PROJECT FINAL REPORT

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Table of content

1 Final publishable summary report

1.1 Executive summary

The RIF project aims to a) systematize knowledge on emerging patterns, trends and drivers of change in STI, b) provide an outlook on future developments in STI by way of transformative scenarios, c) identify and assess perspectives as well as potential for conflict and cooperation among stakeholders, and d) to identify key challenges to be addressed by policy if the overarching goals of a) moving towards more responsible modes of research and innovation (RRI), b) fostering the development of the European Research Area (ERA, and c) tackling Grand Challenges (GC) are to be achieved.

RIF focuses on the dynamics of change resulting from the interplay of developments within STI systems and in their societal context. It is based on the assumption that current trends and developments in STI are likely to give rise to tensions that need to be addressed if STI is to continue to play key role for society. These tensions may be tackled within the confines of current institutional settings, but may also require a substantial transformation of our STI systems as well as of our research and innovation practices.

Five such transformative scenarios have been developed in the RIF project, each sketching a different future image and rationale behind its dynamics:

- Scenario I: Open Research Platforms – self-governance in a networked decentralized research landscape
- Scenario II: Knowledge Parliaments – the free negotiation of knowledge claims world-wide
- Scenario III: Grand Challenges for Real – collective experimentation in socio-technical labs
- Scenario IV: Knowledge Value Chains – research for innovation in a specialized and stratified research landscape
- Scenario V: Researchers' Choice - autonomous researchers go for creativity and wellbeing

The analysis of the perspectives, strategic issues and strategic options of stakeholders allowed identifying six main themes around which joint agendas and action plans could be formulated. Based on an assessment of the scenarios from a European policy perspective, several policy challenges were identified in association with these six main themes; challenges that need to be tackled if the future development of STI practices and institutions is to be in line with the three overarching policy goals of RRI, ERA and GC. The policy challenges are structured in terms of the following six strategic policy packages:

- Towards science with and for society
- Research 3.0 careers - new competences and commitments
- A distributed and diversified research funding landscape
- IPR and open access of knowledge
- Towards the governance of science infrastructures 3.0
- EU and national policies on globalized R&I futures

1.2 Introduction - Project context and objectives

1.2.1 Context

The issue of knowledge dynamics and knowledge production in society has concerned social scientists for almost 50 years. Starting in the 1960s, it was concerned with the social consequences of the then prevailing "big science" model (de Solla Price, 1963; Ravetz, 1971). This debate gained new momentum in the 1990ies, when a number of new concepts were developed to capture the new relationship between science and society in the shaping of the dynamics of knowledge production. Among the most influential of these concepts are, e.g., 'Mode 2' of knowledge production, post-normal science or the triple helix concept (Funtowicz and Ravetz 1993; Gibbons, Limoges et al. 1994; Etzkowitz and Leydesdorff 2000). They have been looking for new patterns of knowledge production, but also for new ways to analyse the complexity of knowledge dynamics and the relationship of scientific knowledge production with other forms of knowledge production in society. These concepts allowed also reflecting on the status of different forms of knowledge production and their relation to the context of application.

Similar developments could be observed with regard to innovation, where system concepts stressed the importance of collaboration between science, industry and society for creating novel solutions (Smits, Kuhlmann and Shapira 2010). More recently, the role of users and competitors in innovation has attracted much attention, giving rise to concepts such as open innovation, open science, collective experimentation, or innovation communities (Gangy and Wasko, 2009; Chesbrough 2003; Joly, Rip et al. 2010). This new openness competes with interests to protect intellectual property.

In parallel to academic debates, knowledge production in society has also been changing in practice. Participatory models of decision-making have become more prominent in many countries since then, aiming to bring considerations of societal relevance more prominently to the fore, alongside with scientific validity, up to the point of regarding science as a commodity (Gibbons and Wittrock, 1985).

While these debates on the general relationship between science and society have continued and have seen ups and downs over the past decades, we can see first of all a growing attention to the blurring boundaries between and the mutual influence of external drivers of science and internal dynamics in the scientific fields. As an example, the role of future-orientation in the form of promises, concerns and expectation dynamics in science and society as affecting STI has been increasingly recognised (Borup et al., 2006), and the convergence of expectations is crucial for achieving 'mutual reflexivity' in the cooperation of scientists, social scientists/humanities scholars, engineers and societal stakeholders (Rip 2009) and in the cooperation within the wider actor network involved in science, technology and innovation (STI). Secondly, there is growing attention paid to the consequences for the institutional foundations of science and research (Geuna, 1999; Van Looy, Ranga et al. 2004). For instance, the entire debate about the re-organisation of universities, their autonomy and novel forms of monitoring university performance gives evidence of the pertinence of these debates.

The practical relevance of these debates is also mirrored in the intensity of current debates about the directions along the lines of which STI systems and organisations should evolve in the future. The controversial nature of these debates can also be observed in European policy debates. Whereas the early years of the millennium saw a strong emphasis on scientific excellence, the prominence of the notion of Grand Challenges in the recent debates about the Innovation Union Flagship Initiative foreshadows the need for a re-positioning of the role of science for society, with inevitable institutional consequences for research funding, priority-setting and new collaborative models between science, society and industry. This

process of change will take place against the background of the still ongoing construction of the European Research Area that is changing the landscape of funding and performing research.

Taken together, these developments that have emerged over the past decades and have been re-invigorated in recent years both by developments within STI and by a changing socio-political context are likely to give rise to major tensions and changes in our STI systems. The focal issue of the RIF project has been to explore whether these developments and tensions can be absorbed within the existing institutional regime of knowledge production or whether a more fundamental transformation of our institutional set-up will be needed. To explore this issue, the best available academic and forward-looking expertise have been mobilized, as well as the perspectives of the stakeholders that could possibly be affected by such transformation.

1.2.2 Objectives

The project RIF – Research and Innovation Futures 2030 deals with future developments in our ways of doing and organizing research. More specifically, it pursues the following main objectives:

1. *Systematize knowledge of the emerging patterns, trends and drivers of change of ways of doing and organising research in our knowledge societies.*
2. *Develop medium-term explorative scenarios of possible future models of doing and organising research in our knowledge societies at a time horizon 2020*
3. *Anticipate and assess possible challenges and tensions resulting from these scenarios*
4. *Develop long-term transformative scenarios of alternative development paths of the way we will do and organize research and innovation in our societies at a time horizon of about 2030*
5. *Identify policy issues and strategic options for the actors and stakeholders affected, as resulting from the two types of scenarios*

Create an open debate between different communities contributing to knowledge dynamics from their respective perspectives and explore room for joint action.

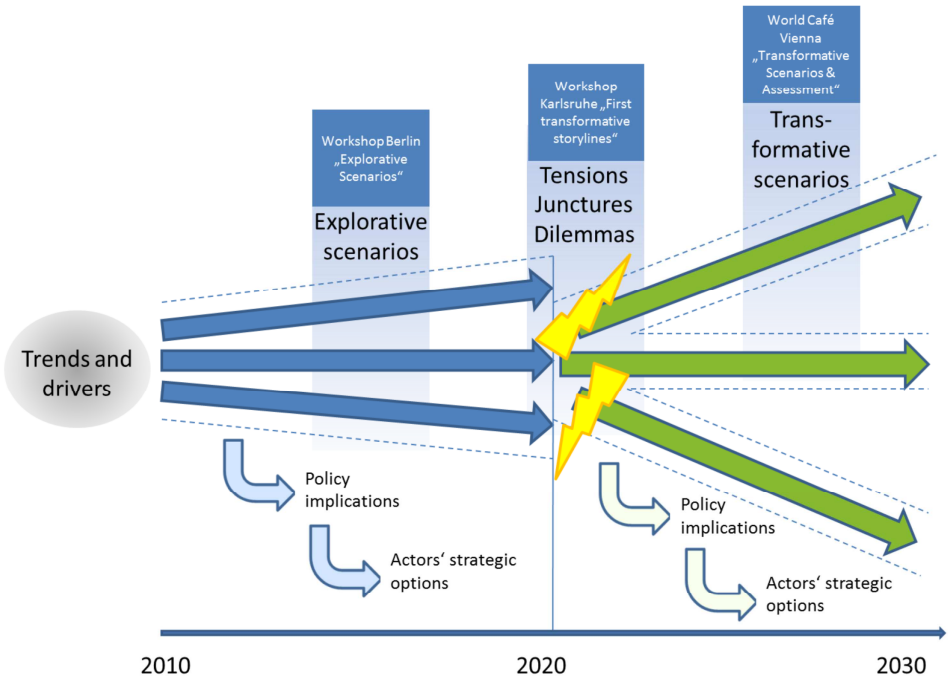
1.2.3 Approach and methodology

In order to reach these objectives, we build on a conceptual framework for analysing transformative change in science and research which is based on a multi-level perspective that distinguishes between actual changes in a) research practices, b) institutional settings for organizing research, and c) the societal context, in which science and research are embedded, and which raises requirements with regard to what science and research are supposed to deliver.

In methodological terms, the RIF project takes a comprehensive stocktaking of forward-looking activities from Europe and worldwide, and an analysis of the most recent findings from academic research as its starting points. This serves as the basis for a two-stage participatory scenario development process, involving experts and stakeholders in science and research. Current and emerging trends provide the basis for sketching explorative scenarios in the mid-term (i.e. in our case 2020), and in particular tensions that are likely to emerge if current trends continue to unfold. In a second stage of scenario development these tensions are taking as a starting point for identifying possible triggers and mechanisms that could drive processes of more radical change in the longer term (i.e. 2030), which then are elaborated further into transformative scenarios. These transformative scenarios thus go beyond sketching future images, and look

also into the transformative dynamics and pathways, and the actor constellations and positions that would be compatible with the transformations explored.

Figure 1: From trends and drivers to transformative scenarios



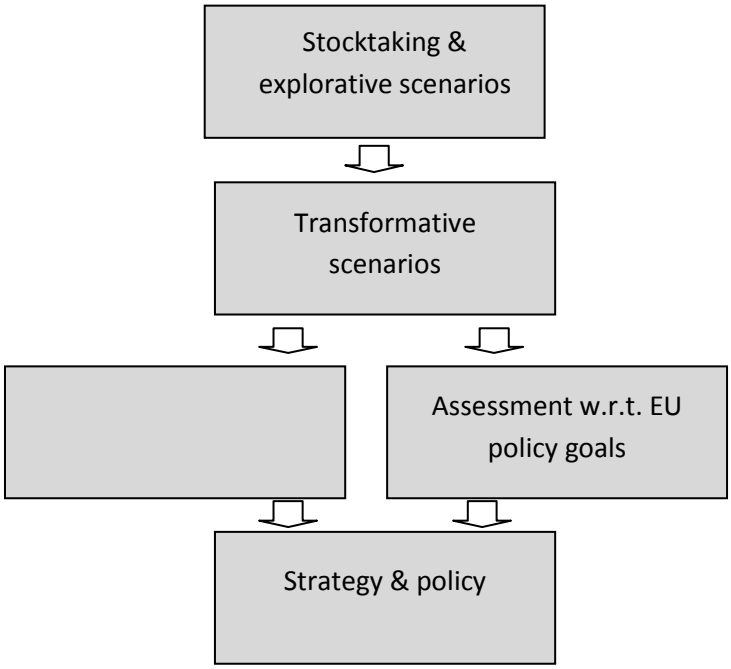
The transformative scenarios represent first of all the basis for the analysis of actor positions and possible strategic issues with regard to which coherence as well as conflict is possible among the different stakeholders. The normative dimension of scenario development is thus not addressed for a scenario as a whole (i.e. in terms of an overall assessment along different dimensions), but from the perspective of the different stakeholders who may regard some scenarios (or specific features of them) more desirable than others. This approach delivers a matrix of strategic issues around which negotiation processes may be needed to agree either on joint actions or on ways of handling potential conflicts.

