Futures of science with and for society: towards transformative policy orientations

Oost, Ellen van; Kuhlmann, Stefan; Ordóñez-Matamoros, Gonzalo; Stegmaier, Peter

Veröffentlichungsversion / Published Version
Zeitschriftenartikel / journal article

Empfohlene Zitierung / Suggested Citation:
Oost, E. v., Kuhlmann, S., Ordóñez-Matamoros, G., & Stegmaier, P. (2016). Futures of science with and for society: towards transformative policy orientations. *Foresight : the journal of futures studies, strategic thinking and policy*, *18*(3), 276-296. https://doi.org/10.1108/FS-10-2014-0063

Futures of science with and for society: towards transformative policy orientations

Ellen van Oost, Stefan Kuhlmann, Gonzalo Ordóñez-Matamoros and Peter Stegmaier

Ellen van Oost is Associate Professor and Stefan Kuhlmann is Professor, both at the Department of Science, Technology and Policy Studies (STePS), University of Twente, Enschede, The Netherlands.
Gonzalo Ordóñez-Matamoros is based at the Department of Science, Technology and Policy Studies (STePS), University of Twente, Enschede, The Netherlands and Universidad Externado de Colombia, Bogota, Colombia.
Peter Stegmaier is Assistant Professor at the Department of Science, Technology and Policy Studies (STePS), University of Twente, Enschede, The Netherlands.

Received 7 October 2014
Revised 21 October 2015
Accepted 26 January 2016

The authors wish to acknowledge the support of the EU Programme "Capacities" – Call ID "FP7-SCIENCE-IN-SOCIETY-2011-1" Proposal No 289058 – *Research and Innovation Futures 2030. From explorative to transformative scenarios.* The paper has benefited from discussions with project partners.

Abstract

Purpose – *How to derive policy implications from five future scenarios of transformed research and innovation (R&I) systems? This paper analyzes methodological and content issues of five future scenarios of transformed R&I systems. The aim of this paper is to provide an outlook on strategic policies capable of facilitating or moderating these transformative changes in R&I practices is discussed in light of overarching intentions to foster "responsible" ambitions (in Europe and beyond, discussed as responsible research and innovation, RRI).*

Design/methodology/approach – *The paper elaborates a four-step methodology to assess the scenario's policy implications: first, by articulating the scenario implications for six core dimensions of R&I systems; second, an RRI assessment framework is developed to assess in each scenario opportunities and limitations for transforming R&I systems towards responsibility goals; the third involves a cross-scenario analysis of similarities and differences between the scenarios, allowing the identification of robust policy options that make sense in more than one scenario. The last analytical step includes again the richness of the individual scenario assessments aiming to provide a broader outlook on transformative policy orientations.*

Findings – *The paper concludes with outlining the contours of a future-responsible R&I system together with some suggestions for transformative policy orientations that aim to govern the R&I system towards such a future, as a source of inspiration and reflection.*

Research limitations/implications – *The analysis is based on five future scenarios that do not systematically cover future developments external to the R&I system.*

Practical Implications – *An outlook of strategic policies capable of facilitating or moderating these transformative changes in R&I practices is discussed in light of the overarching European Union goal of encouraging the performance of RRI.*

Originality/value – *This paper provides inspirational anticipatory strategic intelligence for fostering the responsible ambitions of research with and for society.*

Keywords *Research, Innovation, Research policy, Grand challenges, Responsible research and innovation, Scenario assessment*

Paper type *Research paper*

> To produce knowledge is to accept the risk of putting to the test our beliefs and our ignorance without reducing what we do not know to what we already know and without dismissing as irrelevant what we cannot describe because we ignore it, but is also to exercise prudence and precaution when dealing with the unknown or with the possible consequences of our actions (Sousa Santos *et al.*, 2008, p. 31)

Introduction

Future scenario methodology, based on analysis-founded narrative storylines, is a way to imagine, in a rich and challenging way, various possible future changes. Such scenarios of future research and innovation (R&I) landscapes embody "anticipatory intelligence" that policymakers and other stakeholders can tap into when thinking strategically about their futures, as well as about impacts these anticipated changes may have on them (UNIDO, 2005, p. 23; Kuhlmann *et al.*, 1999, p. 6). The main aim of this paper is to elaborate strategic

policy orientations, based on a scenario implication assessment, that address future R&I challenges.

This paper builds on five transformative scenarios for future R&I landscapes in 2030:

1. open research platforms (ORPs);
2. knowledge parliaments (KPs);
3. grand challenges for real – knowledge and innovation communities (GC-KICs);
4. knowledge value chains (KVCs); and
5. researchers' choice (RC).

Their methodology and features are presented and discussed by Erdmann *et al.* (this issue). The scenario methodology used was characterized by two phases. First, "explorative scenarios" were developed based on stocktaking of current trends and drivers, with "embedded" emergent tensions culminating into more severe tensions between contrasting trends and drivers. Next, "transformative scenarios" were built, involving an imaginative analysis of the way the R&I system might transform in response to the potential resolution of those tensions. By imagining plausible transformation dynamics of the science, technology, innovation (STI) system, R&I stakeholders can better anticipate new ways of acting within the context of the new R&I system. The transformative scenarios can be seen as either "windows of opportunity" or threats when thinking in terms of new STI constellations. For various R&I-active and "-dormant" stakeholders, this is a way to gain insight into how these changes may impact on their role and position. This allows them to anticipate on possible future developments and will stimulate the design of strategic options to prepare for them.

For this purpose, we apply an assessment framework spelling out by way of "controlled speculation", the scenarios' consequences for strategic policy objectives related to the facilitation of a particular goal: responsible research and innovation (RRI). The need for RRI is currently extensively discussed in European, and to some degree also in North American, policy circles and academia (Von Schomberg, 2012, 2013; European Commission, 2013; Owen *et al.*, 2013a, 2013b; Guston *et al.*, 2014; Macnaghten *et al.*, 2014). Although the scope and definition of RRI is in flux, it implies addressing questions about the *direction* R&I should take and suggestions how to perform and *govern* R&I responsibly. The definition of RRI of Von Schomberg (2012) highlights this perspective: "Responsible R&I is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view on the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society)". Often RRI is considered to be an important factor facilitating attempts to address the so-called grand societal challenges[1].

The paper is structured as follows: in the next section, we discuss the role of scenarios in policy-making. We then elaborate the analytical framework used to structure the scenario implication assessment and describe the various steps that are taken to identify strategic policy orientations. Hereafter, we will present the findings of assessments of each of the five research and innovation futures (RIF) scenarios. We start each assessment with a concise description of the core features of the transformed R&I landscape, and then present the outcomes of the scenario assessment[2]. From this assessment, we derive scenario-specific policy options for enhancing RRI goals. Then, a cross-scenario analysis follows for deriving robust strategic policy issues invoked by the scenario assessments. In the last section, we use our findings of the RIF scenario assessments by sketching the outline of a future R&I system that embeds and facilitates practices of responsible R&I. We will outline six dimensions each accompanied by transformative policy orientations that aim to guide the R&I system towards a RRI future. We expect that these transformative R&I

policy orientations too will be valuable for the complex task of effectively addressing grand societal challenges (Kuhlmann and Rip, 2015).

Role of scenarios in strategic foresight and policymaking

Policymaking in times of rapid social change and complexity requires anticipation ("anticipatory governance", Barben *et al*., 2008), by drawing up visions for a defined future, in everyday decision-making processes where assumptions about future effects of the decision are made or through dedicated foresight exercises (Georghiou *et al*., 2008; Eriksson and Weber, 2008). Anticipation will draw on available knowledge for assessing problems and taking decisions. The more specific the knowledge used, the more it can be described as "strategic intelligence". According to Kuhlmann *et al*. (1999), there are various forms of "strategic intelligence" that may help to enhance policymaking. Creating and assessing future scenarios is a well-known and broadly applied way of having foresight.

