RPOs	Primary data	No	Yes	Input	GOV	RPO-survey
GE10	Number and share of female inventors and authors	Primary data	Yes	Yes	Input, output	-	Register data
SLSE1	Importance of societal aspects of science in science curricula for 15-18 year olds	Primary data	No	No	Input	-	Qualitative and desk-research
SLSE2	RRI-related training at RPOs	Primary data	No	Yes	Input	-	RPO-survey
SLSE3	Science communication culture	Secondary data	No	No	Output	PE	-
SLSE4	Citizen Science activities in RPOs	Primary data	No	Yes	Output	PE	RPO-survey
PE1	Models of public involvement in S&T decision making	Secondary data	No	Yes	Input	GOV	-
PE2	Policy-oriented engagement with science	Secondary data	Yes	Yes	Output	GOV	-
PE3	Citizen preferences for active participation in S&T decision making	Secondary data	Yes	Yes	Output	GOV, SLSE	-
PE4	Active information search about controversial technology	Secondary data	No	Yes	Output	SLSE	-
PE5	Public engagement performance mechanisms at the level of research institutions	Primary data	No	Yes	Input	SLSE	RPO-survey
PE6	Dedicated resources for public engagement	Primary data	No	Yes	Input	SLSE	RPO-survey
PE7	Embedment of public engagement activities in the funding structure of key public research funding agencies	Primary data	No	Yes	Input	GOV	RFO-survey
PE8	Public engagement elements as evaluative criteria in research proposal evaluations	Primary data	No	Yes	Input	GOV	RFO-survey
PE9	R&I democratisation index	Primary data	No	Yes	Input	GOV	SiS actor survey
PE10	National infrastructure for involvement of citizens and societal actors in research and innovation	Primary data	No	Yes	Input	GOV	SiS actor survey
E1	Ethics at the level of universities	Primary data	No	Yes	Input, output, context	GOV, PE	RPO-survey
E2	National Ethics Committees Index (NEC index)	Secondary data	Yes	Yes	Depends on tailoring	GOV, SLSE, PE	-
E3	Research Funding Organisations Index	Primary data	Yes	Yes	Depends on tailoring	GOV, PE	RFO-survey
OA1	Open Access Literature (OAL)	Primary data	Yes	Yes	Output	-	Register data
OA2	Data publications and citations per country.	Primary data	Yes	Yes	Output	-	Register data
OA3	Social media outreach/take up of Open Access Literature and open research data	Primary data	Yes	Yes	Outcome	PE	Register data
OA4	Public perception of Open Access – PPOA	Secondary data	No	Yes	Output, context	GOV, PE	-
OA5	Funder Mandates	Secondary data	No	No	Output, context	GOV	-
OA6	RPO support structures for researchers as regards incentives and barriers for data sharing	Primary data	No	Yes	Input	GOV	RPO-survey
GOV1	Composite indicator of RRI governance	Secondary data	No	Yes	Input	GOV	-
GOV2	Existence of formal governance structures for RRI within research funding and performing organisations	Primary data	No	Yes	Input	-	RPO-survey, RFO-survey
GOV3	Share of research funding and performing organisations promoting RRI	Primary data	No	Yes	Input	-	RPO-survey, RFO-survey