As a second normative element, the transformative scenarios are also assessed from the perspective of major European policy goals, namely those related to (a) Responsible Research and Innovation (RRI), (b) European Research Area (ERA), and (c) Grand Challenges (GC). Issues for government policy in particular can be extracted from this analysis by contrasting the current situation with the necessity to prepare for a range of possible transformative futures.

In operational terms, and in line with the creative nature of the entire process, the methodology relies on a series of participatory workshops involving stakeholders from different realms. A certain degree of continuity of participants was sought (and achieved), but balanced with the integration of some newcomers at each workshop.

More specifically, the methodology developed proceeds along five main phases, namely a stocktaking and explorative phase, a phase of developing transformative scenarios, a phase of exploring stakeholder perspective, a phase of assessing the transformative scenarios in the light of European policy goals, and a phase of developing insights for strategy and policy:

Figure 2: Overview of RIF methodology



Phase I: Stocktaking and explorative scenarios

- The initial **stocktaking of current trends and developments** serves the purpose of providing the most up-to-date information on ongoing changes in practices and context developments by analysing foresight documents and scientific literature. It feeds into a process of
- **explorative scenario development and the identification of medium-term tensions**. The key point behind this approach is that we expect tensions to arise from the extrapolation of current trends. Hypes are often based on the simple extrapolation of currently novel developments, but as soon as they are superposed by other (extrapolated) trends, contradictions, tensions and other limiting factors are likely to arise. Such tensions, so we argue, can be interpreted as productive forces that may give rise to transformative scenarios.

Phase II: Transformative scenarios

- Moving **from tensions to transformative scenarios** is based on argument that the tensions serve as triggers that lead to a search for alternative pathways, including radical ones. Continuing along the lines of ongoing trends is not possible any more. Often specific triggering events may lead to the unfolding of new mechanisms of change, and ultimately to the emergence of transformative scenarios. Key to imagining transformative scenarios are plausible self-reinforcing mechanisms that enhance the dynamics of change. These transformative storylines are at the heart of the longer-

term scenarios, which taken together, should ensure that the scenario space is sufficiently stretched to speak of radically transformative change processes, affecting all three levels of analysis considered, i.e. specific practices, organisational and institutional frames, and even the embedding of the phenomenon studied in society.

Phase III: Stakeholder perspectives

The challenge of this third phase consists of the anticipation of stakeholder positions and assessments in a context that is radically different from today's. It is well known that it is difficult to make participants and stakeholders in a participatory workshop think about radically different worlds, but it was crucial to achieve this as part of our methodology.

- As a first step, participants were asked to specify their respective **stakeholder positions** with regard to the different scenarios, i.e. to identify advantages and disadvantages that these scenarios might bring about for them. This approach implies that the diversity of stakeholder positions is taken seriously; there is no overall assessment of the desirability or undesirability of scenarios made, but each stakeholder groups (i.e. in our work science, industry, policy, society) could formulate its respective perspectives and arguments. In particular in qualitatively different scenarios, it would be pretty useless to develop overall scenario assessments; a much more differentiated picture is needed to give justice to the diversity of openness of future perspectives; up to the point of imaging new stakeholders that are currently not yet affected by developments in the science and research system. Accepting this diversity of stakeholder perspective is more useful.
- The next step consisted of **extracting and assessing strategic issues and options** from the stakeholders' perspective, i.e. issues around which they can make choices in each scenario, as well as the options associated to these issues that are available to each stakeholder. The main "issues" tend to be similar in all or most scenarios, but the options, and in particular the preferred options are likely to differ, as reflected in the stakeholder-specific assessment of options. The options available to a stakeholder for addressing a specific issue need to be assessed across scenarios. Given the high degree of diversity of options in transformative scenarios, it is quite difficult to find "robust" options for a stakeholder, i.e. options that would work out reasonably well across different scenarios. Adaptive options that are specific to some scenarios are more frequent.

Phase IV: Assessment of transformative scenarios with regard to European policy goals

In parallel to Phase III, a normative stance was taken in order to assess how the different transformative scenarios relate to over-arching policy goals, in particular those defined at European level. In the RIF project, three such goals have been stressed: (a) the strengthening of a more responsible mode of conducting research and innovation (RRI)[1]; (b) the development of an efficient, effective and well-

[1] According to von Schomberg (2011), Responsible Research and Innovation (RRI) can be defined as *"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)"*.

resourced European Research Area (ERA); (c) the ability to address different types of Grand Challenges (GC).

In methodological terms, the following steps were pursued:

- An analysis of the **implications that the different transformative scenarios** raise with regard to a number of core dimensions likely to be relevant to the three aforementioned policy goals.
- This analysis forms the basis for a more focused **assessment of the scenarios with regard to the three European policy goals**, captured in terms of opportunities, limitations and strategic policy options at European level that the scenarios raise respectively.
- In order to complement the single-scenario assessment, a **cross-scenario analysis** has been conducted in order to identify strategic policy concerns in a robust manner, i.e. taking into account that different scenarios might be realized.

Phase V: Strategy and Policy

While the preceding steps of Phase 3 and 4 were focusing on individual stakeholders' perspectives and the perspectives from a European policy angle, Phase 5 concentrates on strategic considerations of two kinds. First all, the stakeholder-specific options were analysed whether they offer the possibility to be made compatible with those of other stakeholders or not, i.e. whether there is scope for collaboration and/or conflict. This analysis also allows highlighting those issues that – from a cross-scenario perspective – appear to be most important to tackle in the future. The kinds of feasibility considerations are essential, if any of the scenarios is supposed to be realised. Second, the European policy perspective points to areas where policy action is needed, bother related to the issues highlighted in the stakeholder analysis and specifically with a view to ensuring that we move towards achieving the European policy goals associated to R&I. In concrete terms, the following steps were made:

- the **compatibility analysis of options** to point to issues on which cooperation is possible, or conflict likely. Conflict-prone matters will then require negotiations, trade-offs or policy choices to be made if the corresponding scenarios is to be realized.
- On this basis, **strategies of cooperation and conflict** were sketched for each scenario as well as across scenarios. The cooperative options were identified and possible coalitions of interest sketched for each transformative scenario. But also likely conflict lines were identified. Overall, this delivered packages of strategic options for each scenario, as seen from the stakeholder perspective. At a meta-level, it is possible to add some cross-scenario considerations regarding strategy, for instance along the lines of robust and adaptive strategies.
- While the assessment of the individual transformative scenarios has delivered a comparative assessment, the cross-scenario analysis allows pointing out robust as well as flexible or adaptive elements of a future R&I policy strategy that aims to balance the goal-oriented transformation of R&I practices and systems with the need to respect the inherent openness of the future of R&I. This leads to the formulation of six "robust" packages for strategic policy action, as well as some flexible options that take care of specific risks and opportunities in individual scenarios.

In this sense, the methodology sketched here elaborates on earlier attempts of adaptive foresight methodologies (Eriksson and Weber 2008), but here more attention is paid to the elaboration of how to

deal with specific options of individual stakeholders or stakeholder groups in a context of rather extreme scenarios in scenario space.

1.3 Project synthesis – main S&T results

1.3.1 Dimensions of change and emerging tensions

A cross-cutting analysis of secondary sources material collected led to the identification of the following key dimensions of change in ways of doing research as documented in the stocktaking report D1.1. Each dimension is underpinned by a number of more specific issues of change, expressed in terms of trends and emerging developments: As a result of the analysis of current trends and developments, six main dimensions of change could be identified, each underpinned by a number of more specific issues of change (Schaper-Rinkel et al. 2013):

Digitalization & Virtualization: Digital Science, Research 2.0
Digital technology makes codified information accessible worldwide and changes how knowledge is created, accumulated and disseminated. Science 2.0, also named e-science or cyber science is characterized by the crucial role of interactivity and the future quality of data and information. The trend towards science 2.0 includes changing practices in the lab, for instance the online availability of data through Open Notebook Science and it leads to new methods of developing hypothesis ("data-driven research). New research practices and methodologies are arising in many areas and are triggered by different drivers. For example the further development of interactive ICT web based tools calls for a huge set of new research practices and methodologies on different levels (cf. Shneiderman 2008; Williams 2008; Giles 2012). Practices of publishing scientific results are no longer only paper-based but include multimedia (cf.Breivik, Hovland et al. 2009) and take in new ways of fast (pre)publishing and fast feedback (cf. Mandavilli 2011). New practices and methodologies point towards an aggregated level of new types of doing research. This could include for example new ways of collaboration in research (e.g. science-industry relations, strategic research), but also new arrangements due to the integration of huge data sets as in data-driven research (cf. Burgelman and Osimo 2011; ICSU 2011).

Science 2.0 raises questions that go far beyond the sphere of the individual lab or research field. Research and investment is needed to increase fundamental understanding of the technologies needed to manage the massive amount of information and to apply this knowledge to other scientific fields. Science policy initiatives started to support the development of infrastructures to curate, manage, and serve data to different communities. As an increasing amount of data travels across organisational and national boundaries as well as across the boundaries of academia, society, and industry, policy issues such as access, privacy, security, quality, intellectual property, and liability will become increasingly important.

Research is interactive and increasingly organized by using digital science infrastructures. The digitalization of research is captured in terms such as science 2.0 and cyberscience and includes new methods (eg. data-driven research), changing practices in the lab such as online availability of data through Open Notebook Science and international efforts to increase the utilization of big data Digital science is triggered by the trend of distributed data collection and sharing, and related participatory sensing. Not only the practices to conduct research, but also the practices of publishing are changing: Instead of being limited to paper, scientific results are enriched by embedded multimedia content. Scientists use new channels for

distributing scientific literature and they use new ways of communicating research for example by blogging. Digital science tools are tools that foster interaction among researchers at universities, public research institutions, and private businesses and therefore play a major role in the re-contextualization of science in society. The flow of digital data simplifies and supports the increasing interactions between organisations in the national and international research systems and the related tools enable ad hoc interaction and participation as well as more institutionalized coordination and cooperation.

Collaboration& participation: New ways of collaboratively doing & organizing research
Collaboration and cooperation in research are seen as 'a good thing' that should be encouraged (Katz and Martin 1997) and that has become the norm. National and European policies aim at improving the links between science and technology through supporting research collaboration across sectors especially between academia and industry. Furthermore, the governance of science aims at increasing the level of international collaboration. Increasing collaboration in research is still a common trend although its processes and forms are changing. In the context of national innovation policies there is a trend toward the institutionalization of collaborative processes and practices in formal organisational structures (Turpin and Fernández-Esquinas 2011). On the other hand there is a trend toward informal 'bottom-up' cooperation of individual researchers for example by using Web 2.0 tools.

Research collaboration also involves stakeholders to different degrees, e.g. patients in medical research or volunteers in conservation research. One issue of change is therefore the expansion of citizen science. Beside traditional projects that are designed by scientists involving members of the public primarily in contributing data, there are also co-created projects designed by scientists and members of the public. Similar developments can be observed with regard to the diversification of patient participation, e.g. when patients are not only 'partners in research' but also co-researchers.

Recently it has been shown that the use of journal rankings can suppress forms of interdisciplinary collaboration that are acknowledged to be highly important (Rafols, Leydesdorff et al. 2012). These assessment regimes may also hinder transdisciplinary research that is important for tackling Grand Challenges. Research assessment and its specific incentives may also hinder the development of open systems for the dissemination of academic knowledge such as Wikipedia. At the same time new forms of collaboration between researchers relying on the use of Wikipedia emerge: peer review journal papers are combined with Wikipedia through replicating the peer reviewed content.

New actors enter the research arena and foster cross-sectoral research collaboration: e.g. intermediary organisations and networks in science-industry relationships. This kind of cross-sectoral collaboration requires new forms of organizing research projects, e.g. research alliances and joint research activities, and is driven by the growing commercialisation of academic research and universities.