Since the early use of future scenarios in the 1960s, the variety of scenarios and its uses in strategy and policy development increased immensely. Sondeijker (2009) distinguishes three generations of scenarios. The first generation focused on technological and economic forecasting using quantitative data and methods like "trend extrapolation" and "growth models" overlooking uncertainty and producing "surprise-free" futures (van Asselt *et al*., 2007). The unforeseen oil crisis in 1973 shook up the comfortable belief of steady continuity. Scenario interests shifted towards exploratory approaches that could uncover the dynamics for potential discontinuities. The new generation of scenarios offered a range of possible futures and aimed at better understanding of future *uncertainties*. Creativity and imagination became a core scenario-building skill. The third generation of scenarios originated from the upcoming sustainability challenges in the late 1980s that increasingly dominated public policy agendas.

This new generation of scenarios is characterized by acknowledging complexity and a long-term view, based on the idea that there are general patterns in social change. Scenario building is also increasingly seen as an interactive process oriented towards *action learning* in terms of "seeking to question the future and asking questions of preferred, probable and possible futures at all levels" (Sondeijker, 2009, p. 50; Valkering *et al*., 2011). There also is a move in scenario development towards moral and idealized futures, taking account of anticipated winners and losers in the future scenarios. Scholars in transition theory, for example, work towards "transition scenarios" that construct complex future multilevel transitions paths towards sustainability (Elzen *et al*., 2004; Wiek *et al*., 2006). The transformative RIF scenarios clearly fit in this latest generation of scenarios, as the transformative dynamics aim to solve tensions that come to the fore in the current R&I system.

Future scenarios do not aim to predict, they rather promise a systematic, analysis-based and creative way for exploring and imagining potential future pathways of concrete developments (Martin, 1995; Georghiou *et al*., 2008). Scenarios are used strategically in dealing with intrinsic uncertainty of the future. They do not only aim to "think outside the box", but also push for "thinking in new boxes" (de Brabandere and Iny, 2010). The emphasis can be put on strategies or policies that stimulate positively assessed futures (as seen from a policy entrepreneur's point of view) as well as on strategies/policies that mitigate negative implications in (one or more) scenarios. Future scenarios need to be distinguished from "roadmapping", another widely used future technique for research and development (R&D) priority setting (Saritas and Aylen, 2010). While roadmaps are used for projecting concrete chains of actions, which are then held against the different influences from the drafted scenarios, future scenarios draw up *variations* of futures in broader contexts. The RIF scenario project clearly aimed to create a rich spectrum of future R&I systems (Erdmann and Schirrmeister, 2016).

Various R&I policy scholars have argued for the need of a strategic level of innovation policy that aims to facilitate structural changes at the system level (Smits *et al.*, 2010). Smits *et al.* (2010, p. 432) discern three missions of a strategic R&I policy: to generate a new set of policies, to better fit to a new global or domestic context and to facilitate creative destruction and emergence of new combinations. The RIF scenario project explicitly aims to contribute facilitating structural change by offering outlooks into a variety of transformed R&I futures and generate strategic anticipatory intelligence.

So, how to derive policy implications from future scenarios? As the scenario methodology is based on a co-evolutionary view on the development of policy, practice and theory (Erdmann and Schirrmeister, 2016; Kuhlmann *et al.*, 2010), the scenarios embody both transformed R&I practices as well as strategic R&I policy missions and instruments and their interactions. The assessment of the transformed R&I systems in the scenarios is done with regard to their ability to cope with today's European and national R&I policy challenges, including transformation pathways towards responsible R&I, helping to address grand challenges more effectively (Cagnin *et al.*, 2012; Kuhlmann and Rip, 2015). Each of the five RIF scenarios is likely to have system characteristics that can facilitate or constrain practices of responsible R&I.

Scenario assessment: methodology and framework for analysis

Here we describe a four-step methodology for assessing the scenario implications with regard to RRI goals. In the *first* step, we present six core dimensions of R&I systems for the assessment of future implications of each scenario (research practices, knowledge production and coordination and types of research; key players; legitimization of public R&I investments; research funding modes; research careers and mobility; and intellectual property rights (IPR) regimes and open access; Box 1).

These dimensions and the scenario implications were discussed and enhanced in interactive stakeholder workshops organized by RIF partners (Erdmann and Schirrmeister,

Box 1. Core dimensions for elaborating scenario system implications

- *Research practices, knowledge production and coordination, types of research*: How will the research practices look like? (individual/collaboration/coordination/groups/open research/methods) What types of knowledge production (curiosity oriented/applied oriented/challenge oriented) will be facilitated or constrained?
- *Key players*: Who will be the key players in the research landscape, what will be their roles and relations? (power constellations/new actors/institutes/interests/winners/losers). Who will decide or will be able to influence research agendas?
- *Legitimization of public R&I investments*: What value will science return to citizens? How much trust will society have in science? How will public research be evaluated? and What will the science-society contract entail?
- *Research funding modes*: How and by whom will the research be funded (type of funds/sources of funding/criteria and procedures for funding)? How will research proposals be evaluated and based on what criteria (role of competition and excellence /national or international, etc.)?
- *Research careers and mobility*: How will research careers be organized? (building and assessing scientific reputation/labour conditions/mobility/how is excellence defined?)
- *IPR regimes and open access*: What knowledge will be protected, by whom, and how? What will be the conditions for accessing and sharing knowledge?

2016). This systematic implication analysis facilitated a better comparison of the scenario assessments, as the five RIF scenarios are built around rather heterogeneous storylines.

The *second* step addresses the potential of the scenarios to contribute to RRI. What opportunities, limitations and new policy concerns turn up for the practice of RRI in the light of each scenario? This assessment framework requires a more detailed and comprehensive understanding of RRI. Stilgoe *et al.* (2013, p. 1,570) provide a broad definition: "responsible innovation is a collective commitment of care for the future through responsive stewardship of science and innovation in the present". Various scholars acknowledge that orienting R&I systems towards such a "collective commitment of care" implies a dedicated political and systemic transformation (Owen *et al.*, 2013a, 2013b; van Oudheusden, 2014; Walhout and Kuhlmann, 2013). As the RIF scenarios have a transformative character, their assessment could provide inspirational pathways to such systemic transformations.

The move towards RRI entails two major comprehensive ambitions:

1. addressing questions about the *direction* R&I should take with respect to societal challenges (e.g. sustainability, security and well-being), concerning anticipated risks and ethical concerns and towards technology and innovation meeting societal demands and values; and
2. suggestions on how to perform and *govern* R&I responsibly include, *inter alia* through involvement of stakeholders and encouragement of actors' responsiveness and forward-looking attitude.

Often the combination of the two RRI ambitions is considered to be a crucial precondition for the capacity to address the grand societal challenges (Cagnin *et al.*, 2012), with particular attention to the options and limitations of governance (Kallerud *et al.*, 2013; Kuhlmann and Rip, 2015).

Owen *et al.* (2013a, 2013b) highlight four dimensions of RRI: to innovate responsibly entails a continuous commitment to be:

1. anticipatory;
2. reflective;
3. deliberative; and
4. responsive.

Anticipatory activity focuses on describing and analysing intended and potentially unintended impacts (economic, social and environmental, etc.) that may arise from R&I. The anticipatory stance not only articulates existing promissory narratives but also explores other pathways to other impacts. In this context, Von Schomberg (2013) asks an important question:

Q1. What are "right impacts" and how can these be democratically defined.

These political and normative questions can only be answered in a democratic and interactive way by giving voice to various social stakeholder groups and will require reflective as well as deliberative activity. *Reflective activity* takes a critical stance towards underlying purposes, implicit assumptions and potential unintended impacts. What are uncertainties and possible risks? What ethical dilemmas may arise? The *deliberative* dimension (dialogue, engagement, debates and listening to wider perspectives from diverse stakeholders) opens up a variety of visions and perspectives including conflictive and contested issues. Owen *et al.* (2013) discern two types of deliberation: *normative* discussions (related to questions around democracy, social inclusion, justice, equality, cultural values, etc.) and *substantive* discussions (co-producing interactions with various civic actors, aiming to accommodate diverse sources of knowledge, values and meanings in the process).

The fourth and last dimension of RRI is *responsiveness* addressing the ability of the R&I system to include the insights of reflection and deliberation activities into the practice of doing R&I, that is, having impact on research agendas, research methods, design of products, etc. Responsive R&I system supports a practice that keeps all options open as long as possible. Collingridge (1980) denoted this system feature as "corrigibility", an open, iterative and inclusive dynamic of adaptive learning. The feeding back of the insights of technology assessments into technological development process is also a core element in constructive technology assessment approach (Rip *et al.*, 1995). In combination with anticipation and reflection, responsiveness can become a transformative ingredient of "responsibilisation" of actors and institutions in R&I systems (Dorbeck-Jung and Shelley-Egan, 2013; Shamir, 2008).

