The challenge of addressing Grand Challenges

A think piece on how innovation can be driven towards the "Grand Challenges" as defined under the prospective European Union Framework Programme Horizon 2020

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1. Introduction: the need to anticipate transformations

The orientation towards Grand Challenges[1] creates a challenge for science, technology, and innovation (STI) policies and practices as we know them, because they are of a different kind than usual STI policy concerns. Grand Challenges are sometimes seen as priorities for R&D and innovation stimulation, and treated that way, say, through dedicated public funding. But they should rather be seen as open-ended missions, and missions concerning the socio-economic system as a whole, even inducing (or requiring) *system transformation*. Thus, Grand Challenges are ambitious, but not in the way the Manhattan Project (to develop an atom bomb) and the Apollo Project (to put a man on the moon) were. There, the challenge was technical (and organisational), and whether the goals were achieved or not was unambiguous. Grand Challenges, though, pertain to heterogeneous elements and forces, which have to be mobilised, guided and integrated, and include social innovation. Many different actors need to be involved, and the perspectives on what is the problem and what constitutes its resolution differ across various societal groups. Also, we see both *"drivers of novelty and innovation as well as processes of capture and co-optation … involved"* (Kallerud et al. 2013, 4)[2], so Grand Challenges policies have to cope with contestation, non-linearity and bifurcations in developments. This is not a message of despair, but it does imply that our present understandings and practices of STI policy[3] are not sufficient to address Grand Challenges and set priorities accordingly.

These considerations are not new, but need to be kept in mind so as not to fall back on earlier approaches to which present institutions and infrastructures are still largely oriented. There have been several attempts to understand and improve the governance of Grand Challenges. The 2012 Report *"Investing in Research and Innovation for Grand Challenges"* to

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[1] The European Union is focusing in six Grand Challenges: Health, demographic change and wellbeing; Food security, sustainable agriculture, marine and maritime research and the bio-economy; Secure, clean and efficient energy; Smart, green and integrated transport; Climate action, resource efficiency and raw materials; Inclusive, innovative and secure societies.

[2] Kallerud, E., et al. (2013): *Dimensions of research and innovation policies to address grand and global challenges*; Eu-SPRI Forum Position Paper of the project "The emergence of challenge-driven priorities in research and innovation policy (CPRI)" (http://www.euspri-forum.eu/key_missions/CPRI_Position_paper.pdf)

[3] See for example the excellent 2013 NESTA/MIoIR *"Compendium of evidence on the effectiveness of innovation policy"* (http://innovation-policy.org.uk/compendium/).

ERAB did a good job, in particular with its emphasis on concerted action and adaptive programming.[4]

Other discussions in the literature show limitations, and it is instructive to identify them so as to be able to do better. The special issue of *Research Policy* on a new generation of policy instruments to respond to the Grand Challenges reiterates the basic point that *"Manhattan and Apollo are not the right models for new programs aimed at the challenges we now face"*, and suggests that a *"range of existing mission oriented R&D programs can provide useful guidance for the design of new programs aimed at these challenges"* (Foray et al. 2012, 1697).[5] The authors do come up with some valuable insights, for example when discussing agriculture, but do not adequately address the pervasive and potentially transformative character of many of the Grand Challenges:

- First, the authors focus on R&D, and on funding (and more broadly, support of) R&D, while the government role should be conceived broader, certainly when addressing Grand Challenges. In particular, governments should facilitate as well as orchestrate relevant initiatives of actors in society, economy and science, for example by creating and/or enabling spaces for interaction towards innovation.[6]
- Second, a strong distinction is made between public and private funding, with only passing reference to public-private programmes. There is little or no consideration of the role of other actors, especially charitable foundations.[7][8]
- Third, and in spite of the distance the authors want to create to big mission-oriented programs, the recurrent perspective is on designing to achieve a mission. We will come back to this limitation, but note here that there are alternative approaches, such as 'tentative governance' which are suited to situations where the mission is open-ended and will evolve over time, partly because of the work that is done to address the challenge. The notion of 'tentative governance' captures *"provisional, flexible, revisable, dynamic and open approaches that include experimentation, learning, reflexivity, and reversibility"*.[9]

[4] This report to ERAB (2012) distinguishes three modes of addressing Grand Challenges: policy mainstreaming, jumping to S&T, concerted action. Another item is their emphasis on having an independent agency responsible (this is linked to their interest in the concerted-action mode) plus the need for responsive and adaptive programming (see http://ec.europa.eu/research/erab/pdf/erab-study-grand-challanages-2012_en.pdf).