Access: Access to research data, funding, infrastructure, results, benefits, and careers
The access to research data, funding, infrastructure, results, benefits, and careers is contested. Initiatives that aim at enabling open science and open research get increasing support from governments at the same time private enterprises (such as Thomson Reuters) are the basis of research assessment. The practices in realizing openness in science become diverse and despite the many visions of open access, the access to scientific literature is unstable, especially in poorer regions were access is organized through public-private partnerships.

Many initiatives aim at defining and coordinating policies on access to scientific information and preservation of scientific information. The European Commission plans to adopt a communication and a recommendation on this subject soon (European Commission 2012). The UK Research Councils established a new Open Access policy that includes that peer reviewed research papers which result from research that is funded by the Research Councils must be published in journals which are compliant with Research Council policy on Open Access. These policies will transform the traditional publication system by shifting the costs to authors ("pay to publish").The access of women to careers in research is still limited. The European Commission recently stated that "European research still suffers from a considerable loss and inefficient use of highly skilled women" (European Commission 2012). One indicator is that the annual increase in women researchers is less than half the annual number of women PhD graduates. Access to leadership positions is also limited, asin2009 only13% of the heads of higher education institutions were women (European Commission 2012).

The concept of benefit sharing, i.e. a systematic approach for access to research benefits, is specific to research using genetic resources. There, the question of how to provide "fair benefits to various stakeholders involved in research" (Lairumbi, Parker et al. 2012) was addressed and led to a debate on how to prevent exploitation in various research contexts. This concept is still challenged by a lack of related policy measures regulating the sharing of benefits. Access to financial resources is further explored for the academic perspective, when addressing changes in the funding of universities.

Impact: Assessment, public accountability & tackling grand challenges
Regarding the impact of research, the initial research objectives describe a basis for the assessment of research results. Current trends show that research goals are increasingly oriented toward grand challenges and societal issues. In this context research cooperation is mainly initiated and organized through establishing interdisciplinary research fields. Funding is attracted under the paradigm of foundational breakthrough research to overcome mainstream-oriented research that stays within disciplinary boundaries.

Though new forms and ways of thinking in research funding have emerged, the use of bibliometric indicators for research assessment is still increasing. More and more the limits of traditional assessment regimes, e.g. the endangerment of research diversity in social science and humanities, are recognized and new tendencies as well as refinement approaches to the traditional assessment mechanisms appear. A recent trend fosters the scientification of higher arts education in the form of artistic research.

A general dissatisfaction among scientists with the idea of impact assessment drives the debate on impact assessment of research. Who should count as peer when it comes to assessing the impact of science on society is a central question.

Globalisation & internationalisation: Global scientist, global research and international cooperation
Science is influenced by internationalisation and globalisation; researchers are driven by globalisation and their global cooperation is also a driver of further globalisation. Researchers have been both enabled and motivated to work across national borders by technological developments and shifts in geopolitics. Science has always pushed boundaries, so that the globalisation of research is also nothing new. Today there are many different trends and drivers that lead to the trend of globalisation of science and research. Processes of internationalisation and globalisation occur within a scientific landscape that includes many of political, technological, infrastructural, social, and economic drivers affecting structures, patterns and trends in

research collaboration. The globalisation of research is seen as a process in terms of transnational research collaboration agreements, shared resources, joint activities, migration of researchers and flows and exchanges of knowledge and skills (The Royal Society 2011; Tijssen, Waltman et al. 2012). Globalisation of research is related to the access to research literature. “The spread of access to academic journals across the world is a key factor in the globalisation of research.” (The Royal Society 2011).

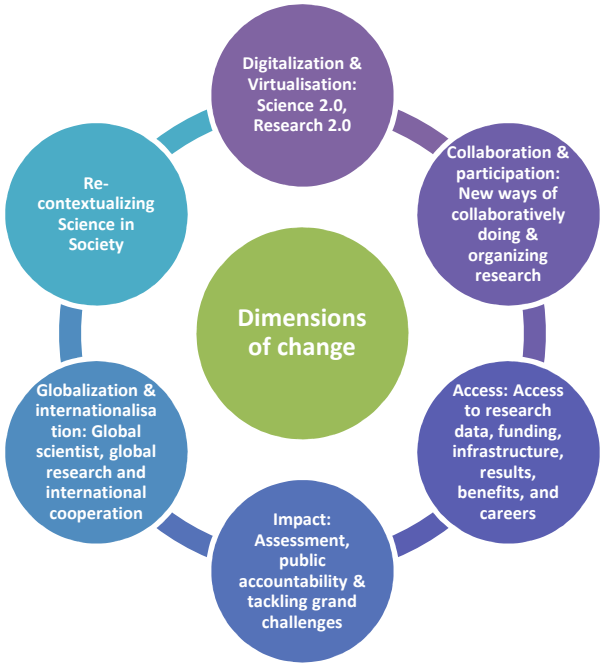
Within the area of science, internationalisation and globalisation is depicted and measured in different ways. The different dimensions of globalisation and internationalisation point moreover to a variety of different phenomena connected with the global flow of data, trans-border cooperation of institutions and researchers, and international mobility of researchers. Globalisation of research can be distinguished for instance by the percentage of the research effort performed outside the country of origin of the multinational companies (MNC), the geographical spread of the multinational companies’ research facilities, and the existence of international research facilities with distinctive capabilities and significant roles in the overall technology strategy of multinational companies. The growth and importance of cross border technological alliances in the research strategy of firms, and the existence of an international division of labour in research and the degree of integration and coordination of a MNC’s international research effort are additional dimensions of internationalisation and globalisation(c.f. for the pharmaceutical industry: Ramirez 2006).

Re-contextualizing Science in Society

The ways of doing and organizing scientific research, the practices of science and its institutions become increasingly re-contextualised in society. Science is seen as being currently re-contextualized in society (Siune, Markus et al. 2009; Rip 2011) while the reconfigurations of science are characterized by high interdependencies between politics and science (Barben 2007). Science is expected to play a key role in society's response to emerging global grand challenges over the coming decades (ICSU 2011; The Royal Society 2011; Keenan, Cutler et al. 2012). The ways how agenda-setting and the conduct of science will be organized and how results of scientific research will be disseminated and used are therefore critical. How these issues will be framed at a societal level and at a global level is yet unknown and disputed.

Contrary to the perception of growing importance of science to tackle grand challenges, some observers see alarming signals with regard to paradoxical features of contemporary science, stating the “contradiction between the essential integrity and impartiality of the research community, and its involvement with vested interests of the State and commerce on policy issues, threatens to destroy public trust, with potentially grave consequences” (Ravetz 2011). Traditional authorities are being questioned (Bijker, Bal et al. 2009) and the mechanism is changing from giving authority to earning authority over and over again (Hanssen 2011).As a consequence the classic science career is losing its attractiveness (Newsome 2012), which still especially impacts the position of women (and minorities) in science and engineering.

Figure 3: Dimensions of Change identified in the RIF Stocktaking



From tensions to explorative scenarios

The explorative scenario stage was based on the assumption that ongoing developments will give rise to tensions and dilemmas in research and innovation if current institutional settings are still in place in the mid-term. The analysis of such ongoing developments in the stocktaking delivered a first set of such tensions, which are likely to emerge by 2020. In the explorative scenarios, these tensions were then condensed into five main topics that were subsequently taken up for the transformative scenario development (Erdmann et al. 2013; Schaper-Rinkel et al. 2012):

1. The coordination of research and innovation is complicated by the increasing fragmentation of the research and innovation landscape and by conflicting actor strategies.
    - Tension between research collaboration and competition for research funding
    - Tensions between actors' interests within STI systems
    - Tension between short-term project-orientation versus long-term development of new forms of research

    → Topic: Recontextualisation of science meets the new governance of science

2. A worldwide struggle breaks out between scientific expert knowledge and other forms of knowledge, such as traditional or lay knowledge, competing for credibility, legitimacy, and funding.
    - Tension between epistemic cultures in providing knowledge for decision-making
    - Tension between abundance of scientific information versus shortage of individually manageable and reliable information
    - Tension between diversity and uniformity in research

    → Main Topic: Expertise and contestation (and research integrity)

3. Societal unease grows about the failure of conventional research and innovation programs to address pressing societal challenges effectively.
    - Tension between scientific excellence that is associated with value-free, curiosity-driven research versus research that is relevant to contributing to societal needs
    - Tension between research efficiency and targeting foundational breakthroughs in research
    - Tension between diversity in research and quality standards

    → Main Topic: Struggles for excellence and promising high tech

4. Economic pressure on research-performing organisations intensifies due to requirements for fund raising and evaluation as well as stiff competition for limited research funds.
    - Tension between open science versus commodification of research

    → Main Topic: Private sector research and public-private collaboration and coordination

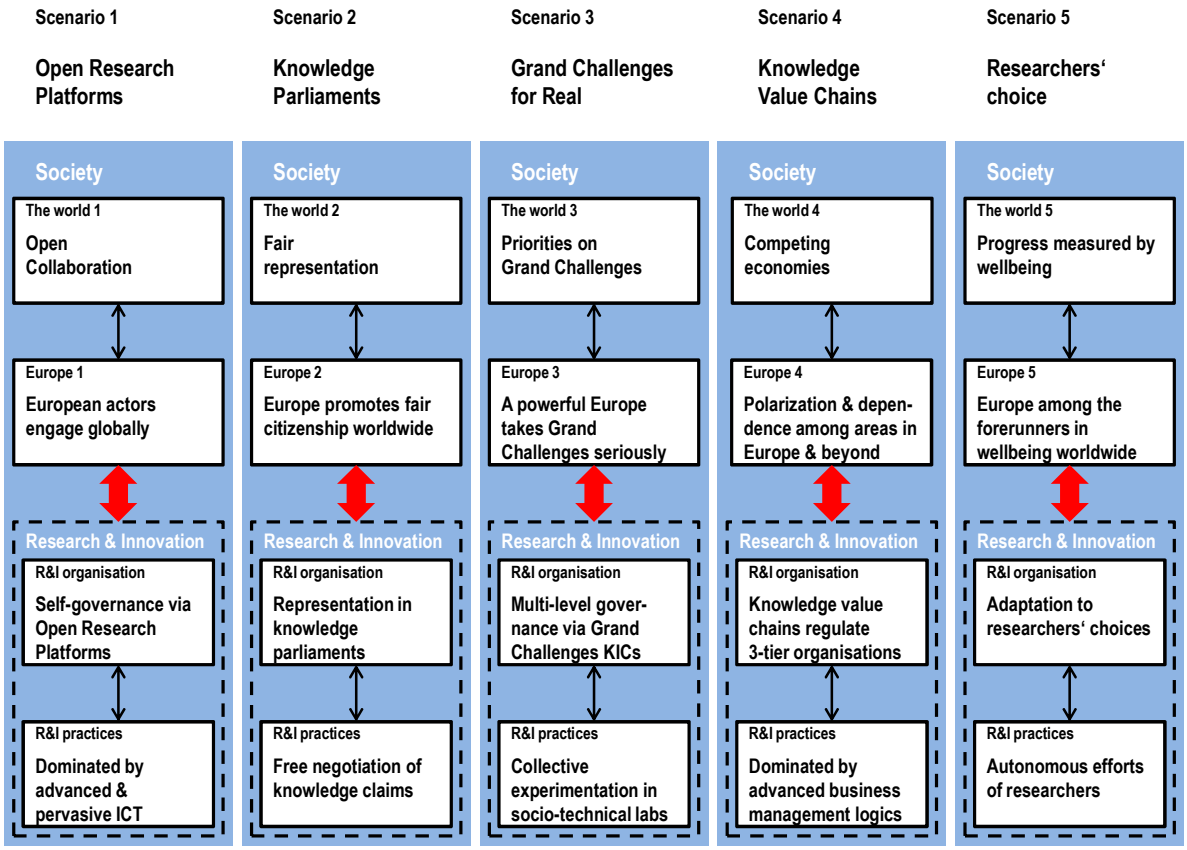
5. The attractiveness of usual academic careers declines because of conflicting demands on individual researchers from different directions eventually leading to identity crisis.
    - Tension between collaborative research versus individual incentives

    → Main Topic: Research careers and reproduction of scientific communities

1.3.2 From explorative to transformative scenarios – an overview

Based on the explorative scenarios and the associated main topics and tensions, the transformative scenarios were developed to describe different R&I futures nested in different futures of Europe and the world by 2030. The tensions and dilemmas of 2020 are overcome at large by the transformation of the R&I system into a new configuration in 2030. However, the transformed R&I organization and practices face new tensions and dilemmas in 2030. Figure 4 shows the composition of R&I futures and their embedding in global and European contexts for each of the five scenarios in terms.