To sum up, in the second step of our assessment methodology, we adopted a heuristic assessment framework based on recent conceptualizations of RRI. The five transformative RIF scenarios are analyzed and assessed in terms of their options and limitations to cope with and facilitate a *collective* and *continuous* commitment to be *anticipatory*, *reflective*, *inclusively deliberative* and *responsive*. This heuristic qualitative assessment is performed systematically on each of the six dimensions of R&I systems that we elaborated upon in the first step. This systematic approach allows comparison of the assessment of the five scenarios. To facilitate this comparison, we scored for the RRI assessment each dimension on a five-point scale indicating the direction and strength: ++ for very positive (much facilitation) to − − for very negative (many limitations); "o" is neutral/not relevant.

The *third* step entails a cross-scenario analysis. Here, we highlight similarities and differences between the five scenarios with the help of an assessment matrix (scenarios × dimensions). Positively assessed scenario dimensions point to likely fruitful policy orientations for reaching the respective policy goals. Similarities in the scenario assessment point to "robust" policy orientations that are effective in various futures. Due to the particular scenario methodology chosen in the RIF project, the future R&I landscapes are neither mutually exclusive nor fully complementary (RIF, 2013). They explore futures in a multi-dimensional fashion. The "robustness" of these policy orientations therefore is limited to the dimensions of future changes sketched in the five RIF scenarios. So, "flexible" policy orientations derived from a single RIF scenario can also contribute to inspirational "anticipatory intelligence".

As a last and *fourth* step we sketch, based on the acquired "strategic intelligence" (Kuhlmann *et al.*, 1999) in the prior three steps drawing on both the robust policy orientations and the richness of the individual scenarios, the contours of a future R&I system embodying and facilitating RRI practices. The outlining of the contours follows to a large extent the analytical core dimensions of the R&I system we used in the scenario assessment; however, also, two important trends are articulated: globalization and digitization. These trends are prominent in all five transformative scenarios, yet in quite different shapes. This last step comes with some suggestions for transformative policy orientations as a source of inspiration and reflection.

In the following three sections, we will present the outcomes of these four methodological steps. The next section – combining Steps 1 and 2 – describes the assessment and the RRI policy issues for each of the five RIF scenarios.

Scenarios' assessment for responsible research and innovation policy goals

Here we will assess the five RIF scenarios of transformed future R&I systems in terms of their capability to cope with and facilitate a *collective* and *continuous* commitment to be *anticipatory*, *reflective*, *inclusively deliberative* and *responsive*. We first briefly describe the core of each scenario (for more detailed information on the scenario dynamics, see Erdmann and Schirrmeister, 2016) and the scenario report of the RIF project (RIF, 2013).

Then we will assess the scenarios systematically along the six core dimensions of R&I systems on the options and limitations to facilitate RRI practices[3].

Assessment of Scenario 1: open research platforms

The ORPs' scenario in a nutshell: this scenario "describes an R&I future of self-governance in a networked decentralized research landscape. By 2030, the research landscape with its research-performing organizations (and individuals) and funding mechanism is fully decentralized, global and open. Virtual communities initiate research that is integrated into virtual platforms and openly accessible. Self-governance of research around "open research platforms", fully open to industry, individuals, foundations and society at large, is the norm. Into the vast knowledge flows passing through these ORPs, governments of open societies worldwide embed their soft coordination activities such as monitoring of research, assistance in connection of research activities and targeted provision of incentives for researchers to contribute to certain ORPs of public interest (RIF, 2014).

The ORP scenario sketches an R&I future that is quite positively responsive to RRI practices. Table I provides an overview of the assessment of the ORP scenario in light of the RRI goals along the six core R&I system dimensions.

The ORP landscape provides capabilities where RRI can flourish, but not on all dimensions necessarily will do so. Strong points are the open character of data and knowledge, accessible to everybody. Also the common platform for meeting and sharing knowledge and perspectives is very relevant for RRI. Crowdfunding, charity and dedicated funds will strengthen mutual involvement and engagement between research stakeholders and civil society stakeholder groups. Yet, the ORP scenario also has vulnerable dimensions that would be in need of additional policy measures. The openness of the online platform is positive, but it needs to be secured that all stakeholders, researchers and civil groups possess intercultural and interdisciplinary collaboration skills. For these skills to develop and survive in the R&I system, they need to become a regular part of academic teaching and integrated in career incentives. Another vulnerable factor is the effective self-governance and moderation of online knowledge sharing that is needed to guarantee the quality of scientific data and knowledge. Also ORPs addressing topics with high stakes involved or ethically sensitive problems need productive and effective online interaction and communication.

In sum, we conclude that the ORP scenario partially supports the realization of the RRI goals, as it depends on the extent to which an active policy and governance framework is in place for that purpose.

Table I Overview of RRI assessment of ORP scenario dimensions

Type of research	All in all, the assessment of the RRI goals related to types of research in the ORP scenario is positive, but is subject to active RRI policy	+
Key players	The ORP scenario facilitates more influence of societal stakeholders, and opens up options for practicing science with and for society, yet good (self) governance is prerequisite to secure new balances between collaboration and competition	+
Legitimization	Due to effective multi-stakeholder collaboration on societal challenges, the societal legitimization of ORP-driven research is high, and this is likely to increase engagement with research from various societal groups	++
Funding modes	The rise of multiple funding sources for R&I will likely increase responsiveness of R&I to future societal needs, yet these funding actors are not necessarily anticipatory, reflexive and deliberative	o
Academic careers	Research coordinated by an ORP offers many potentials for more varied career paths, with a broader definition of academic competences; however, RRI-related skills (communication and reflection) are not necessarily included	o
IPR regimes	Open data and knowledge allow various stakeholders to engage actively in co-production modes	+

Assessment of Scenario 2: knowledge parliaments

In brief, "The core change of this scenario is the free negotiation of knowledge claims worldwide. By 2030, all kinds of knowledge claims are raised by new knowledge actors and negotiated in the so-called "knowledge parliaments"[4]. They prioritise research topics and provide "trading zones" in which actors with particular research interests, topics and epistemologies compete for acceptance. This form of forum also facilitates the building of research consortia. Citizens and a variety of other local stakeholders and epistemic cultures (e.g. lay and indigenous knowledge) are incorporated. Neglected research topics and unconventional knowledge domains are brought to the fore (RIF, 2014).

The tension that triggered the transformation of the R&I system towards the KPs' scenario was rooted in the discontent among various civil society actors with their marginal role and influence in the R&I system, even with RRI practices in the traditional R&I. Therefore, it will not come as a surprise that the evaluation of the KPs' scenario with respect to RRI goals is very positive (Table II).

One can even argue that the KPs' scenario sketches a practice of R&I that even goes far beyond RRI as formulated today. The KPs' scenario outlines a future R&I system in which different types of knowledge, perspectives and anticipatory intelligence are *fully integrated* (from setting of research agendas to exploitation of research results). Yet, it is also clear that the KPs' scenario is only *an extremely demanding and challenging* R&I future. The KPs' model is more difficult to apply in the R&I domains of high-tech and sciences that require expensive laboratories or research facilities (e.g. nano-labs or particle accelerators, etc.).

Key policy issues in the RRI assessment of the KPs scenario relate to the role of governments and policy in KPs future. While this role will primarily be a facilitating one, it will be crucial for securing democratic ways and fairness of procedures in KPs. Also, traditional tools, for example measuring research quality, career incentives and impact assessment, have to be recalibrated fundamentally for KPs' governed research. Third, new collaborative skills in research are important for all stakeholders and epistemic community members. The opening up of universities and specialized research facilities to society and wider publics is core in this scenario[5].

In sum, we conclude that the KPs' scenario is highly supportive for the realization of the RRI goal *by definition*; yet, there are some important issues that need active policy engagement.