Source: (European Commission 2015a) MoRRI progress report D.3.2: 33

Appendix 2 Full list of potential indicators of RRI benefits by RRI dimension

No.	Description	Source table
PE-DEM1	*Citizen's knowledge in R&I*	*3.1*
PE-DEM2	*Citizen's perspective in R&I policymaking*	*3.1*
PE-DEM3	*Citizens understand & accept S&T policy decisions*	*3.1*
PE-DEM4	*Collective R&I decision-making*	*3.1*
PE-ECON1	*R&I outputs match consumer demand*	*3.2*
PE-ECON2	*Expanded scientific and social capital networks*	*3.2*
PE-ECON3	*More efficient data production and utilisation*	*3.2*
PE-ECON4	*More RFOs*	*3.2*
PE-SOC1	*Educational curriculum matches citizen's needs*	*3.3*
PE-SOC2	*R&I matches citizen's expectations*	*3.3*
PE-SOC3	*Broadens shared understandings of S&T trajectories*	*3.3*
SLSE-DEM1	*Citizens are aware of and understand S&T policy decisions*	*3.4*
SLSE-DEM2	*Better science education for students with special learning requirements*	*3.4*
SLSE-DEM3	*Better understanding of S&T choices & decisions*	*3.4*
SLSE-ECON1	*New research questions & applications from citizen science*	*3.5*
SLSE-ECON2	*Reduction in cost of introducing S&T innovations*	*3.5*
GE-DEM1	*Sharing of good gender practices*	*3.7*
GE-DEM2	*Reduction in bias against women (in R&I and society)*	*3.7*
GE-ECON1	*Better quality scientific outputs*	*3.8*
GE-ECON2	*R&I better reflects societal and consumer demands*	*3.8*
GE-SOC1	*R&I outputs are more relevant*	*3.9*
ETH-DEM1	*Debate on social issues and S&T*	*3.10*
ETH-ECON1	*Social appropriateness of R&I*	*3.11*
ETH-SOC1	*R&I system adapts to ethical standards*	*3.12*
ETH-SOC2	*Social appropriateness of R&I improves image & attractiveness of R&I careers*	*3.12*
ETH-SOC3	*Recognition of ethical basis of R&I choices to address societal challenges*	*3.12*
OA-ECON1	*Increases efficiency of knowledge and resource use*	*3.13*
OA-ECON2	*More actors capitalising on knowledge resources*	*3.13*
OA-SOC1	*Increased social innovation and localised problem-solving*	*3.14*

Appendix 3 Potential indicators of RRI benefits by type of benefit

This Appendix synthesizes the potential RRI benefits identified in the MoRRI Project process into a small number of potential indicators of RRI benefits *by benefit type (democratic, economic, societal)*. This exercise is tangential to the development of indicators of RRI benefits by RRI dimension. It is attached here simply to prompt discussion and for possible consideration in further developments of RRI benefit indicators.

The rationale for the exercise is both conceptual and methodological. Highlighting the multiple linkages of RRI dimensions to the emergence of specific benefits can highlight the complementarities among the dimensions in producing these broad and deep effects.

The logic underlying this discussion is that pathway processes that generate RRI benefits are not discrete, but overlap and create synergies that can lead to a transversal definition of RRI benefits that crosses RRI dimensions. This logic shares much in common with the recommendations of the recent review of the UK Research Excellence Framework (REF) that suggested societal impact could also be assessed at the level of 'institutional case studies' that were inclusive of impact generated across a variety of different disciplines/units within a university.

The list contained in Table A3.1 was developed by synthesising the modelled effects and types of benefits summarised in Table 3.15. Each of these items was included in the synthesizing of at least one of the proposed indicators. Only six items were included in the synthesizing of more than one proposed indicator and none were included more than twice. The list includes three potential indicators of democratic benefits, five potential indicators of economic benefits and four potential indicators of societal benefits.

Table A3.1: Potential indicators of RRI benefits by type of benefit*

No.	Description	RRI linkages	Potential data type/ source
DEM1	R&I is open to diverse perspectives and interests and responsive to diverse challenges and needs	PE, SLSE, GE	Perceptions
DEM2	R&I is aligned with democratic choices about the future	PE, SLSE, Ethics	Perceptions
DEM3	R&I policy- and decision-making are aligned with democratic values (transparency, participation, responsiveness)	PE, SLSE, Ethics	Perceptions, audit of participation processes
ECON1	Increase in the sources of inspiration and creativity available to R&I	SLSE, OA, GE, PE	
ECON2	R&I outputs of improved quality are available to citizens	GE, OA	
ECON3	R&I outputs are better aligned with intermediate and final consumer demand	PE, GE	
ECON4	The costs associated with market entry and adoption of R&I outputs are reduced	PE, SLSE, Ethics	Survey - firms
ECON5	Financial, knowledge and other resources that are invested in R&I are utilised more efficiently	PE, OA	
SOC1	Young people are better prepared for, and more attracted to, careers in science, R&I and technology policy	PE, SLSE, Ethics	Survey, perceptions
SOC2	R&I is aligned with societal values and expectations and R&I outputs are relevant to citizens	Ethics, PE, GE	Perceptions
SOC3	R&I contributes directly to social innovation and situated problem-solving	PE, OA	
SOC4	Active and engaged S&T citizenship shapes and modifies societal challenges and interests	PE, SLSE, Ethics	