Figure 4: The set of five nested scenarios for Research and Innovation futures 2030 (Source: RIF)



Note: ICT – Information and Communication Technology, KIC – Knowledge and Innovation Community, R&I – Research and Innovation

Scenario 1: "Open Research Platforms" (ORPs) - *self-governance in a networked decentralized research landscape*

The first scenario Open Research Platforms described a research and innovation 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" (ORPs), 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. The main features of the scenario are presented in the following table.

Table 1: Main features of Scenario 1: "Open Research Platforms" (ORPs)

Explorative scenario	**≈ 2020: R&I landscape fragmented: research performed & accessed nearly free by everyone. Govt coordination of research agendas toward a mission questioned**
Conditions of change	• Global cooperation & open knowledge sharing grow rapidly in a still dominant "close science" system • The R&I landscape is complex and fragmented, composed by loosely articulated actors with conflicting interests and strategies. Government coordination is difficult • Demand to tackle "Grand Challenges" increases while confidence on government capabilities to deliver solutions centrally decreases
Core tensions	A hardly understood infectious disease emergency case calls for a concerted global effort of researchers as government R&I coordination fails
Transformative scenario	**≈ 2030: R&I following principles of self-governed Open Research Platforms (ORPs)**
Triggers & transformation	•An open wiki platform enables a new path to tackle the infectious disease collaboratively. It serves as a model for the scientific community to work on future research problems •Governments, universities, RTOs, industry and CSOs promote the development of self-governed-problem-oriented-bottom-up ORPs •Risk of fraud and information pollution intensifies •New, tailored open IPR regimes emerge
Outcomes	ORPs provide a new powerful mechanism to solve particular problems in an open, bottom-up and collaborative manner

Scenario 2: "Knowledge parliaments" (KPs) – *the free negotiation of knowledge claims world-wide*

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 so-called 'knowledge parliaments'. 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.

Table 2: Main features of Scenario 2: "Knowledge Parliaments" (KPs)

scenario	
Conditions of change	Inspiration & innovation from non-conventional K domains Epistemological wealth of regions & people defended globally against unlimited exploitation Increasing significance of non-European funding agencies
Core tensions	Worldwide redistribution struggle between "conventional" scientific & non-conventional types of knowledge (lay, indigenous) Despite Responsible R&I in Europe, corporatist dominance and participation procedures too rigid & inflexible
Transformative scenario	**≈ 2030: a new science-in-society deal**
Triggers & transformation	Struggles between Responsible R&I and conventional science in established fora lead to split communities "Fair knowledge" movements linking up to allies across the world
Outcomes	Knowledge parliaments evolve into a new governance model for socially accountable science in society Increased role of civil society in setting R&I projects on societal issues A global research landscape with plurality of knowledges, IPRs & research styles reshaped

Scenario 3: "Grand Challenges for real" (GC-KICs) – collective experimentation in socio-technical labs

The third 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 Knowledge and Innovation Communities (GC-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.

Table 3: Main features of Scenario 3: "Grand Challenges for real" (GC-KICs)

Explorative scenariol	**≈ 2020: EU Research "Grand Challenges as Grand Opportunities"**
Conditions of change	Global move towards challenge-driven research opens up major economic opportunities KICs approach as organisational model for R&I&E Global shift in funding of R&D for GC solutions
Core tensions	EU GC research fails to deliver; Global level GC research dominated by new players (China) and downplays EU industry interests
Transformative scenario	**≈ 2030: EU knowledge and innovation communities focus on collective experimentation, offering real solutions**
Triggers & transformation	Growing claims to take GC seriously and involve citizens in R&I, in response to KICs' failure to deliver solutions Emergence of organised learning processes involving technology as well as social practices – collective experimentation Re-framing of KICs towards collective experimentation
Outcomes	European R&I organised around 12 GC-KICs wopening-up to new actors, SS&H, & new experimental forms; Socio-technical labs as main instruments for learning about effective solutions Each KIC oversees a number of regional and local labs

Scenario 4: "Knowledge Value Chains" (KVCs) – research for innovation in a specialized and stratified research landscape

In this scenario research and innovation 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 innovation. Research is carried out in "Knowledge Value Chains" (KVCs) 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 research and innovation.

Table 4: Main features of Scenario 4: "Knowledge Value Chains" (KVCs)

scenario	
Conditions of change	New Public Management" (NPM) is reinforced worldwide to evaluate and govern the ever more fragmented research and innovation (R&I) landscape, and fewer but larger projects are funded. The global race for technological innovation leadership is accelerating further.
Core tensions	A boost in efforts for fund raising & evaluation and stiff competition for limited research funds increasingly put pressure on Research-Performing Organisations (RPOs).
Transformative scenario	≈ 2030: a new science-in-society deal
Triggers & transformation	Consultancy-led (and similar) consortia prove their strengths in efficient research management in an EU R&I program on electromobility. Specialized consultancies, businesses and RTOs take leadership in running large-scale complex "projects that deliver" efficiently.
Outcomes	RPOs specialise and stratify, operating in three-tiered Knowledge Value Chains (KVCs): 1. Research Integrating Organisations (RIO), 2. Research Service Organisations (RSO) and 3. Third-tier providers of fragmented research contributions.KVCs rationalize research by applying business management principles, and continuously direct research towards innovation in close cooperation with industry. Governments worldwide support their industry and RPOs to play an active role in the globally operating KVCs.

Scenario 5: "Researchers' choice" (RCs) - autonomous researchers go for creativity and wellbeing

Autonomous researchers that go for creativity and wellbeing are the drivers of this scenario. Society is characterized by highly individualistic values and strong emphasis on individual wellbeing, autonomy and creativity. Autonomous 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.

Table 5: Main features of Scenario 5: "Researchers' Choice" (RC)

Explorative scenario	**≈ 2020: academic research under pressure**
Conditions of change	•Increasing competition in the academia for funding and tenured positions •Declining societal reputation of scientists •Creativity and autonomy are increasingly valued by young academics, as well as a good work-life balance
Core tensions	(Young) researchers increasingly leave the academia and look for jobs outside academia
Transformative scenario	**≈ 2030: autonomous researchers go for wellbeing and creativity**
Triggers & transformation	•New orientations of scientists beyond established institutions: small scale and individual research practices flourish: slow science, science entrepreneurship •Social web and open data allow for global networks and science practices and collaborations •Slow scientists, part of global slow science movement, create new alliances with local actors (citizen groups, local SME's, local government) aiming the strengthen wellbeing (in a broad sense)
Outcomes	•Networked autonomous researchers transform the research landscape •Quality of life and creativity is seen more important then traditional career paths •They offer their research skills and academic knowledge on various different research markets and develop new earning models (e.g., fee per download)

Complementarity of scenarios

A closer look across all the scenarios suggests that each scenario may represent a partial picture of how the future research landscape may look like and that some of them can well co-exist as they as highly complementary to each other. For instance, "Open Research Platforms" (sc. 1) and "Grand Challenges for Real" (sc. 3) are variants focusing on different ways for addressing societal challenges by way of research. At the same time, scenario "Knowledge Value Chains" (sc. 4) represents the industry-oriented part of future research which may or may not be directed towards grand challenges. Thus, scenarios 3 and 4 could well co-exist together.

The scenario "Researchers' Choice" on the other hand, reflects the quality and mobilization concerns of researchers from an individual perspective, and thus an important bottom-up component of the future of research. This is also in line with the features of "Open Research Platforms". "Knowledge Parliaments" could also be considered complementary to "Open Research Platforms" as regards the way research agendas are set. It becomes evident that the way ahead probably lies in an intelligent combination of them.

1.3.3 Stakeholder perspectives on the transformative scenarios

If we want certain developments to occur, we need to know what stakeholders and actors think about alternative futures, and how they would position themselves. In one regard, this is a normative question because it reflects the desirability of the different scenarios from the stakeholders' points of view, but at the same time it is an important matter for the expected feasibility of the scenarios. In the end, actors and stakeholders determine with their choices, decisions and actions what shape the future of R&I will take. If contradictory or conflict-prone positions are taken, a scenario is unlikely to materialize, whereas is may easily unfold if stakeholders' perspectives converge and give rise to cooperative strategies.

In order to move towards a better understanding of stakeholder perspectives, the strategic issues they perceive and the options they have available for shaping and adjusting the scenarios, an assessment of the

different scenarios was conducted from the perspective of the individual stakeholder groups. These were subsumed under four main headings: academia, industry, (civil) society and government. The assessments allow identifying the main strategic issues that matter from the perspective of the different stakeholders.

The positions and interests of the different stakeholder groups can be summarized as follows:

- As expected academia is mainly concerned about the degree of open access and ensuring fair representations in the structures and processes formed alongside the availability and continuity of funding and ability to cover all research types by also ensuring high research quality.
- Industry is primarily interested in safeguarding their own private interests and this is reflected in the IPR issues, and fair representation in the research areas' selection and prioritisation processes. At the same time, they also wish to avoid bureaucracy while they also see collaboration especially with academia positively and are not keen on too rigid structures that may hinder generation of innovations. Intense competition is also another of their concerns.
- Society wishes to get more involved in the processes of decision-making in the future. Thus, fair representation is among their mainconcerns. Increased involvement also brings forth issues of funding and acquiring the necessary skills and knowledge. Society also has to deal with its local references in view of a globalised research landscape.
- Justifying legitimacy of public interventions and ensuring public accountability in response to the needs and concerns of the other stakeholders are the major concerns for policy. Thus, they need to ensure fair representation of all and allow for a diversity of approaches in open access, researchers' careers, funding possibilities and IPR regimes to accommodate engagement and collaboration between academia, industry and society while not neglecting support for certain areas of research. At the same time they are concerned with overcoming current problems in the policy arena like fragmentation and lack of coordination within and across different levels of governance.

A more detailed analysis reveals the underlying strategic issues that each stakeholder group associates with the different scenarios. These are summarised in Table .