Table II Overview of RRI assessment of KPs' scenario dimensions

Types of research	Research practices decided on in KPs are characterized by collaboration between pluriform epistemic cultures worldwide, thus providing research practices that embody diverse sources of knowledge, values and meanings. KPs aim to produce *fair knowledge* for and with societal stakeholders worldwide	++
Key players	*Citizens in the driver's seat*: this scenario fully transforms power relations between key players, granting citizens and civil society organization much more influence and engagement in all stages of the R&I process. A substantial part of public research is under direct control of the civil society. Various traditional borders, dichotomies and power relations are *blurred* (epistemological, disciplinary, cultural; north–south, expert–layman, etc.)	++
Legitimization	Direct involvement of civil groups and citizens in decision-making provide high social legitimization	++
Funding modes	National policy has opened their R&I budgets (partially) for citizens worldwide to decide on. Direct citizen involvement in funding decisions will increase public engagement	++
Research careers	More permeable borders between academia and society, and *enriching of academic competences* will *diversify career paths*. *Opening up universities for citizens*	++
IPR regimes	*Fair IPRs*: KPs' decision on IPR regimes of knowledge are subject to negotiation and deliberation in fair procedures. It certainly is a challenge to secure the fairness of this decision-making, certainly in cases with potential high stakes	++

Assessment of Scenario 3: grand societal challenges for real

The GC-KICs' scenario in short: this scenario "describes a future that revolves around a new research practice of collective experimentation in socio-technical labs. In 2030, the research landscape in Europe is characterized by making extensive use of collective experimentation. Research on grand challenges is organized around large KICs, each one overseeing several socio-technical laboratories in which a large number of different solutions responding to grand challenges are developed and tested. Diverse actors such as citizens, companies, universities and social entrepreneurs engage in collective experimentation. Experimentation, measurement of practices and impacts and co-creation go hand in hand so that real progress towards grand challenges becomes evident (RIF, 2014).

Overall the GC-KICs scenario strongly facilitates meeting RRI goals (Table III). This is a result of a strong European Union (EU) governance arrangement focused on research having real impact on local (and global) societal challenges, with active involvement of local knowledge and experiences, working towards solutions that actually work in a social satisfactory way. Local socio-technical laboratories, open to all stakeholders, imply a responsive R&I system able to take along a variety of knowledge, visions and perspectives. Research practices of GC-KICs have permeated fully in the society's social fabric.

A strong point, but, at the same time, also a weak aspect, is the dominant role of one single-actor group, the EU-organizations. A top-down governance can regulate various conditions as favourable for RRI (the only scenario in which impact assessments are part of regular R&I), but there is a risk of both technocracy (where goals or ends can be perceived more important than processes and means in light of this scenario, therefore limiting open participation) and bureaucracy (where the EU R&I policy is vulnerable to political tensions within EU and globally).

For these reasons, we conclude that the GC-KICs' scenario is also highly supportive for the realization of the RRI goal, provided it allows for more bottom-up decision-making process than top-down processes.

Assessment of Scenario 4: knowledge value chains

In a nutshell: In this scenario, R&I are intimately intertwined in a specialized and stratified research landscape. By 2030, the public research landscape is closely intertwined with the private research landscape globally. Research in Europe proceeds at various national and regional speeds aiming to improve their competitiveness in global markets through

Table III Overview of RRI assessment of GC-KICs' scenario dimensions

Types of research	Societal needs are leading research agendas. Co-production and collective experimentation are guiding principles and produce knowledge with high societal impact; this makes GC-KICs' coordinated research a very responsive system to RRI goals	++
Key players	EU Government is in the drivers' seat of GC-KICs under the pressures of civil society actors. The EU secures power balances among stakeholders in decision-making on R&I funding	++
Legitimization	Research is challenge-oriented, and societally embedded research is highly visible, accessible and legitimized. Traditional boundaries between science and society become fundamentally blurred. GC-KICs' research is fully embedded in and related to the practice and challenges of everyday life	++
Funding modes	EU and national Governments are the main funders of GC-KICs. A strong EU implies more public funds (= taxes) taking a long, indirect and likely bureaucratic route for citizens to the benefits of their taxes	+
Research careers	Collective socio-technical experimentation will increase the variety of people who become acquainted and attracted to science. Careers in science are likely to diversify, and research skills will be broadened including multidisciplinary collaboration skills and impact assessment skills	++
IPR regimes	Free knowledge sharing and circulation is a core implication in this scenario. Ideally, the European future will be post-patent era, allowing access and creative and innovative use of knowledge by everybody to realize effective solutions for GC	++

innovation. Research is carried out in "knowledge value chains' organizing the cooperation between three types of highly specialized and stratified organizations: research integration, research services and third-tier organizations. KVC actors interact according to management practices. Research is closely tied to industry processes adapting the respective degrees of openness in R&I (RIF, 2014).

The KVC scenario is not quite supportive of an R&I system ecology that facilitates open and receptive-to-RRI activities and goals (Table IV). In this scenario, the R&I system is characterized by efficiently managed large multinational organizations, with public–private funding modes, primarily aiming at producing knowledge with added economic value. This system is not likely to be very responsive to extensive deliberations with various societal stakeholders.

In case this R&I system is endowed with neoliberal morality and short-term profit goals, it will be detrimental to RRI. However, business and industry can adopt a more responsible mode of governance, in which case, innovative knowledge-intensive products addressing societal needs (e.g. sustainable energy solutions and sustainable transport) can be developed and marketed effectively; so, the dimension "societal legitimization" can be assessed as slightly positive. Besides, in a market economy, citizens and civil society have the power to indirectly influence R&I by creating a "responsible" market demand culture on which KVCs need to anticipate.

Key policy issues in the RRI assessment of the KCV scenario are, first, the stimulation and creation of incentives for business and industry to further their social responsibility. A second issue is the need to foster more long-term research goals (to address complex societal challenges) to compensate the systems bias towards short-term profit for stakeholders. A third policy issue is that the public funding needs to be accompanied with a set of requirements (soft governance) or even demands (hard governance), e.g. with respect to open access[6]. A fourth policy issue is the need for supporting effective civil organizations voicing the interests of the voiceless and vulnerable actors (animals, nature, fugitives, etc.).

To sum, we conclude that the KVCs' scenario provides a weak environment for the realization of the RRI goals. Strong governance measures are needed for providing some room for RRI practices.

Assessment of Scenario 5: researchers' choice

The RC scenario in brief: Autonomous researchers who go for creativity and well-being are the drivers of this scenario. Society is characterized by highly individualistic values and a strong emphasis on individual well-being, autonomy and creativity. Autonomous

Table IV Overview of RRI assessment of KVCs' scenario dimensions

Type of research	RRI goals like reflexivity, deliberation and the inclusion of (voices of) civil stakeholders will be hardly articulated in this efficiency-driven R&I system, social sciences and humanities are endangered	– –
Key players	Industry and research integrating organisations (RIOs) are key players; citizens and societal stakeholders are relegated to their consumer role. However, in this role, they have slightly indirect influence, as they collectively shape market demands	– –
Legitimization	Rigidly managed KVCs with weak inclusion of many societal stakeholders' interests run the risk of losing legitimacy, yet society's and environmental needs can be efficiently addressed when perceiving by industry and RIOs as "economic value"	o
Funding modes	Non-conventional or minority-relevant R&I will be less favoured in KVC-driven funding modes, yet KCV might be open to other funding sources	–
Research careers	RRI-related skill and competences are not valued and heterogeneity of types of researchers is not likely to be valued	– –
IPR regimes	IPR regimes are primarily driven by industrial interests; however, some of them could prefer open innovation models, allowing also other societal stakeholders to access this knowledge	–

researchers are at the heart of scientific research. To realize their ambitions, researchers choose options within a broad spectrum of models, ranging from new forms of science entrepreneurship to more collective forms under the umbrella of "slow science" with a strong orientation towards local societal needs (RIF, 2014).

The RC scenario's assessment has no clear-cut outcome towards meeting RRI goals (Table V). The slow science movement clearly favours RRI, whereas the entrepreneurial researcher ecology is more ambivalent. The knowledge market may well reinforce existing power of societal relations and interests. It neither stimulates anticipatory and reflexive knowledge nor is it necessarily deliberative and responsive to different interests, but it also does not explicitly hamper RRI goals.