[5] See D. Foray, D.C. Mowery, R.R. Nelson, Public R&D and social challenges: What lessons from mission R&D programs? *Research Policy* 41, Issue 10, December 2012, Pages 1697-1702, ISSN 0048-7333, http://dx.doi.org/10.1016/j.respol.2012.07.011.

[6] Rip and Joly, and their report to EU-SPRI Forum, develop the notion of 'spaces' in science, technology and innovation policy, and their emergence and intentional creation, using EU Framework programs like BRITE and EURAM in the early 1980s as one of their examples (following the studies by Edler). 'Spaces' are a non-traditional policy instrument, and are definitely a way to address the transformative aspect of Grand Challenges (see http://www.euspri-forum.eu/key_missions/rip_emerging_spaces_and_governance.pdf).

[7] Except for the paper of Wright, B.D. (2012): Grand missions of agricultural innovation, *Research Policy* 41 (2012) 1716– 1728. The paper discusses the important role of the Rockefeller Foundation.

[8] But (OECD, *The OECD Innovation Strategy. Getting a Head Start on Tomorrow*; 2010: 181). It is an issue of "empowering new players": "Non-governmental organisations, private, often philanthropic, foundations and social entrepreneurs which often are driven by non-profit motives can play an important role in catalysing innovation to solve social problems that are insufficiently addressed by governments or the market."

[9] Kuhlmann, S., Stegmaier, P., Konrad, K., Dorbeck-Jung, B. (2012): *Tentative Governance—Conceptual Reflections and Impetus for Contributors* to a planned Special Issue of Research Policy on "Getting hold of a moving target—the tentative governance of emerging science and technology".

Through this brief exercise, we indicated important building blocks to address the orientation on Grand Challenges productively. Further building blocks have to do with the necessary long-term perspective, and with the recognition that addressing Grand Challenges through innovation has to work with a more complex notion of innovation than is usual. Policy instruments, and more generally, policy approaches, tend to be defined and studied in terms of the current R&D and innovation system (and are occasionally shaped to work at the system level).[10] But in a longer-term perspective, the R&D and innovation system has to be seen as evolving itself, and perhaps undergoing transformative changes. Thus, there is another Grand Challenge: how to modulate such R&D and innovation system changes so that Grand Challenges can be addressed productively.[11] The evolution of R&D and innovation systems is the result of many interfering forces, among them the introduction of an orientation on Grand Challenges and the way these are being perceived, debated, negotiated and finally defined by relevant actor groups in science, society, economy and politics.

The strategic initiatives required to address a particular Grand Challenge will depend on its "nature" (quotes because the nature is not given beforehand), and on what relevant actor coalitions consider as key points of leverage: social issues and innovation, natural phenomena, lack of advanced or even breakthrough scientific knowledge, new forms of doing science, better and innovative technologies. As the definition and further articulation of Grand Challenges are a result of social perception, communication and negotiation, this also holds for key points of leverage – hence of the kind of policy approach: a matter of more or less deliberate choice. For example, it makes a difference whether the challenge is seen to derive from more or less inevitable developments so that one has to go for *adaptation* measures, or whether its sources can be influenced, so that *mitigation* measures are also in order. (This terminology is used for climate change, but can be applied more widely.) Another feature is whether the Grand Challenge is about desirable development (like better agriculture, integrated in the environment and in new transport and production structures) or avoiding undesirable developments (like shortages of energy or clean water).[12]To take this into account, one approach is to develop *scenarios* to explore such potential changes.

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[10] An overview and identification of system-changing policy options is offered by Smits, R.; Kuhlmann, S.; Teubal, M. (2010): A System-Evolutionary Approach for Innovation Policy. In: Smits, R.; Kuhlmann, S.; Shapira, P. (eds.): *The Theory and Practice of Innovation Policy. An International Research Handbook*, Cheltenham, UK (Edward Elgar), 417-448; cf. their Table (p. 432).

[11] The notion of such "another Grand Challenge" was introduced in Rip (2011) and developed through a scenario in which the present "race" for excellence in science collapsed under its own weight, and the race for promising high tech developments was modified by requiring attention to actual applications and their embedding in society. One can entertain the possibility that in such a transformed system there might be a another race, the race to address Grand Challenges (Rip, A. (2011): Science Institutions and Grand Challenges of Society: A Scenario, *Asian Research Policy*, vol 2, issue 1).

[12] Kallerud et al. 2013, in their EU-SPRI Forum Report, offer an extensive discussion of the nature and status of Grand Challenges. They appear to be variations on a core list which is already visible in the Lund Declaration: "sustainable solutions in areas such as global warming, tightening supplies of energy, water and food, ageing societies, public health, pandemics and security.... turning Europe into an eco-efficient economy". Such lists can be further analysed in terms of the two dimensions identified above (degree of inevitability; (un)desirability). This will actually require in-depth studies – a further component of addressing Grand Challenges.