Table 6: Strategic issues emerging in each scenario from the stakeholders perspectives

	ORPs	KPs	GC-KICs	KVCs	RC
Academia	**Openness & access** to research **Financial viability** of ORPs Distant conduct of research **Fair representation** **Researchers' mobility** Progress monitoring & **research excellence**	**Multiple knowledge** claims Issue of lobbying and **fair representation** Dominance of certain types of research – neglect of others **Funding** issue	Issue of **fair representation** Operationalizing GC research GC **selection & prioritisation** issues Risk of GC non-relevant **areas neglected**	Issue of **selection** of research areas; risk of **neglect of fundamental** research or other areas of less interest to industry Risk of **excluding** certain institutes	Lack of **funding** continuity **Research quality** issue Limited possibility for complex research and **access to large infrastructure** Funds for **basic research** High and open competition; IPR issue

Industry	How to protect **IPR and own interests**? Degree of **openness; differentiated approach** per different sectors and s&t issues examined Which ORPs to join?	How to protect **own interests**? Issue of **fair representation** Risk of **bureaucracy**; lack of **collaboration**	Protect **own interests** GC **selection & prioritisation** issues **ELSI** issues in research Risk of GC non-relevant **areas neglected** Risk of **SMEs** left behind	risk of **hindrance of radical innovations** risk of **neglect of fundamental** research increased **competition**; challenges for new-commers	sector specificities **SMEs** able to compete for the best talents?
Society	Clash between **global ORP agendas and local level** of societal organisations Issue of **skills and knowledge** **Science in society** issue	Issue of **fair representation** Lack of **skills / knowledge needed** Issue of **funding**	issue of **fair representation** issue of **skills and knowledge needed** issue of **local needs vs. global GCs**	weakened **role of society** no entry point for the views, interest and concerns of society	opportunity for stronger **role of society** issue of **funding** sources and **continuity**
Policy	Issue of **legitimacy** for public intervention Issue of **openness and fair representation** **Research quality** **Fragmentation** across institutions **Science in society** issue	**Legitimacy** issues **Fair representation** **Diverse knowledge** claims Issue of **accountability** Issue of global nature of certain scientific issues	**Conflicting policies** across world regions Issue of **selection** of GC; **neglect** of other areas **lobbying and fair representation** **Funding** issue cross-level **coordination**	KVC purely driven by **profit-making interests** different mind-sets of **academia - industry** **global benefits vs. national** funding risk **hindering innovation** **low attractiveness** for res.	no complex research; **neglect** of certain **areas** issue of **funding** sources and **continuity** risk of increasing **fragmentation** in research and **inequalities** across countries/regions

(*) Phrases in bold fonts indicate the main concerns of each stakeholder type that are common across the different scenarios

The assessment of the individual scenarios, together with the main strategic issues for each stakeholder group, represents an interesting piece of information. However, ultimately the stakeholder need to define their strategy and their corresponding options against the background of a range of different possible scenarios, with the scenario space being reflected in a simplified way in our five transformative scenarios. A cross-scenario assessment of the scenarios from the perspectives of the different stakeholders is thus much more instructive for understanding their potential strategies. The subsequent analysis summarizes this cross-scenario view of the stakeholders, based on assessment criteria derived from the stakeholders' main interests.

Cross-scenario assessment by different stakeholder groups

Academia

As noted above, assessment criteria for academia include independence, researchers' autonomy, collaboration opportunities, support of different research types (curiosity-driven as well as challenge-driven), funding options, and research quality.

One of the key criteria for the research community is to have more active engagement and independence in setting their research agenda. ORPs (#1) and Researcher's Choice (#5) provide the greatest independence to researchers. However, they would still like their research to lead to exploitable results. Therefore, they prefer collaborating with industry. The KVC model can provide this; however, in that case the research agenda is mainly set by Industry towards more applied research.

Thus, considering the researchers' autonomy, it can be said that the first scenario is the most preferred one. This scenario is more institutionalised than Scenario 5, where individual researchers would be under continuous pressure not only with their counterparts in academia, but from the wider pool of researchers and science entrepreneurs from different constituents of society. Researchers prefer to operate in a more secure environment, where research and researchers have been assessed and awarded based on their performance.

Curiosity-driven research remains an important aspect for research communities. Therefore, the research community would prefer those scenarios with more freedom. Scenario 1 and 5 provide the largest room for this. Scenario 3 and 4 provide opportunities for more directed research. In Scenario 2, the room for curiosity-driven research is more ambiguous. It can only be the case if the idea is well-represented in the Knowledge Parliaments and attracts sufficient attention from the other stakeholders.

Applied research is appreciated. This is one of the areas where the research community can demonstrate real impact. However, the role of basic research is still considered to be important. This type of research is usually less inclusive and is mainly conducted in a more closed or restricted fashion. Larger research infrastructures, labs and access are required. This is certainly not possible in Scenario 5. Again Scenario 2 does not suggest a particular solution to this issue. Scenario 4 is oriented towards applied research. Scenario 1 and 3 are considered to be the ones to provide greater opportunities for basic research.

The research community also prefers flexibility in formulating research topics and exploring collaboration opportunities. Once again, if the quality standards can be provided the ORP scenario is the one which can meet this expectation. It is also important for researchers that they can associate themselves with one or more ORPs in a flexible manner.

Funding of research is considered to be an important concern for researchers. Orientated towards GCs, scenario 3 provides greater opportunities for funding at the EU and international levels. Scenario 5 is the least desirable one as it is short-term, competitive and does not support basic research. Scenario 4 provides secure funding at the expense of limited freedom and less basic research. If backed by strong lobbies, Scenario 2 can provide solid funding. Scenario 1 can be moderately desirable if public and industry support is attracted through the ORPs.

Regulation, quality of research, profile of researchers, performance assessment criteria are important aspects for the research community. These are the limiting factors for open access to research platforms; however researchers also expressed a great interest in the engagement of broader societal groups through user-driven research.

Industry

For industry important assessment criteria as seen in Table 6 above include protection of IPR and own interests, flexibility in access to the best researchers, collaboration with academia, support of different types of research, bureaucracy and costs of research organisation and sources of research funding.

Among all the actors, industry appears to be the most pragmatic one with expectations for maximising benefits and profits, ensuring the protection of their rights and interests, and reducing risks, even at the expense of changing their geographical locations. While making an assessment about the industry's position, it is important to bear in mind that there is not one uniform body. There are a number of enterprises involved in this stakeholder group producing a wide variety of goods and services at different levels. Therefore, it is natural to consider that there will be differences in their expectations and business models.

Scenario 3 seems to be more favourable for large companies. There are large-scale GCs to be tackled. Governments at the national and international levels will be willing to pay to mitigate the negative impacts of these challenges. There will also be a great support from the society, which will make industry's position stronger.

Meanwhile, scenario 5 provides more opportunities for SMEs. They will not need to employ full time researchers. They can be in a project based relationship. This is favourable for industry as they will avoid the bureaucracy of employing full time personnel. Meanwhile, researchers will be flexible enough with short term engagement. Once they are done with their projects they will have a chance to pursue new ventures with different partners.

The ORP scenario provides a good platform as long as the IPR issues are addressed. This demand from industry coupled with the expectation of involving high-profile researchers from the academia side threatens the idea of openness. However, once these issues are resolved, both parties will create favourable working groups. Both stakeholders need also to find an agreement on basic research regarding its organisation and funding. Industry might find it costly and risky to be involved in basic research.

The industry group is precautious about the Knowledge Parliaments as they raise concerns about research being too bureaucratic and costly. They also think that groups like labour associations may slow down the process. Although it is not favourable, if this scenario goes ahead, industry will have a strong presence in KPs with lobbying groups and they will defend their interest as much as possible. If they find that the model is not working, then they will consider relocating their businesses seriously.

Scenario 4, KVCs, provide good opportunities for industry to play a more influential role. Big competition on the researchers' side to be involved in KVCs with secure funding, will in turn increase the quality and quantity of innovations. Again, basic research is raised as a major issue by the research community. Industry may need to spare some funding for basic research, considering that - if successful - there will be immense impacts on applied research. Therefore, industry might be willing to take a risk in certain promising basic research fields.

Society

The main assessment criterion from the society's perspective is safeguarding societal interests as also reflected in Table 6 above. This calls for increased engagement of society in policy-making.

Out of the different levels of engagement (i.e. being informed, being asked before decisions are made, and actively participating in decision- and policy making) the society group concluded that the highest level of

engagement can be facilitated in the framework of scenarios 3 (Grand Challenges for Real) and 5 (Researchers' Choice). Scenario 1 (Open Research Platforms) and 2 (Knowledge Parliaments) are more about society's mobilisation in relation to scientific issues while scenario 4 (Knowledge Value Chains) only touches upon the role of society as a passive end-user of results.

Society has to set a common overall aim / vision across all the scenarios. This is to increase the participation and engagement of society and in this regard move from "Science in Society" to "Science with Society". In pursuing this aim specific strategic actions across the scenarios can be suggested, the main difference being that in some scenarios they would be realised more easily and be more effective than in others.

It is important in all the scenarios to bring science closer to society starting with specific programmes in schools and universities as well as public campaigns and awareness raising activities. This primarily addresses a shortcoming of the present that has to be remedied. Open platforms bringing societal actors together can form a step towards giving society a voice across the different scenarios even though they would be more facilitated within the special conditions of scenarios 1 and 5.

Creating specific partnerships of societal organisations is also an option for getting an active role in dealing with specific societal challenges. This would seem more relevant in scenario 3. Society organises itself in some form of concrete structure or institution to be able to take part in the structures featuring the scenarios. This might be less relevant for scenario 5 while it seems more relevant for scenario 3.

Policy

The assessment criteria from the policy perspective is a) the legitimacy question, i.e. whether there is actually a need for intervention or not, b) the opportunity question, i.e. what policy could or should actually do, and c) the additionality question, i.e. whether policy could make any difference. Beyond these criteria, policy needs to accommodate the interests and concerns of the other stakeholders. These as shown in Table 6 above span carious areas like strengthening links between academia-industry-society, ensuring funding sources, regulating participation and securing data. These areas are addressed below.

The role for policy ranges considerable across the scenarios; from a rather limited role as in scenario 1 (Open Research Platforms) to a very active role in scenario 3 (Grand Challenges for Real). These different levels of engagement are justified on the basis of clear rationales why policy action is needed.

There are various types of policy interventions suggested across the scenarios. The most commonly mentioned has to do with setting up of proper regulation and control mechanisms: ensuring access to and invest in infrastructure (scenarios Open Research Platforms and Researchers' Choices), setting up quality assurance mechanisms, controlling data exchange and security (scenario Open Research Platforms). Regulating participation and ensuring fair representation of stakeholders was seen important in scenarios 1(Open Research Platforms), 2 (Knowledge Parliaments) and 3 (Grand Challenges for Real).

At the same time, the role of policy in strengthening linkages among research and innovation actors was deemed important. Facilitating linkages between academia and industry was crucial in scenario 4 (Knowledge Value Chains), while engagement of society alongside academia, policy and industry was necessary in scenarios 2 (Knowledge Parliaments), 3 (Grand Challenges for real) and 5 (Researchers' Choices).

Associated to this, policy also bears the role of orienting and adjusting research and innovation activities to societal needs and interests ensuring that actual benefits accrue for citizens. This was especially noted for

the scenarios that were less convincing that this would be the case in the future (3: Grand Challenges for Real and 4: Knowledge Value Chains).

The role of policy in finding the necessary funding required by the several instruments and structures suggested in the scenarios was a common concern. However, the consequences for funding policies differ quite considerably across scenarios. While better forms of allocating resources was highlighted in scenario 2 (Knowledge Parliaments), in scenario 1 (Open Research Platforms) an active funding policy faced reluctance. In scenario 5 (Researchers' Choices), the need to ensure funding from a variety of sources was stressed. Given the great possibility of limited research budgets over the next years however widening the range of possible funding sources for research is also relevant for the other scenarios.

Strategic choices

In addition to the assessment of the scenarios against the background of the main strategic issues for the different stakeholders, it is also possible to look at the strategic choices available to them. This can be done per scenario, but also from a cross-scenario perspective. Table provides an overview of the strategic choices available to the different stakeholder groups. The colour coding indicates two important types of insights:

- It points to strategic choices that are apparently 'robust' for a specific stakeholder across all or many scenarios. For instance, pursuing an approach based on social platforms and networks for defining research agendas is very much in line with civil society stakeholders' interests in all scenarios.
- It points to choices that seem to be convergent among several stakeholder groups, either in a single scenario or even in several scenarios. For instance, the reinforcement of alliances between academia, industry and other research agents seems to be a choice that suits several stakeholders' interests in the Knowledge Parliament scenario.

Taking into account the different interpretations under each scenario, these common themes around which the strategic choices of stakeholders evolve across the different scenarios can be summarised as shown in Table . Being common across most of the scenarios, these strategic themes can be regarded as possible themes around which strategic packages of action may be designed by the relevant stakeholders.

As the table shows, academia regards of prior importance to ensure flexibility and freedom for researchers in 'open' environments, as well as transparency and fair representation in any new structure to be created. They stress that 'openness' needs a differentiated approach regarding the types of research or scientific issues at stake. At the same time, they value collaboration with the private sector in general when specific challenge-driven research is the focus while they stress the importance of not neglecting the value of curiosity-driven research.