Science-entrepreneurs are reflecting society's values. If society wants RRI, science-entrepreneurs will deliver RRI. If society is indifferent to RRI, the science-entrepreneur will be indifferent too. Slow science actors are inclined towards societal values that support basic ideas of RRI. In sum, we conclude that the RC scenario is rather ambiguous in its facilitation for RRI practices.

To conclude on this step of the individual scenario assessments, we see the assessments and the subsequent rising policy issues quite heavily diverge. The most positively assessed scenarios are the KPs and the GC-KICs; the least supportive scenario is KVCs. The ORP scenario and the RC scenario imagine more ambiguous future R&I systems that are open to RRI but are in need of additional policy measures to actually realize and secure RRI practices.

Cross-scenario analysis: robust policy options for advancing responsible research and innovation goals

The cross-scenario analysis aims to distil some robust policy concerns for the present European and national R&I policy for advancing practices of RRI. Table VI provides an overview of the five scenario assessments on each of the six core dimensions of the future R&I landscapes with the assessment codes and the main features on which the assessment is based.

When looking at the columns of Table VI, we find that three scenarios are rather open and receptive to RRI goals, these being Scenario 2 (KP), Scenario 3 (GC-KICs) and the slow science part of Scenario 5 (RC). Scenario 4 (KVC) is likely to impede RRI activities, whereas Scenario 1 (ORPs) and the researcher entrepreneur part of Scenario 5 (RC) is more neutral

Table V Overview of RRI goals assessment of the RC scenario dimensions

Type of research	The autonomous research scenario is almost seamlessly linked to existing needs, as it is regulated by the societal knowledge-market. Slow science research by definition strives towards a sustainable future and local community goals	++
	Research done by the science entrepreneur is not necessarily anticipatory, reflexive and deliberative. This depends on the research commissioner. Dominant actors on knowledge market steer research focus	–
Key players	Individual autonomous researchers and their clients (various societal stakeholders) are core players, but their relations are continuously under negotiation, with no *a priori* impact on RRI ambitions	o
Legitimization	Entrepreneurial researchers have in principle a high legitimization (market demand and creative and innovative) and slow scientists for enhancing quality of living	++
Funding modes	Entrepreneurial attitude opens up multiple funding sources, yet, not necessarily including RRI goals . . .	o
	. . . apart from slow science	++
Research careers	Researchers are autonomous and find new creative ways of earning money with value-driven research services. Science entrepreneurships – especially slow science – may well open up for entrepreneurs with various types of non-academic knowledge	+
IPR regimes	Science entrepreneurs have an ambivalent relation to IRP regulations	o
	Slow science will prefer open access	++

Table VI Cross scenario assessment matrix for addressing RRI goals

Core dimensions	*Scenario 1* *ORPs*	*Scenario 2* *KPs*	*Scenario 3* *GC-KICs*	*Scenario 4* *KVCs*	*Scenario 5* *RC*
Research practices and type of research	+ Research for society, but not necessarily with society	++ Fair research for society, heterogeneous epistemologies	++ Locally co-created knowledge for real solutions of societal challenges	− − Research for economic value serving industry	− Knowledge market steers research focus ++ Slow science includes RRI
Key players	+ Researchers in the driver's seat, open to and collaborating with other stakeholders	++ Citizens in the driver's seat, blurring various boundaries, dichotomies and power relations	++ EU in the driver's seat, top-down governance with fair participation of various stakeholders	− − Industry and RIO managers are key actors	o Researchers' and clients' groups balanced
Societal legitimization	++ Effectively (globally) coordinated research for society, open knowledge	++ Research for fair society, democratic decision-making	++ Research addressing local societal challenges, fair decision-making	o High return of value of public funding; yet, little affinity with non-economic societal concerns	++ Open knowledge market can facilitate RRI demands
Research funding	o Multiple funding sources, but not necessarily reflective and deliberative	++ (Global) Democratic decision on public funds	+ Mainly tax-based public funding, indirect but fair decision-making	− Public–private funding; yet, open to other funding sources	o Multiple funding sources, but market dependent ++ Slow science funding is RRI
Academic careers and competences	o Broadening academic skills, but not necessarily reflective and deliberative	++ Broadening academic skills; Diversification of career paths; Opening up of universities to citizens	++ Broadening of academic skills; Diversification of career paths; Opening up of universities to citizens	− − High pressure on performance; little room for heterogeneity	+ Broadening academic skills (entrepreneurial) + opening up to non-academic knowledge
IPR regimes	+ Open knowledge and data, but limited accessibility by societal stakeholders	++ Flexible IPR, yet serving fair society	++ Open knowledge and innovation	− Flexible IPR, yet primarily serving industry	o Ambivalent relation with IPR ++ Slow science adheres to open knowledge

in character. Although this conclusion is interesting and relevant in itself, is it also useful to perform a cross-scenario analysis. Comparing the scenario assessment on each of the six system dimensions – in other words, analysing the rows – one can identify common features across the scenarios. Some dimensions – type of research, careers and IPR regimes – in more than one scenario point – to *similar* features that make the R&I system open and responsive to RRI. Other dimensions, like legitimization and funding, also seem to point at *different* directions leading to an RRI-sensitive R&I system. This implies that one can discern between two types of policy suggestions for endorsing systemic changes towards RRI openness. The first type refers to *robust* policy options that stimulate positively assessed developments that are similar in most scenarios (Valkering *et al.*, 2011). The other type refers to *flexible* policy options likely to function in only one scenario but with the potential to advance RRI goals. Below we will summarize the policy issues that we identified to be important for advancing RRI goals, with an emphasis on robust policy options.

Based on the analysis of the main features underlying the assessment, as presented in Table VI, we can identify several robust policy options that steer the present R&I system towards an RRI-friendly system. The robust policy options emanate from system features that were found in more than one scenario.

Research practices and types or research

Robust policy options include the addressing societal challenges and close collaboration with civil society actors in research practices. Individual scenarios highlight specific types of societal challenges research that can be stimulated by flexible policy options like: endorsing "fair research epistemic heterogeneity", "slow" research and/or co-creative practices of knowledge production and innovation.

Key players

Robust policy options include enhancing the engagement and participation of citizens (grassroots movements and civil society organizations) in R&I decision-making and practice. Here, too, the individual scenarios highlight different forms of citizens involvement that can by stimulated by flexible policy options (co-creation; public-private-people partnerships, democratic decision-making of research agendas and funding). In two positively assessed scenarios (KP and GC-KICs), civil society actors are key to initiating transformation.

Legitimization

Robust policy options include more democratic and fair decision-making on research programming. Equally important is empowering citizens and civil groups by developing their competences and skills in articulating (local) societal demands (e.g. the engaged university that opens up for citizens).

Research funding

Robust policy options include funding decision modes giving a broader scope of stakeholders a say (e.g. crowd funding; "fair" funding'), rendering higher commitment and engagement with the funded research. Fundamental democratization of public research funding is a powerful flexible policy option (KP scenario).

Academics careers and competences

Robust policy options include a broadening of academic skills with multidisciplinary, multicultural collaboration, entrepreneurial and reflexivity skills. Another recurring policy issue is the diversifying career paths in academia. Opening up universities for non-academics (citizens, community) and increasing community competences (e.g. offering community modules) is a third robust policy issue. Overall, there is a clear need for revision of new public management governance of universities and public research institutes.

IPR regimes

Robust policy options include a better regulation of global open access, open knowledge and open data of publicly funded research. When open source is not an option, tailored decision-making on IPR with fair deliberative procedures (fair IPR) is a flexible policy option.

To conclude, the cross-scenario analysis yielded six core dimensions of R&I systems' strategic policy options that would facilitate the RRI goals in more than one scenario. These robust strategies are clearly an outcome of "strategic intelligence" (Kuhlmann *et al.*, 1999) generated by the scenario assessment work performed in the prior three steps. Yet, these policy options are not a "logical" and unambiguous result and end-point of the strategic analysis of the RIF project. The specific character of the RIF scenario methodology, describing pathways of transformative change triggered by culminating tensions in the R&I system can – in principle – provide a multitude of plausible future scenarios. Thus, the five RIF scenarios do not fully complement each other. Some scenarios can very well (at least partially) co-exist (Erdmann and Schirrmeister, 2016). Consequently, this scenario methodology invites for one further analytic step, drawing also on the richness of the individual scenario assessments. In the next section, we will sketch the contours of an R&I system open to RRI goals, based on the broader insights gained during the whole scenario assessment process.