One implication that we can note here is that it may be more important to get Grand Challenges on the agenda of all relevant actors, than to try to find a one-fits-all policy approach.[13] If Grand Challenges require innovation, it may not only be innovation as traditionally studied and stimulated, but also novel ways of assembling and re-assembling heterogeneous bits of work (including traditional innovation) into evolving constellations that address a Grand Challenge, including modifying it. In the end, addressing Grand Challenges is about system transformations, and choices what entrance points to give priority.

All this has crucial implications for the way how policy makers (and implementers) and other actors should think of addressing Grand Challenges. In a nutshell, we suggest that one should go for appropriate *tentative policy mixes, also facilitating system changes* where relevant (for a particular Grand Challenge). The mixes may draw on classical priority setting and implementation approaches, on transformation in science (systems) or breakthrough innovation, and demand-side and procurement policies, but will have to focus on system-oriented strategic interventions, tentative and experimental in design, including out-of-the-box approaches like new combinations of actors and alliances.

Given the limited time and resources that could be spent on this study, we decided to focus on interesting present trends and possible future developments, rather than offer comprehensive reviews of past experience which may not be relevant to current challenges of addressing an orientation on Grand Challenges. In Section 2, we will discuss potential contributions from business-as-usual innovation policy approaches), and recent policy developments. In Section 3, we will address options and limitations of existing priority setting and innovation stimulation approaches. To illustrate our approach we will include a possible scenario. In the concluding section, we will collect and discuss policy recommendations.

2. Options and limitations of existing priority setting and innovation stimulation approaches

Chapter 2.1: "Business as usual" priority setting procedures

Most of the procedures and practices of priority setting focus on R&D rather than innovation. "Business as usual" is decisionistic: the problem is seen as one of defining and articulating priorities (often in consultation). Their implementation and realisation is then a matter of creating financial and other incentives. The actual dynamics are more complex, however. Innovation stimulation is often limited to general measures (fiscal measures, innovation-friendly climate). There are attempts to be more directive, e.g. in the health sector, in the energy sector. There can be government-funded projects, there can be procurement, and there can be delegation to parties (consortia) of relevant actors (cf.

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[13] One example is how Grand Challenges can give rise to new scientific fields like 'ageing society research' (not a traditional scientific field, but an interorganisational field dedicated to knowledge production and use, cf. Rip, A., Voss, J. (2013): Umbrella Terms as Mediators in the Governance of emerging Science and Technology *Science, Technology & Innovation Studies*, Vol. 9, No. 2, ISSN: 1861-3675).

Netherlands Top Sectors, see below). There was an earlier tradition of identifying key technologies (US, France); a key word now is "emerging technologies".

In Germany, business-as-usual procedures included: In case of problem and/or industrially oriented research and innovation funding, the funding body (e.g. ministry, public agency) would develop thematic programmes (drawing on strategic intelligence-based information on technological or sectorial strengths and weaknesses, foresight exercises, brainstorming events with key science, industry and society stakeholders), launch public calls for proposals, organise proposal appraisal and selection procedures with the help of independent experts, etc. (see practices of the German Federal Ministry for Education and Research, BMBF: http://www.foerderinfo.bund.de/en/166.php). Selection decisions are then made against the following criteria: Degree of innovation - how innovative is a project from a scientific or technical perspective? Utilization - how can the prospects of success be assessed? With technological developments, is there a utilization strategy? Avoidance of double funding - has funding already been provided for the project idea? (see http://www.bmbf.de/en/1398.php). These procedures can address open-ended missions to some extent, but have problems in taking transformative changes into account.

In the Netherlands similar procedures were and are in place, for example in the Innovation-Oriented Research Programs (IOP). The Knowledge Infrastructure Program was oriented to societal challenges, but relied on bottom-up proposals for funding, and worked that way, strengthening the existing system (even if there were new initiatives, for example about sustainable transition management). Recently, the government revamped its overall S&T policy framework by focusing it on so-called top sectors in the Dutch economy and society (http://topsectoren.nl/over-topsectoren). The articulation of priorities was delegated to standing panels of stakeholders (selected by the government). While the actual implementation of priorities still depends of initiatives of various relevant actors, there is some system change in the sense that traditional institutions and ongoing programmes now refer to the top-sector policy. Up to the division of humanities of the national research funding agency NWO producing a memorandum on their contribution to top-sector policy.