Industry is primarily concerned with protecting their own rights while also acknowledging the necessity for a multi-stakeholders approach in most of the scenarios. Policy has a multiple role to play. In 'open' environments like in "Open Research Platforms" and "Researchers' choice" access to infrastructures and knowledge needs to be ensured alongside multiple funding sources. In such environments safeguarding data security is also crucial from a policy perspective. In more 'closed' or structured environments

strengthening collaboration between academia, industry and society and facilitating fair representation is important.

Table 7: Strategic themes reflecting the strategic choices of stakeholders across all scenarios

	OPRs	KPs	GC-KICs	KVCs	RC
Academia	Flexibility and freedom;	Openness & transparency;	Co-creation of research;	Avoid fragmentation;	Flexible careers;
	openness & transparency;	academic alliances;	user integration;	collaboration with industry	ensure research quality
	differentiated approach;	fair representation	multi-disciplinary research;		
	fair representation		PPPs		
Industry	Protect IPR & own interests;	Protect IPR & own interests;	Business opportunities	Face increased competition;	Differentiated strategies
	open approach sector-specific;	high potential for PPPPs	multi-stakeholder approach	challenges for new-commers;	flexible / creative business models
	selectivity of joining			collaboration with academia	
Society	develop necessary skills & knowledge;	develop necessary skills & knowledge;	fair representation;	Feedback mechanisms for society's views;	develop necessary skills & knowledge;
	2-way dialogues research – society;	participatory research budgeting;	develop necessary skills & knowledge;	open platforms for societal players;	participatory research budgeting;
	social ORPs;	social platforms	social partnerships	promote "co-creation"	social platforms
Policy	fair representation;	Improve science-based debates;	Common approach in Europe;	Adjustment to societal needs and interests;	Access to infrastructure and knowledge;
	differentiated approach in supporting ORPs;	strengthen links in research-society;	some harmonisation of systems;	measures to connect Unis to KVCs;	incentives for entrepreneurs and researchers;
	access to infrastructure and knowledge;	improve public accountability;	regulation and direction for industry;	exchange of good practices	multiple funding sources
	quality assurance;	global governance	fair representation		
	data control and security;	Multiple funding sources			
	HR development;				
	better allocation of resources				

(*) Legend: Groups of common choices across the difference scenarios

	Researchers careers		New roles of society
	Participation, selection and prioritisation processes		Skills / knowledge needed for engagement
	Differentiation across sectors, S&T areas / issues		Funding
	Knowledge property		Organisation of society
	Collaboration within and between stakeholders		Knowledge access
	Research quality and data security		

Society seems to have a less differentiated strategy across the different scenarios. Organising society in relevant formal or less formal institutions and acquiring the necessary knowledge, skills and resources is important for increasing society's engagement and moving from the 'science in society' to the 'science with society' mode. This strategy is the one to follow across all scenarios although it may be more difficult or less effective to apply in rigid scenarios like "Knowledge Value Chains".

A word of caution is nevertheless needed in this interpretation. Certain themes may indeed be common across scenarios and stakeholders, but may nonetheless entail significant differences in interpretation. This is, for instance, the case for IPR issues, funding or fair representation. IPR requires a differentiated approach the ORP scenario, while needs more openness and diversity in the KP scenario. Similarly, fair representation appears in all scenarios, but with different interpretations as well. It is linked with democratic representation in the KP scenario, but with excellence in the ORP scenario, and with prioritisation in the GC-KICs scenario.

The specific themes that are repeated across the scenarios relate to four broader groups according to the legend of the table: a) collaboration within and across the different stakeholders, b) participation, selection and prioritisation processes, c) funding and d) organisation and education/training of society. Verifying this, indeed the need for collaboration, being represented in the (new) structures formed, defining an agreed selection and prioritisation process of research areas, while also ensuring the necessary funds were among the main issues that emerged across all scenarios and in many of the stakeholders (cf. Table 6)

The table also points to some strategic themes necessary to handle some specific features of individual scenarios. These scenario-specific strategic themes reflect the special needs of certain stakeholders. Allowing flexibility for the evolution of researchers' careers is a key strategy to academia and more relevant in scenarios in 1 (Open Research Platforms) and 5 (Researchers' Choice). Ensuring research quality and data security is key for both academia and policy and more needed again in the less 'structured' scenarios, i.e. 1 and 5. A public strategy for access to infrastructure and knowledge is also key for scenarios 1 and 5 while a differentiated approach in open access and knowledge property in collaboration with academia and industry is vital again for the more 'open' scenarios 1 and 5.

Across the different scenarios those with the most scenario-specific strategic themes are scenarios 3 (Grand Challenges for Real) and 4 (Knowledge Value Chains). Not surprisingly, 'Grand Challenges for Real' calls for a common public policy approach in Europe implying some degree of harmonisation at the national level in dealing with grand challenges, while also offering new business opportunities. 'Knowledge Value Chains' on the other hand, following a much more free-market approach needs steering on the side of policy to balance private and societal interests while not excluding SMEs and new-comers due to increased competition.

Six major fields for action

The strategic themes presented in Table 7 reflect on which major issues the different stakeholders actually do have options available, and whether and how these would differ across the scenarios. The strategic themes and the associated strategic choices also represent normative orientations, in the sense that they are the "preferred" options for each stakeholder in the individual scenarios considered ("desirability").

The next step consists of exploring what strategies might be possible to pursue jointly, as a first step towards what might ultimately be called a roadmap. Strategic packages represent those combinations of options around the main issue, which the different stakeholders could agree upon ("cooperation") and which are somehow mutually compatible ("compatibility"). In other words, strategic packages are combinations "that work" of options available to the stakeholders across scenarios.

The main difficulty in analysing compatibility obviously arises when options differ strongly across scenarios, or – to be more precise – are mutually exclusive (either we go for strong IPR protection or not). In such a case, conditional considerations regarding a major issue may be necessary ("adaptive packages"), but overall the scenarios are sufficiently complementary to accommodate for options that allow handling different scenarios at the time. The simplest case is obviously when combinations of options by different stakeholders can be pursued that work reasonably well across different scenarios anyway.

Box 1: Six major fields for action

1. **Towards science *with* 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 research funds and execution of research. Multiple actors and stakeholders coproduce knowledge to effectively address inherently complex grand challenges. Setting up mechanisms, processes and structures to enable a two – way dialogue with society is as important as conducting research that is both of high quality and high relevance to societal challenges. This also entails the need for new ways to evaluate diverse knowledge claims and epistemic cultures.
Keywords: coordination, participation, legitimation, responsible innovation, valorization of diverse knowledge claims, coproduction of knowledge

2. Research 3.0 careers: new competences and commitment

Careers and competences of scientists will change drastically. How to keep careers in the academic institutes attractive interesting for the talented? In search for new incentives. Increasing relevance of virtual research communities and networks. From institutionalisation to individualisation? New R&I hubs and the changing position of universities.
Keywords: autonomy and creativity, flexibility, labour conditions, academic career paths.

3. A distributed and diversified research funding landscape

Raises policy questions regarding research coordination and continuation of research, 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. Keywords: multiple funding actors, democratization of public funding, responsible promise management, accountability, transparency, legitimation of policies.

4. IPR and open access of knowledge.

This issues has to be examined under the principle of "Responsible research and innovation" directing private interests towards the public good with respect to the environment and societal needs through fair representation and active engagement of all stakeholders. The specific issue addresses the 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 research and innovation. Keywords: access to knowledge, open innovation

5. Towards the governance of science infrastructures 3.0

While access to infrastructure is important across all the scenarios, open access needs to apply a differentiated approach depending on the type of research conducted and/or the scientific issues being

dealt with. It is important to ensure data security in response to ethical, legal or social issues addressed by society or to avoid misuse by confrontational groups. Issues such as big data management and ensuring scientific quality also become crucial. Keywords: quality of big data, vulnerability of ICT infrastructure.

6. EU and national policies on globalised R&I futures

With the rising power of other world regions and the changing world order, is there a need to look beyond ERA goals? What alliances are to become necessary in dealing with certain global challenges? What would this imply for the EU R&I policy and its internationalisation?

Against this background of stakeholder constellations, strategic options and possible areas of joint action, the role of policy is important to understand. What are rationales for policy intervention? If options are robust or complementary, policy can just play the role of facilitating them, removing some (minor) barriers to their realization. If they are contradictory or conflictual, real choices may need to be made. In both regards, policy may have a role to play with regard to facilitating cooperation between stakeholders, either to realize robust or complementary options, or to bridge and mediate in conflict-prone situations.

1.3.4 The normative perspective – Assessment of scenarios with regard to policy goals

The exploration of future scenarios needs to be complemented by a normative perspective if it is to be useful to policy making. At European level, major normative orientation for STI policy are provided by the three guiding goals goals of a) moving towards more responsible modes of research and innovation (RRI), b) fostering the development of the European Research Area (ERA, and c) tackling Grand Challenges (GC). It is against this background that the transformative scenarios and the major fields of action are now going to be assessed, as a basis for pointing out major policy challenges and options for shaping the future of R&I.

Assessment approach

The assessment with regard to the three overarching policy goals is conducted along the lines of a three-step approach. First all, the scenarios are analysed in terms of the implications they raise along the lines of six main dimensions that are regarded to be important with regard to the three policy goals. In other words, this first step represents a further elaboration of the scenarios in terms of important policy implications they may raise. Six core dimensions have been analysed:

- *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 for money will science return to citizens? How much trust will society have in science? How will public research be evaluated? What will the science-society contract entail?

- *Research funding modes:*
  How and by whom will research be funded? (type of funds/criteria and procedures for funding/role of competition & excellence /national or international) How will research proposals be evaluated and based on what criteria?
- *Research careers & mobility:*
  How will research careers be organized? (building & 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?

As a second step, the implications are assessed with regard to the three policy goals RRI, ERA and GC goals of European R&I policy. A qualitative five-point scale from (++, +, 0, -, --) is applied. The scenarios are assessed one by one, but then, as a third step, a cross-scenario analysis is conducted in order to identify similarities and differences between the five scenarios. 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[2]. They explore futures in a multi-dimensional fashion.[3] 'Robust' policies – that is, policies that make sense across all scenarios – are likely to address the types of changes that occur in more than one scenario (robust changes). Other relevant policy insights of a cross scenario analysis are those that either aim to effectuate major opportunities in a particular scenario or prevent major risks or overcome important limitations.

Cross-scenario analysis with regard to RRI goals

Assessing the Scenarios in terms of their capability to cope with and facilitate a collective and continuous commitment to be anticipatory, reflective, inclusively deliberative and responsive (RRI) some policy implications can be identified for todays' European and national R&I policy for advancing practices of Responsible Research and Innovation. Table8 provides an overview of the five scenario assessments on each of the six core dimension of the future R&I landscapes, with the coloured assessment codes as well as the main features on which the assessment is based.

Table8 shows that three scenarios are rather open and receptive to RRI goals, being scenarios 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) is neutral or slightly supportive. Although this conclusion is interesting and relevant in itself, is it alsoimportant to perform a cross scenario analyisis.

[2] Some scenario methods are more likely to produce complementary scenarios e.g. the methodology where scenarios are positioned in the four quadrants of two core dimensions of future developments (e.g. strong vs. weak European governance or high vs. low economic growth, etc.).
[3] See RIF deliverable of WP2: RIF D2.1 Modular scenario report "New ways of doing research: from explorative to transformative scenarios (p.43).