Contours of a responsible research and innovation system: towards transformative policy orientations

For the sketching of the contours of a responsible R&I system, we will highlight six policy orientations that cover in the main insights of the transformative RIF scenario assessments regarding their openness to RRI practices. Four of these orientations link directly to the analytical core dimensions of the R&I system: type of research, academic careers, research funding and IPR[7]. The two other policy orientations address dynamics of globalization and digitization, both featuring prominently in all RIF scenarios (Erdmann and Schirrmeister, 2016) and thus are seen in the RIF project as essential and robust elements of future R&I landscapes. For each orientation, we accumulated the lessons drawn from the cross-scenario analysis and the challenging new ways of thinking in individual RIF scenarios into building blocks for challenging transformative policy orientations. Each building block is linked to relevant academic discourses by including some core references.

We hope that these policy orientations and building blocks will act as inspirational guidelines, allowing for "thinking in new boxes" as de Brabandere and Iny (2010) have formulated it, for governing the current R&I system towards a future RRI system.

Towards science with and for society

The role of science in society is changing and becoming more complex. Science is expected to contribute to solving challenges that society faces, at local, national and global levels. Societal actors will gain more influence on setting agendas, allocation of research funds and execution of research. Multiple actors and stakeholders will coproduce knowledge to effectively address inherently complex grand challenges. Setting up mechanisms, processes and structures to enable a two-way dialogue with society seems to become more and more important, and as much as conducting research that is both of high quality and high relevance to societal challenges. This would also entail a need for new ways to evaluate diverse knowledge claims and epistemic cultures.

Transformative policy orientations include:

- Strengthening of the societal legitimation of science through active involvement of citizens and civil society organizations in setting research agendas and allocation of public research funds. This is particularly important in areas where major societal challenges are addressed (Callon, 1999; Jasanoff, 2003; Irwin, 2006).

- Exploiting and developing heterogeneous and localized knowledge to realize smart, sustainable and socially inclusive solutions for the societal challenges (Jasanoff, 2006). This asks for policies blurring the traditional boundaries between science and society, among scientific disciplines and across governance levels (Fisher *et al*., 2014). It is important to find the right level and instruments to enable participatory forms of *co-creation* of knowledge, taking into account the need for multi-level governance and coordination (Swedlow, 2012).
- Revisiting the science-society contract (e.g. public engagement and in case of controversial knowledge: deliberation/consensus conferences; Felt *et al*., 2007). In public funding programmes, the societal orientation would become an integral part of the definition of excellence (assessed by involving societal actor in *ex ante* and *ex post* evaluations).

Towards a digital research infrastructure 3.0

Digital infrastructures will shape general research practices and individual trajectories. Access to the digital infrastructure is important across all the scenarios. However, it is not enough to provide general openness. Open access needs to apply a differentiated approach depending on the type of research conducted and/or the scientific issues being dealt with. Transformative policy orientations include:

- Providing and maintaining a powerful and easily accessible research infrastructure to boost the flows of information, collaboration and coordination[8].
- Facilitating and accommodating new types of online research communities that rise through the opportunities offered by new developments in information and communication technology (ICT) and social media (Science 2.0) (Fuster Morell, 2010). Self-organized and challenge-oriented communities allow for bottom-up coordination of knowledge, but also require different kinds of funding instruments and IPR regulation. Open data and open access policies play a crucial role in dealing with this challenge.
- Ensuring data security in response to ethical, legal or social issues addressed by society or to avoid misuse. Issues such as Big Data management and ensuring scientific quality also become crucial.

Towards Research 3.0 careers: new competences and commitments

Careers and competences of scientists will change drastically. What new skills and competences will be required for responsible research? How to keep careers in the academic institutes attractive and interesting for the talented? In search for new incentives, the relevance of virtual research communities and networks will become increasingly relevant. New R&I hubs, individualization and the changing position of universities are important drivers for Research 3.0 careers – "science with and for researchers".

In most scenarios, the very concept of "university" unravels into a set of heterogeneous missions, tasks, ways of funding and organization, with at least two opposite profiles: strongly teaching oriented "regional" universities with a low research profile, on the one hand, internationally competitive excellent research universities (fully-fledged academia or highly specialized) on the other. Transformative policy orientations include:

- Keeping science careers and mobility attractive by enhancing heterogeneity of career paths and broadening of academic skills with collaboration skill, reflexive skills and multidisciplinary skills; new instruments for assessing and evaluating the quality of researchers and research groups are needed that also capture the societal value of the research.
- Rethinking science education (new competences and motivations) and providing new incentives for scientific careers (broadening criteria for excellence and types of

affiliation to institutions); opening up universities for civil groups and different epistemic cultures and fostering creativity and playful experimentation in everyday life to avoid a creativity divide.

- Equipping research groups with greater resources (personnel, facilities and time) to be able to broaden research horizons and to publish more and with more differentiated foci (Estabrooks *et al.*, 2008). It is about letting researchers grow cognitively, in scientific community, and within their organizations substantially in a changing world that increasingly requires "pluralist experts" (Laudel and Gläser, 2008; Grin, 2004; Stegmaier, 2009; Rip, 2009).

Towards a distributed and diversified research funding landscape

In all five scenarios, in different ways, representativeness of societal concerns appears to be an issue. Involving more diverse and heterogeneous societal stakeholder groups, varying from NGO's to informal citizen groups, in shaping and deciding on agendas of publicly funded research, is a core issue. The KP scenario is most radical in this respect, raising policy questions regarding research coordination and continuation of research, the dominance of one research type (e.g. challenge-driven) over another (e.g. curiosity-driven), as well as fair representation of all stakeholders' interests in agenda setting and funding decision-making (Sousa Santos *et al.*, 2008; Iorns, 2013). Transformative policy orientations include:

- Stimulating and rewarding heterogeneous sources of funding: public, private and civil, for classical scientific and "grassroots knowledge". Directing civil funding (e.g. crowd sourcing) and directing involvement in decision-making on research agenda and funding by citizens increase the societal legitimacy of science.
- Providing European research funding agencies with a strategy to deal with the increasing significance of non-European and non-scientific or not only scientific funding agencies.
- Finding of political and organizational new ways for defending epistemological wealth of regions and people globally. The challenge is to secure funding for minority epistemic cultures and to provide legal certainty for negotiation, decision-making and dedicated IPR regimes.

Towards multiple and heterogeneous IPR regimes

The regulation of intellectual property would need to be redefined under the principle of responsible R&I. Private interests would be redirected towards the public good with respect to the environment and societal needs through fair representation and active engagement of all stakeholders. There is a need for multiple IPR regimes and open access approaches that have to fit diverse interests and sectors/research areas' peculiarities given the growing heterogeneity in R&I (e.g. for biotech regimes: Fresco, 2003; Singer and Daar, 2001).

Accessibility of scientific and other forms knowledge is a core policy challenge for all scenarios striving towards democratization of science (Willinsky, 2006; Hope, 2008). Open access of publicly funded research is the minimal policy option, a post-IPR landscape is the most radical option for the future.

Transformative policy orientations include:

- Stimulating and facilitating (global) *open access* of publicly financed research. Formalizing the role of a Global Research Council.
- Developing sophisticated and intelligible policies dealing with intellectual property in research fields that generate tensions, e.g. industry interests vs societal interests.

Towards balanced globalized research and innovation futures

In a globalizing world of research with manifold forms of engagement for all kinds of stakeholders and participants, knowledge and cultures, Europe would be wise to find power and knowledge strategies for R&I that increase a non-hegemonic "fair knowledge trade". With the rising power of other world regions and the changing world order, there is a need to look beyond intra-European goals. New alliances are necessary in dealing with certain global challenges. The appreciation for and collaboration in developing fair and new configurations of knowledge (Sousa Santos *et al.*, 2008, p. 29) could enable the Europe to be a welcome and sought-for partner in the new world of knowledge. Transformative policy orientations include:

- Enabling of "glocalization" of R&I practices. Foster localized socio-technical experimentation embedded in global networks for knowledge transfer and social learning, balanced with legitimate protection and economic exploitation of knowledge in a global context.
- Creating global platforms that enable the design and funding of EU-Framework Programme-and European Research Council (ERC)-like global efforts to support high-level and creative R&I projects, guided by RRI and aiming to address the grand challenges.