* DEM = democratic benefit, ECON = economic benefit, SOC = societal benefit.

This list of 12 indicators has the potential to reflect transformations in society that are consistent with the direction of change promoted by RRI interventions. As can be seen by the RRI linkages column in Table 4.2, it can also be informative to think across RRI dimensions. Each item reflecting one type of benefit has linkages to multiple RRI dimensions. This is due to the existence of complementary effects arising from RRI interventions along different dimensions that contribute to emergent benefits of different types.

Complementarities are also evident at the level of the proposed indicators themselves. For example, DEM1 in part reflects more diverse participation in the R&I system whilst ECON1 in part reflects the boost to creativity and innovation that can result from this enhanced participation.

DEM1 and DEM2 are both intended to capture the way in which RRI interventions lead to change in the relationship between science and citizens of a democracy. DEM1 focuses on the increased permeability of the R&I system in relation to the diverse groups, interests and perspectives that can be found within this citizenry, and the

engagement of the R&I system with the problems and needs that citizens introduce. DEM2 focuses on whether the trajectory of the R&I system reflects sufficiently the outcomes of processes of democratic representation and government by parliament that ground decisions regarding future developments and applications of S&T. DEM3 shifts the focus on the democratic benefits of RRI to the policy-making process. It is designed to capture whether RRI interventions have improved policy- and decision-making in terms of democratic values that can be considered central to moving R&I closer to society.

ECON1 captures the extent to which RRI interventions lead to increases in the sources of inputs and ideas that can drive R&I. This could come from better delivery of education, public participation in citizen science, the participation of women in R&I and improved access to knowledge and data, for example. ECON2 reflects the idea that RRI interventions may transform the work of science in particular ways. What constitutes 'better quality' of R&I outputs is obviously context dependent and contestable. Taking RRI interventions in gendered research content as an example, however, it does not seem quite so difficult to pinpoint the designing of products with more than simply a male subject/user in mind as leading to improvement in the overall quality of the product.

ECON4 captures the degree to which R&I outputs are in concert with market demands. This refers to both intermediate demand by value-adding organisations and final consumer demand. ECON4 reflects to some degree the effects captured by ECON2 and ECON3, and seeks to capture the extent to which the suppliers benefit from reductions in the costs of introducing new technology-based products into markets. ECON5 is a potential indicator of the extent to which, as a result of RRI interventions, investments in R&I can be observed to be being utilised or exploited more efficiently. For example, OA interventions can lead to the multiplication of the uses emerging from, and applications derived from, the creation of a new research dataset.

SOC1 and SOC4 are designed to capture societal benefits in terms of the effects of RRI interventions on the nature of citizenship. SOC1 captures the preparedness and motivation of young citizens to participate professionally in the R&I system. SOC4 captures the societal benefit of a citizenry who are active in identifying and defining what are the important S&T questions and challenges of the time.

SOC2 and SOC3 are focused on how RRI interventions bring science closer to society. SOC2 captures how appropriate the R&I system is in terms of societal values and how relevant the outputs of the R&I system are for the lives of citizens and communities. SOC3 addresses the question whether the R&I system influences or contributes directly to the resolution of localised problems or challenges by citizen-driven movements or other knowledge-focused approaches led principally from the local level.