Table8: Cross scenario assessment matrix for addressing RRI goals

	Scenario 1 ORPs	Scenario 2 KPs	Scenario 3 GC-KICs	Scenario 4 KVCs	Scenario 5 RC
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 &RIO-managers are key actors	Researchers and clients groups balanced
Legitimization	Effectively (globally) coordinated research for society , open knowledge	Research for fair society, democratic decision making	Research addressing local societal challenges , fair decision making.	High return of value of public funding, yet, little affinity with non-economic societal concerns	Open knowledge market can facilitate RRI demands
Funding	Multiple funding sources, but not necessarily reflective and deliberatve	(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	Multiple funding sources, but market dependent Slow science funding is RRI
Careers	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	Open knowledge and data, but limited accessible by societal stakeholders	Flexible IPR, yet serving fair society	Open knowledge & innovation	Flexible IPR, yet primarily serving industry	Ambivalent relation to IPR Slow science adheres open knowlegde

Identification of policy options for advancing RRI goals

On the level of the six R&I system dimensions, where for each scenario the core system features as based on the assessment are summarized, 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 a RRI sensitive research and innovation 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. This type we will denote with *flexible policy options.* These reflect other features of the transformed R&I systems are receptive to RRI activities.[4] Below

[4] The specific RIF scenario methodology generates glimpses into possible R&I futures in a multidimensional way. This implies that the five RIF scenarios cover only a limited number of possible systemic transformations, yet, plausible ones. The type of scenarios primarily serve as inspirations source for policy makers and other involved R&I stakeholders to think beyond the currently dominant policy discourses. Yet, if positively assessed – with respect to the three policy goals - system features come to the fore in more than one scenario, then one might call policies directed at realizing these features, 'robust' policy options. Not all RIF scenarios describe futures of an entire R&I system, some are only partial. Scenarios 2 (KPs) and scenario 5 (RC) are partial, whereas scenarios 1 (ORPs), 3(GC-Kics) and 4 (KVCs) are describing the general future R&I systems, scenarios 1 (ORPs) and 4 (KVCs) even on

we will summarize the policy issues that we identified to be important for advancing RRI goals, both for robust and flexible policy options.

Robust policy options for RRI

Based on the analysis of the main features underlying the assessment as presented in Table we can identify several robust policy options that can support an RRI-friendly system. The robust options emanate from system features that were found in more than one scenario:

- *Types or research*: stimulate science for & with society (addressing societal challenges and close collaboration with civil society)
- *Key players*: increasing influence, engagement and participation of citizens (grassroot movements & civil society organizations) (co-creation/ PPPP-partnerships). In two positively assessed scenarios (KP & GC-KICs) civil society actors were key actors to initiate transformation.
- *Legitimization*: Endorse development of competences and skills of citizens and civil groups (engaged university).
- *Funding:* in scheme 4.6 the scenario assessment include different types of funding (democratic decision, crowd funding, fair funding), yet all share an underlying mechanism: the stronger the influence of funding decisions, the higher commitments and engagement with that research.
- *Research careers & competences*: Robust policy options include:
    - broadening of academic skills with multidisciplinary, multicultural collaboration, entrepreneurial and reflexivity skills.
    - Diversifying career paths
    - Opening up universities for non-academics (citizens, community), increasing community competences (e.g. offering community modules)
    - Overall: clear need for revision of NPM governance of universities and public research institutes
- *IPR regimes*: Open knowledge & open data, access for all.

Flexible policy options for RRI

These policy options tend to occur only in one scenario but can advance RRI goals:

- *Type of research*: fair research; slow research, stimulate epistemic heterogeneity, co-creation of knowledge and innovation
- *Legitimization*: open knowledge markets can facilitate RRI demands
- *Funding*: Flexible policy options (direct democratization of decision making, stimulating crowd funding)
- *IPR regimes*: tailored decision making on IPR with fair deliberative procedures (fair IPR).

global level. The partial scenarios mostly address limited types of research. The RIF scenarios may well co-exist. Robust policy options however interesting as they are likely to be effective a broader range of the R&I futures.

Cross-scenario analysis with regard to ERA goals

The purpose of this chapter is the assessment of the various RIF futures of transformed R&I practices and organization in terms of their capability to endorse the ERA goals, that is the development of an efficient, effective and well-resourced European Research Area. We will now make an effort to distil from a cross-scenario analyses some policy concerns for todays' European and national R&I policy for advancing a strong European Research Area. Table provides an overview of the five scenario assessments on each of the six core dimension of the future R&I landscapes, with the coloured assessment codes as well as the main features on which the assessment is based.

Table 9: Cross scenario assessment matrix for addressing ERA goals

	Scenario 1 ORPs	**Scenario 2 KPs**	**Scenario 3 GC-KICs**	**Scenario 4 KVCs**	**Scenario 5 RC**
Type of Research	Effective international coordination. Tackle national borders	Multiple epistemologies impedes R&I coordination	Strong coordination of sociotechnical research (smart specialization), FET & blue sky less	Strong efficient international coordination of FETs, ERA needs global repositioning	No coordination of R&I
Key players	Researchers focus on GC not ERA	High complexity of ERA policy arena	GC-KICs strong EU coordinating player	Strong institutional player, but ERA needs global repositioning	Lack of powerful research institutes
Legitimization	National public funding of international researchers (ORPs)	Advancing knowledge society ; broad knowledge and interest in R&I	Strong legitimization and increased science literacy of citizens	Improved efficiency, but no sense of control	Open knowledge markets create high legitimization
Funding	R&I global funding (reciprocity)	More public funds through high legitimization	More public funding, less industrial	Strong funding actor are attracted to efficient system, but global	Creating tapping of heterogeneous funding sources
Careers	International careers, need for good regulations	More diversity but uncertain for EU attractiveness	More diversity in careers & competences, risk brain drain high tech	Facilitation of mobility of talented, but risk of brain drain	More academic mobility by flexible researchers, no career options
IPR	Open access, but little options for EU regulations	Fair IPR: little impact on EU competitiveness	Open access and free knowledge sharing	Highly regulated IPR, no open access	Ambivalent towards IPR

The ERA assessment leads to a rather scattered outcome. Apart from the third scenario (GC-KICs) the other scenarios offer no explicit outlook on a strong European ERA. Scenario 3 (GC-Kics) is the only scenario that presumes strong European coordinated actor, GC-KICs. Other scenarios are globally oriented and realizing ERA goals are subordinate to other goals. Scenario 4 (KVCs) most in line with current ERA goals (effective R&I system) however, KVCs act strategically from global concerns. Scenario 1 (ORPs), 2 (KPs) and 5(RC) are more varied in their (non) support for ERA targets.

Future ERA policy is likely to need a shift towards a global positioning of European R&I. The RIF scenarios fall short on taking explicitly account of the global power relations general and specific for Research and Innovation. The most important policy concern is how the ERA can be a powerful and attractive place in this global-level organized research landscape.

Identification of policy options for advancing ERA goals

On the level of the six R&I system dimensions, where for each scenario the core system features as based on the assessment are summarized, one can identify common features across the scenarios. Some dimensions in more than one scenario point to *similar* features that make the R&I system effective for addressing ERA goals, implying *robust policy options*. Other dimensions seem to point at *different* directions and are starting points for *flexible policy options.* Below we will summarize the policy issues that we identified to be important for advancing ERA goals, both for robust and flexible policy options.

Robust policy options for ERA

There are two major common issues raised in the scenario assessment. The first one is that research organizations (like multinationals) internationalize, implying that research goals and national/European goals in interests not automatically align. ERA thus is in need of a fundamental reorientation towards the globalizing research landscape. More emphasis on reciprocal relationship with European and non-European R&I actor must be taken into account (rising new economies). This implies for the R&I dimensions the following robust policy challenges:

- *Types of research & research coordination:* recognize and facilitate the potential of (global) self-governance of researchers to coordinate their knowledge domain (ORPs and RC) and facilitate ICT infrastructures for this type of bottom-up coordination.
- *Funding:* Research funding (both public, private as well as social funding by e.g. charity funds) will become more internationally competitive (ORPs, KPs, KVCs) .Repositioning of ERA in the international funding arena is a core ERA policy concern. This involves an opening up of EU and national funding schemes for global competition, and simultaneously to increase the ERA's attractiveness and competitiveness in the global arena.
- *Research careers & competences:*
    - prepare students for international career: language skills, multi-cultural collaboration skills, etc.
    - embed European research institutes effectively in global networks
- *IPR regimes*: Open knowledge & open data of all public financed research, facilitated on global level. Extent and formalize the role of the Global Research Council.

A *second* shared issue raised in more scenarios is that civil society and individual researchers also become core drivers of the other scenarios. Both groups are new actors in the ERA arena. Current ERA goals hardly cope with these developments, yet, they provide powerful new mechanisms of e.g. bottom-up coordination of researchers (both in the ORPs and RC scenario, or with fundamental new roles of civic stakeholders (KPs). This further re-contextualisation of the R&I system poses new challenges of ERA governance of including civic stakeholders and individual researchers into reoriented ERA policies.

- *Types or research*: stimulate science for & with society (addressing societal challenges and close collaboration with civil society (co-creative modes of knowledge creation)
- *Key players*: increase the influence, engagement and participation of citizens and civil society organizations. Endorse more Public-Private-People-Partnerships (PPPP)-.

- *Legitimization*: Endorse development of competences and skills of citizens and civil groups, e.g. by opening up universities for wider publics (the engaged university offering community modules).
- *Research careers & competences*: Careers too will become more Robust policy options include:
    - broadening of academic skills with multidisciplinary, multicultural collaboration, entrepreneurial and reflexivity skills.

Flexible policy options for ERA
These policy options tend to occur only in one scenario but can advance ERA goals:

- *Type of research*: flexible policy options for ERA include:
    - fair research, slow science and smart specialization stimulate the societal legitimization of public funding and thus the recourses for ERA
- *Legitimization*: open knowledge markets in combination with creative science entrepreneurs can facilitate an effective return of value
- *Funding*: stimulating crowd funding for research

Cross-scenario analysis with regard to Grand Challenge goals

The assessment of the various RIF futures with regard of their capability to address various types of Grand Challenges aims at analysing policy implications for todays' European and national R&I policy for advancing a future R&I system that is capable of addressing various types of Grand Challenges. Table 10 provides an overview of the five scenario assessments on each of the six core dimension of the future R&I landscapes, with the coloured assessment codes as well as the main features on which the assessment is based.

Table 10 Cross scenario assessment matrix for addressing GCs

	Scenario 1 ORPs	**Scenario 2 KPs**	**Scenario 3 GC-KICs**	**Scenario 4 KVCs**	**Scenario 5 RC**
Type of Research	Effective high-tech oriented complex global GCs; multidisciplinary & international collaboration	Heterogeneous type of knowledge, fair knowledge, not necessarily GC orientation	Effective in local GCs; multidisciplinary, oriented towards valorization/ social innovation	Effective high-tech, oriented at global GCs, yet directed mainly at short-term economic gains.	Creative solutions, out of the box thinking; limited high-tech complex global GCs
Key players	Various knowledge players, yet limited variety epistemologies	Citizens worldwide decide, complex GC research lacks coordination	Variety of stakeholders	Strong research-industry actors; civil society & citizens little influence	Researchers and clients balanced (idem RRI)
Legitimization	Improved efficiency, yet not optimal social robust solutions	Research for fair society; vulnerable for heterogeneous (conflicting) perceptions	Blurred boundaries between science and society; citizen science	Improved efficiency appreciated, yet little social innovation	Open knowledge market can facilitate GC research (idem RRI)
Funding	Multiple, coordinated funding	Variety of funds, yet industrial funding not subtantive	Multiple (local) funding sources, less for high-tech research on global GC	Effective public-private funding for high-tech solutions, little social funders	Creative ways for finding (new) funding
Careers	international career and more heterogeneous competences	Cross cultural collaboration, trans-disciplinary competences	Diversified career paths, heterogeneous academic skills,	Challenging highly talented, international careers,	Broadening of careers – broadening skills, little vertical career paths
IPR	Open access and likely effective valorisation	Fair IPR regulations	Open access; effective local valorization	Rigid IPR regulation	Ambivalence towards IPR

Most of the scenarios are supportive in addressing GCs, however, not the same challenges nor the leading to the same types of solutions. So the core policy question is not so much *if* GCs are addressed but *how* and *what* types of GCs are addressed in the different scenarios. GC research is likely to be contested and includes controversial value-laden types of solutions that are sought after. Here one can also think of high-tech solutions versus low-tech solutions (e.g. think of care robots versus supportive social networks as solutions for the ageing society).