The above account of transformative policy orientations is meant to be neither exhaustive nor prescriptive. Rather it lends itself as a source of inspiration and reflection on options and limitations of transforming R&Is' systems towards more responsible ambitions.

Conclusion

The paper aimed to derive policy implications from five future scenarios of transformed R&I systems. For this purpose, the paper elaborated a three-step methodology for the scenario-assessment (articulation of scenario implications for six core dimensions of R&I systems; identification of opportunities and limitations for transforming R&I systems towards responsibility goals; and elaboration of "robust" and "flexible" policy options across scenarios). The assessment revealed significant structural and institutional transformations in R&I processes and policies. The paper concluded by outlining the contours of a future-responsible R&I system, together with suggestions for transformative policy orientations that aim to govern towards such a future, as a source of inspiration and reflection.

Notes

1. The European Union is focusing in six Grand Challenges: health, demographic change and well-being; food security, sustainable agriculture, marine and maritime research and the bio-economy; secure, clean and efficient energy; smart, green and integrated transport; climate action, resource efficiency and raw materials; and inclusive, innovative and secure societies.
2. For the underlying analysis of the opportunities, limitations and perspectives for implementing and achieving the RRI objectives, we refer the reader to the RIF document (RIF, 2014).
3. This paper only presents the outcomes of the assessments. For the fully elaborated assessments, we refer to the RIF D3.1 report (RIF, 2014).
4. In The Netherlands, researchers criticize the national funding agency NWO for using inappropriate peer review methods in the decision-making over the distribution of research funds. Equally good projects would sometimes get no funding. Critics ask for other forms of taking decisions, so, for instance, by lottery, or more radically, for an open democratic society-wide decision making process. Sources: www.utnieuws.nl/nieuws/60457/Kritiek_op_NWO_zwelt_aan; www.volkskrant.nl/wetenschap/wetenschapsselectie-van-de-nwo-is-ontmoedigende-farce~a3741402/; both last accessed 4 October 2014).
5. An interesting project presently is "the engaged university in 2020" (www.publicengagement.ac.uk). Here, a strong plea is made to open universities – financed with public money – to wider publics to stimulate public engagement with science.

6. See Open Science Grid (www.opensciencegrid.org).

7. The dimensions – "key players" and "legitimation" – are not addressed as a separate policy orientation but are taken account of in an integrated way.

8. See e.g. the UK charity Jisc and its Research 3.0 campaign (www.jisc.ac.uk/whatwedo/campaigns/res3.aspx).

References

Barben, D., Fisher, E., Selin, C. and Guston, D.H. (2008), "Anticipatory governance of nanotechnology: foresight, engagement, and integration", in Hackett, O.A.E., Lynch, M. and Wajcman, J. (Eds), *The Handbook of Science and Technology Studies*, MIT Press, Cambridge, MA, pp. 979-1000.

Cagnin, C., Amanatidou, E. and Keenan, M. (2012), "Orienting European innovation systems towards grand challenges and the roles that FTA can play", *Science and Public Policy*, Vol. 39 No. 2, pp. 140-152.

Callon, M. (1999), "The role of lay people in the production and dissemination of scientific knowledge", *Science, Technology, & Human Values*, Vol. 4 No. 1, pp. 81-94.

Collingridge, D. (1980), *The Social Control of Technology*, Pinter, London, New York, NY.

Dorbeck-Jung, B.R. and Shelley-Egan, C. (2013), "Meta-regulation and nanotechnologies: the challenge of responsibilisation within the European commission's code of conduct for responsible nanosciences and nanotechnologies research", *Nanoethics*, Vol. 7, pp. 55-68.

de Brabandere, L. and Iny, A. (2010), "Scenarios and creativity: thinking in new boxes", *Technological Forecasting and Social Change*, Vol. 77 No. 9, pp. 1506-1512.

Elzen, B., Geels, F.W. and Green, K. (Eds) (2004), *System Innovation and the Transition to Sustainability: Theory, Evidence and Policy*, Edward Elgar Publishing.

Erdmann, L. and Schirrmeister, E. (2016), "Constructing transformative scenarios for research and innovation futures", *Foresight*.

Eriksson, E.A. and Weber, K.M. (2008), "Adaptive foresight: navigating the complex landscape of policy strategies", *Technological Forecasting and Social Change*, Vol. 75 No. 4, pp. 462-482.

Estabrooks, C.A., Norton, P., Birdsell, J.M., Newton, M.S., Adewale, A.J. and Thornley, R. (2008), "Knowledge translation and research careers: mode I and mode II activity among health researchers", *Research Policy*, Vol. 37 Nos 6/7, pp. 1066-1078.

European Commission (2013), "Options for strengthening responsible research and innovation", Report of the Expert Group on the State of Art in Europe on Responsible Research and Innovation, Luxembourg.

Felt, U., Wynne, B., Callon, M., Goncalves, M.E., Jasanoff, S. and Jepsen, M. (2007), "Taking European knowledge society seriously", Report of the Expert Group on Science and Governance to the Science, Economy and Society Directorate, Directorate-General for Research, European Commission, Office for Official Publications of the European Communities, Luxembourg.

Fisher, E., O'Rourke, M., Kennedy, E.B., Evans, R., Gorman, M. and Seager, T. (2014), "Mapping the integrative field: taking stock of socio-technical collaborations", *Journal of Responsible Innovation*, Vol. 2 No. 1, pp. 39-61. doi: 10.1080/23299460.2014.992769.

Fresco, L.O. (2003), "A new social contract on biotechnology", available at: www.fao.org/ag/magazine/0305sp1.htm (accessed 3 October 2014).

Fuster Morell, M. (2010), "Governance of online creation communities: provision of infrastructure for the building of digital commons", EUI PhD thesis, European University Institute, Florence, available at: http://hdl.handle.net/1814/14709

Georghiou, L., Cassingena Harper, J., Keenan, M., Miles, I. and Popper, R. (Eds) (2008), *The Handbook of Technology Foresight: Concepts and Practice*, Edward Elgar Publishing.

Grin, J. (2004), "Health technology assessment between our health care system and our health. Exploring the potential of reflexive HTA", *Poiesis & Praxis*, Vol. 2 No. 1, pp. 157-174.

Guston, D.H., Fisher, E., Grunwald, A., Owen, R., Swierstra, T. and Van der Burg, S. (2014), "Responsible innovation: motivations for a new journal", *Journal of Responsible Innovation*, Vol. 1 No. 1, pp. 1-8.

Hope, J. (2008), *Biobazaar: the Open Source Revolution and Biotechnology*, Harvard UP, Cambridge, MA.

Iorns, E. (2013), "Research 2.0.1: the future of research funding", available at: http://blogs.nature.com/soapboxscience/2013/06/12/research-2-0-1-the-future-of-research-funding (accessed 3 October 2013).

Irwin, A. (2006), "The politics of talk: coming to terms with the 'new' scientific governance", *Social Studies of Science*, Vol. 36 No. 2, pp. 299-320.

Jasanoff, S. (2003), "Technologies of humility: citizen participation in governing science", *Minerva*, Vol. 41, pp. 223-244.

Jasanoff, S. (2006), *States of Knowledge: The Co-Production of Science and the Social Order*, Routledge, London.

Kallerud, E., Amanatidou, E., Upham, P., Nieminen, M., Klitkou, A., Olsen, D.S., Toivanen, M.L., Oksanen, J. and Scordato, L. (2013), "Dimensions of research and innovation policies to address grand and global challenges", EU-SPRI Forum Position Paper, available at: www.euspri-forum.eu/key_missions/CPRI_Position_paper.pdf

Kuhlmann, S., Boekholt, P., Guy, K., Heraud, J.-A., Laredo, P., Lemola, T., Loveridge, D., Luukkonen, T., Polt, W., Rip, A., Sanz-Menendez, L., Smits, R. and Georghiou, L.G. (1999), "Improving distributed intelligence in complex innovation systems", Final Report of the Advanced Science and Technology Policy Planning Network, Fraunhofer ISI, Karlsruhe.

Kuhlmann, S. and Rip, A. (2015), "The challenge of addressing grand challenges", in Von Schomberg, R. (Ed.), *The Future of Research and Innovation*, European Commission.

Kuhlmann, S., Shapira, P. and Smits, R. (2010), "Introduction. A systemic perspective: the innovation policy dance", in Smits, R., Kuhlmann, S. and Shapira, P. (Eds), *The Theory and Practice of Innovation Policy. An International Research Handbook*, Edward Elgar, Cheltenham, pp. 1-22.

Laudel, G. and Gläser, J. (2008), "From apprentice to colleague: the metamorphosis of early career researchers", *Higher Education*, Vol. 55, pp. 387-406.

Macnaghten, P., Owen, R., Stilgoe, J., Wynne, B., Azevedo, A., de Campos, A., Chilvers, J., Dagnino, R., di Giulio, G., Frow, E., Garvey, B., Groves, C., Hartley, S., Knobel, M., Kobayashi, E., Lehtonen, M., Lezaun, J., Mello, L., Monteiro, M., Pamplona da Costa, J., Rigolin, C., Rondani, B., Staykova, M., Taddei, R., Till, C., Tyfield, D., Wilford, S. and Velho, L. (2014), "Responsible innovation across borders: tensions, paradoxes and possibilities", *Journal of Responsible Innovation*, Vol. 1 No. 2, pp. 1-9.

Martin, B.R. (1995), "Foresight in science and technology", *Technology Analysis & Strategic Management*, Vol. 7 No. 2, pp. 139-168.

Owen, R., Bessant, J. and Heintz, M. (Eds) (2013a), *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society*, Wiley, Chichester.

Owen, R., Stilgoe, J., Macnaghten, P.H., Gorman, M., Fisher, E. and Guston, D. (2013b), "A framework for responsible innovation", in Owen, R., Bessant, J. and Heintz, M. (Eds.) (2013), *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society*. John Wiley and Sons.

RIF (2013), "Modular scenario report 'new ways of doing research: from explorative to transformative scenarios', deliverable 2.1 of the EU-FP7 Project Research and Innovation Futures 2030", available at: www.rif2030.eu/ (accessed 30 September 2014).

RIF (2014), "Strategic policy document on future scenarios for research a innovation policy, era development and grand challenges policies, deliverable 3.1 of the EU-FP7 project Research and Innovation Futures 2030", available at: www.rif2030.eu/ (accessed 30 September 2014).

Rip, A. (2009), "Futures of ELSA", *EMBO reports*, Vol. 10 No. 7, pp. 666-670.

Rip, A., Misa, T. and Schot, J.W. (1995), *Managing Technology in Society: The Approach of Constructive Technology Assessment*, Pinter Publishers, London.

Saritas, O. and Aylen, J. (2010), "Using scenarios for roadmapping: the case of clean production", *Technological Forecasting and Social Change*, Vol. 77 No. 7, pp. 1061-1075.

Shamir, R. (2008), "The age of responsibilization: on market embedded morality", *Economy and Society*, Vol. 37 No. 1, pp. 1-19.

Singer, P.A. and Daar, A.S. (2001), "Harnessing genomics and biotechnology to improve global health equity", *Science*, Vol. 294, pp. 87-89.

Smits, R., Kuhlmann, S. and Teubal, M. (2010), "A system-evolutionary approach for innovation policy", in Smits, R., Kuhlmann, S. and Shapira, P.h. (Eds), *The Theory and Practice of Innovation Policy*, Edward Elgar, Cheltenham, pp. 417-448.

Sondeijker, S. (2009), "Imagining sustainability: methodological building blocks for transition scenarios", PhD thesis, Rotterdam.

Sousa Santos, B. de Arriscado Nunes, J. and Meneses, M.P. (2008), "Introduction. Opening up the canon of knowledge and recognition of difference", *Another Knowledge is Possible. Beyond Northern Epistemologies*, Verso, London, pp. 1-62.

Stegmaier, P. (2009), "The rock 'n' roll of knowledge co-production", *EMBO Reports*, Vol. 10 No. 2, pp. 114-119.

Stilgoe, J. Owen, R. and Macnaghten, Ph. (2013), "Developing a framework for responsible innovation", *Research Policy*, Vol. 42 No. 9, pp. 1568-1580.

Swedlow, B. (2012), "Cultural coproduction of four states of knowledge", *Science, Technology, & Human Values*, Vol. 37 No. 3, pp. 151-179.

UNIDO (2005), *Technology Foresight Manual. Organization and Methods. Part 1*, United Nations Industrial Development Organization, Vienna.

Valkering, P., van der Brugge, R., Offermans, A. and Rijkens-Klomp, N. (2011), "Scenario analysis of perspective change to support climate adaptation: lessons from a pilot study on Dutch river management", *Regional Environmental Change*, Vol. 11 No. 2, pp. 229-241.

van Asselt, M.B.A., Mesman, J. and van't Klooster, S.A. (2007), "Dealing with prognostic uncertainty", *Futures*, Vol. 39 No. 6, pp. 669-684.

van Oudheusden, M. (2014), "Where are the politics in responsible innovation? European governance, technology assessments, and beyond", *Journal of Responsible Innovation*, Vol. 1 No. 1, pp. 67-86.

Von Schomberg, R. (2012), "Prospects for technology assessment in a framework of responsible research and innovation", in Dusseldorp, M. and Beecroft, R. (Eds), *Technikfolgen abschätzen lehren*, Springer, Berlin, pp. 39-61.

Von Schomberg, R. (2013), "A vision of responsible research and innovation", in Owen, R., Bessant, J. and Heintz, M. (Eds.), *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society*, Wiley, Chichester, pp. 51-74.

Walhout, B. and Kuhlmann, S. (2013), "In search of a governance framework for responsible research and innovation", *IEEE International Technology Management Conference & 19th ICE Conference*, 24-26 June, The Hague.

Wiek, A., Binder, C. and Scholz, R.W. (2006), "Functions of scenarios in transition processes", *Futures*, Vol. 38 No. 7, pp. 740-766.

Willinsky, J. (2006), *The Access Principle. The Case for Open Access to Research and Scholarship*, MIT Press, Cambridge, MA.

Further reading

Guston, D.H., Clark, W., Keating, T., Cash, D., Moser, S., Miller, C. and Powers, C.H. (2000), *Report of the Workshop on Boundary Organizations in Environmental Policy and Science*, Global Environmental Assessment Project Environment and Natural Resources Program, Environmental and Occupational Health Sciences Institute, Rutgers, the State University of New Jersey and the University of Medicine and Dentistry of New Jersey – Robert Wood Johnson Medical School, Cambridge, MA.

Hoppe, R. and Wesselink, A. (2014), "Comparing the role of boundary organizations in the governance of climate change in three EU member states", *Environmental Science & Policy*, Vol. 44, pp. 73-85.

Nelson, R.R. (2011), "The moon and the ghetto revisited", *Science and Public Policy*, Vol. 38, pp. 681-690.

Owen, R.P., Macnaghten, Ph. and Stilgoe, J. (2012), "Responsible research and innovation: from science in society to science for society, with society", *Science and Public Policy*, Vol. 39, pp. 751-760.

Ringland, G. (2010), "The role of scenarios in strategic foresight", *Technological Forecasting and Social Change*, Vol. 77 No. 9, pp. 1493-1498.

Rip, A. (2011), "Processes of technological innovation in context – and their modulation", *Futures of Science and Technology in Society*, IGS Institute for Innovation and Governance Studies, Enschede, pp. 53-79.

Rip, A. (2014), "The past and future of RRI", *Life Sciences, Society and Policy*, pp. 10-17.

Silberglitt, R. Hove, A. and Shulman, P. (2003), "Analysis of US energy scenarios: meta-scenarios, pathways and policy implications", *Technological Forecasting and Social Change*, Vol. 70 No. 4, pp. 297-315.

Slaughter, R. (2002), "From forecasting and scenarios to social construction: changing methodological paradigms in futures studies", *Foresight*, Vol. 4 No. 3, pp. 26-31.

Corresponding author

Ellen van Oost can be contacted at: e.c.j.vanoost@utwente.nl