GC research is, by definition, meant to have societal impacts, therefore the need for political and democratic deliberations is a key issue in the democratic governance of GC research. In the ORP and GC-KICs scenarios addressing Grand Challenges (defined as they are in local/time spaces) is a core issue, both involve a variety of actors in the question *how* to address the GCs. In the KP scenario, the citizens are leading in defining GCs. Definitions of GC negotiated in KPs are likely to differ from the definitions made by governments or by local sociotechnical laboratories or the slow science movement. In the KVC scenario the Grand Challenges are assessed as subordinate to KVC interests. As KVC are closely intertwined with industrial research, GC' problem definitions will be framed by industrial interests. Tensions may arise between various new types of knowledge and solutions that civil organisations strive for and rather focused high-tech solutions from the side of industry. So addressing GCs is not sufficient for understanding the scenario implications, a more relevant issues is what types of solutions (=type of research; type of knowledge) are aimed for in the research programs (social/ sociotechnical /lowtech/high tech/base on different epistemologies) as all solutions have important social, economic and political impacts. Involving different societal stakeholders in decision making *and* in co-production of GC relevant knowledge is a key strategic issue. Public trust in GC research is prerequisite for a wide support of public funding of GC research.

Identification of policy concerns for addressing GCs
From the Tablewe can see that scenario 1(ORPs) and 3(GC-KICs) are assessed most positively. In a way this is not surprising , as both scenarios both explicitly developed as new ways to effectively address Grand Challenges. However the other scenarios all have strengths too. For researching certain types of high-tech solutions scenario 4 (KVCs) can be effective. The KPs scenario could provide ways to *co-define priority setting* of types of research for complex global challenges (types of solutions: low-tech, high tech, based on what epistemology) . The RC scenario enriches the R&I system with highly creative research entrepreneurs. They not only provide an easy fit with society's knowledge demand, but also are most likely to come up with highly creative solutions that may even transcend vested interests of stakeholders. Below we will summarize the policy issues that we identified to be important for addressing Grand Challenges, both for robust and flexible policy options.

Robust policy options for addressing GCs:
Based on the analysis of the main features underlying the assessment as presented in Table, we can identify some robust policy options that steer the today's R&I system towards a system that is capable of addressing various types of Grand Challenges and to produce socially robust solutions. Above all, effective GC research for complex wicked challenges is highly endorsing the Responsible Research and Innovation (RRI) goals, and are in principle anticipatory, reflexive, deliberative and responsive)

- *Types or research*:
    - CGs research needs facilitation and stimulation of interdisciplinary and socially responsible research and innovation..

    - Not only agenda setting for types of research that are legitimized by aiming to contribute to GCs is important but also the close collaboration with civil society actors.
    - A mix of both high tech oriented and sociotechnical oriented research is needed. Facilitate in the especially in the latter co-creative modes of research.
    - For global complex challenges a policy to enable 'glocalisation'of R&I practices is an important robust policy option. Here localized sociotechnical experimentation is embedded in global networks for knowledge transfer and social learning.
- *Key players*:
    - Increase influence of civil stakeholders in decision making on and practice of GC research. Further engagement and participation of citizens (grassroot movements and citizen scientists. In two positively assessed scenarios (KP & GC-KICs) civil society actors were key actors to initiate the transformation.
- *Legitimization*:
    - Endorse development of competences and skills of citizens and civil groups, e.g. in the engaged university, to become engaged in GCs research.
- *Funding:*
    - Facilitate and stimulate multiple new types of funding (crowd funding, charity funding, etc).These new types of yet all share an underlying mechanism: high social involvement and societal legitimization
    - Stimulate forms of democratic decision making on public GC research funding stimulates socially robust solutions for the challenges
- *Research careers & competences*:
    - Overall there is a need for revision of current NPM oriented governance of universities and public research institutes towards broader criteria of academic quality.
    - broadening of academic skills with multidisciplinary, multicultural collaboration, entrepreneurial and reflexivity skills.
    - Diversifying career paths for researchers especially towards mediator (science-society) positions
- *IPR regimes*:
    - Policy is aimed to stimulate open knowledge & open data, with access for all.

Flexible policy options for addressing GCs

These policy options tend to occur only in one scenario but can advance addressing GCs in an effective way:

- *Type of research*:
    - The stimulation of fair science, slow science, epistemic heterogeneity
    - Stimulate creative autonomous science entrepreneurs to come with creative solutions.
- *Key players*:
    - To decide on research agendas for wicked complex global GCs new global procedures like the KPs can help *co-defining* research priorities.
- *Legitimization*:
    - Open knowledge markets can facilitate GCs demands
- *IPR regimes*:
    - Tailored decision making on IPR with fair deliberative procedures (fair IPR).

Some cross-cutting observations

The first thing to signal is that only one scenario is positively assessed for all dimension for all three R&I policy goals: scenario 3 GC-KICs. One can conclude that this scenario represents an interesting path for EU R&I policy to focus on. This conclusion, however, would do injustice to the various opportunities that the other scenarios offer. As the RIF scenarios provide glimpses into a multidimensional future space, they may well co-exist and present an challenging R&I future for specific scientific domains. The scenario 3 GC-KICs is quite suitable for Grand Challenges that allow a local approach (e.g. aging or energy supply), yet, for specific complex global challenges that too may be subject to high contestation (e.g. global warming) this scenario is not the most suitable one. Here scenario 1 (ORPs) or 4 (KVCs) would be better options.

A second point to signal is that ERA goals are least endorsed by the scenarios compared to RRI and Grand Challenges. Earlier, we discussed the underlying reasons: the globalization and recontextualisation of Research and Innovation. If ERA goals would be redefined towards these new settings, new opportunities for strengthening would occur.

Thirdly, we can see that the 4th scenario on KVC has most negative assessments of the five scenarios, especially for the RRI goals the assessment is negative, contrary to the other four scenarios. This bias of scenarios towards positive assessments, is likely a product of the specific scenario methodology used in the RIF project. The transformative scenarios were built around tensions that are currently at stake in the R&I system. The transformations aimed to solve these tensions. It is likely that these solutions are quite in line with favorable conditions for RRI and Grand Challenge goals.

Yet more important than this general discussion on the scenarios are the underlying challenges for current policy to head towards the positive assessed features of future R&I landscapes. In the prior three chapters we have already presented robust and flexible policy options for addressing the three policy arenas (RRI, ERA and GCs) in a separate way. We already noted that these three arenas in practice are closely intertwined, especially RRI and GCs goals. In the next section we will align and synthesize the three fore-mentioned clusters of policy options into the six packages for strategic action.

1.3.5 Strategic packages and policy challenges

The last step in this deliverable a synthesis of the three sets of policy options related to the three main European R&I policy goals. The structuring of this synthesis will be done along the six strategic packages that were developed in close collaboration with RIF colleagues of WP4.[5] The six themes are presented in figure 5.

Figure 5: Themes of Strategic Packages for Policy Action

We can see that three of the core dimensions that we used in our scenario implication assessment are directly represented in three packages. These are research careers, funding modes and IPR regimes. The other three dimensions (type of research, key players and legitimization) are embedded in more the more thematic packages "Science with and for Society", "Towards the governance of science infrastructures 3.0'and "EU and national Policies on globalized R&I futures". These themes came to the fore also in the prior scenario assessment.

Below we will provide a short description of each of the six clusters and subsequently elaborate the main policy challenges that we identified under each package. These main challenges are not intended to cover all the prior identified robust and flexible policy option, but to highlight some key messages. For more detailed issues relevant for policy we refer to the findings as presented in the chapters 4, 5 and 6.

[5] See RIF Deliverable D4.3 Strategic options for policy and action (www.rif2030.eu).

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 research funds and execution of research. Multiple actors and stakeholders coproduce knowledge to effectively address inherently complex grand challenges. Setting up mechanisms, processes and structures to enable a two – way dialogue with society is as important as conducting research that is both of high quality and high relevance to societal challenges. This also entails the need for new ways to evaluate diverse knowledge claims and epistemic cultures.

Main policy challenges:

- Strengthen 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, such as in the third pillar of Horizon 2020.

- Exploit and develop heterogeneous and localized knowledge should be developed and exploited to realize smart, sustainable and socially inclusive solutions for the societal challenges. This asks for policies that necessitate the blurring of traditional boundaries between science and society, among scientific disciplines, and across governance levels.

- 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. Our understanding of these new experimental forms of R&D is still very limited, yet very important, for instance in the context of European Innovation Partnerships and EIT-KICs.

- Revisit the science - society contract (e.g. public engagement and in case of controversial knowledge: deliberation/consensus conferences). In public funding programmes the societal orientation should become an integral part of the definition of excellence (assessed by involving societal actor in ex ante and ex post evaluations). Open hubs for science could be stimulated.

Research 3.0 careers: new competences and commitments
Careers and competences of scientists will change drastically. 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, individualisation and the changing position of universities are important drivers for research 3.0 careers.
In most scenarios, the very concept of 'university' will unravel 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. Who will take care of this process of differentiation (just "the market"?), how conscious are key actors of this dynamic? What does this process imply for teaching and academic careers?

Main policy challenges:

- Keep 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 evaluation the quality of researchers and research groups are needed that also capture the societal value of the research.

- Rethink science education (new competences and motivations), and provide new incentives for scientific careers (broadening criteria for excellence as well as types of affiliation to institutions). Open up universities for civil groups and different epistemic cultures. Foster creativity and playful experimentation in everyday life to avoid a creativity divide.

A distributed and diversified research funding landscape

In all scenarios, in different ways, representativeness of societal concerns appears to be an issue: Which actors will be involved in shaping the agenda of publicly funded research? How "democratic" or legitimate is this process? 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.

Main policy challenges:

- Stimulate heterogeneous sources of funding: public, private and civil. Direct civil funding (e.g. crowd sourcing) and direct involvement in decision making on research agenda and funding by citizens increase the societal legitimization of science.

IPR and open access of knowledge.

IPR issues have to be examined under the principle of "Responsible Research and Innovation" directing private interests towards the public good with respect to the environment and societal needs through fair representation and active engagement of all stakeholders. The specific issue addresses the 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 research and innovation.

Accessibility of scientific and other forms knowledge is a core policy challenge for all scenarios striving towards democratization of science. Open access of publicly funded research is the minimal policy option, a post IPR landscape is the most radical option.

Main policy challenges:

- Stimulate and facilitate fully (global) *open access* of publicly financed research. Formalize the role of the Global Research Council

- Develop sophisticated and intelligible policies dealing with intellectual property in research fields that generate tensions, e.g. industry interests vs. societal interests.

Towards the governance of science infrastructures 3.0

While access to infrastructure is important across all the scenarios, open access needs to apply a differentiated approach depending on the type of research conducted and/or the scientific issues being dealt with.

Main policy challenges:

- Facilitate and accommodate new types of online research communities that rise through the opportunities offered by new developments in ICT and social media (Science 2.0). 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.

- Ensure data security in response to ethical, legal or social issues addressed by society or to avoid misuse by confrontational groups. Issues such as big data management and ensuring scientific quality also become crucial.

EU and national policies on globalized R&I futures

With the rising power of other world regions and the changing world order, is there a need to look beyond ERA goals? What alliances are to become necessary in dealing with certain global challenges? What would this imply for the EU R&I policy and its internationalization?

Main policy challenges:

- Enable "glocalization" of research and innovation 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.
- Create global platforms enabling the design and funding of Framework Programme-like and ERC-like global efforts to support high-level and creative research and innovation projects, guided by RRI and aiming at addressing the Grand Challenges.

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