Chapter 2.2: Beyond "Business as usual"

Procurement has been important in the defense and now also the security sector, based on negotiations in the military-industrial complex about what is promising and what is feasible. Procurement is now pushed as an approach in the civilian sector, to realize public goods[14]. Because procurement involves a contract relationship, the deliverables have to be specified. This may be difficult for Grand Challenges where it is not clear what the requirements for new knowledge and new artefacts are. Still, it might be possible to define functionalities, and support public and private actors to deliver on such functionalities.[15] A further mode of

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[14] See NESTA/MIoIR *"Compendium of evidence on the effectiveness of innovation policy"* (http://innovation-policy.org.uk/compendium/), Report 13 on Review of Pre-commercial Procurement Approaches and Effects on Innovation.

[15] For emerging technologies, this would be a way to support their development. Such a possibility has been explored for Organic Large-Area Electronics with the help of scenarios. (See Alireza Parandian and Arie Rip, Scenarios to explore the futures of the emerging technology of organic and large area lectronics, *European Journal of Futures Research*, Vol. 1, Issue 1. Published online 13 July 2013, DOI 10.1007/s40309-013-0009-2.)

pushing desirable innovation is technology forcing through regulation, as in the California Clean Air Act, where requirements were set for clean-exhaust motor cars without specifying how companies should meet these requirements. In the real world, such technology forcing may not be effective, but overall societal pressures may help, as in the example of clean motor car engines.

This last consideration indicates the importance of diffuse articulation of priorities and agenda setting in society, including credibility pressures. One example is so-called green energy, and companies compete, at least in their advertising, to show that they are concerned, and work towards green energy[16]. Green energy can be viewed as a Grand Challenge. For other, more complex Grand Challenges, agenda setting in response to credibility pressures will be less straightforward. Also because new knowledge may be needed to understand what a Grand Challenge is actually about.

Here, we are moving away from a focus on government and its responsibilities to consider the possibility of challenges (Grand or otherwise) being taken up in the R&D and innovation system. This is important because most of knowledge production and innovation take place outside the sphere of direct influence of government agencies.

Concertation is still possible to some extent, for example through road mapping. While road mapping can be used by public agencies, for example US National Institutes of Health, itis commonly a public-private undertaking (for example, in the European Technology Platforms). Road mapping exercises do require a prior definition of the goal to be reached, but the actual exercises tend to discuss the nature and values of these goals as well. Thus, road mapping might be useful to address Grand Challenges, not just to specify how to get there, but also to help to articulate what the Grand Challenge might be.

Chapter 2.3: Concerted policy initiatives

One can learn from historical attempts to tackle "Grand Challenges", for example the United States "grand missions" and the related international efforts that led to the yield increases in wheat and rice, i.e. the "Green Revolution."[17] While government agencies played an important role, they were not the only ones. Big (charitable) foundations like the Rockefeller Foundation were important as well: they serve the public interest, but could define it in their own terms, and their officers could take initiatives without bureaucratic and democratic constraints.[18] In the UK, the Wellcome Foundation (with a budget larger than the Medical Research Council) could and did take initiatives for innovative R&D and demonstration approaches. When the challenges are mostly technical, concerted action can also be realised in the private sector, in spite of competition. An interesting example is the Catalytic Research Association, established in the late 1920s by oil and chemical companies to develop heterogeneous catalysis, a challenge at the time to crack oil into useful components.

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[16] See footnote 14.

[17] Wright, B.D. (2012): Grand missions of agricultural innovation, *Research Policy* 41, 1716– 1728

[18] For example, Warren Weaver at the Rockefeller Foundation in the 1930s and 1940s, pushing the emergence of what is now called molecular biology.

While the role of (charitable) foundations has been important for a long time, recently they are becoming more visible and pro-active, e.g. the Bill and Melissa Gates Foundation with its focus on health challenges in developing countries.

It is against this backdrop that we have to consider governmental concerted policy initiatives.

An interesting example of a concerted major policy initiative is the German Federal Government's "High Tech Strategy". In 2006, the German government decided to focus a variety of existing policies and instruments, run by different ministries and agencies, together under the umbrella of one integrative High Tech Strategy (HTS). *"Originally a main initial goal was to contribute to higher R&D spending through increasing public R&D and incentivising private R&D in a more coordinated manner (…). Over the years, however, a more strategic definition of goals was developed, with buy-in from a range of departments and a more fine-tuned, pro-active design of instrument mixes. In 2012, an action plan (until 2020) was agreed at Cabinet level, giving a clear signal that the approach would be continued and broadened for the longer term. It included 10 "future projects", derived from clear societal needs, but defined broadly enough to allow for flexibility and inclusion. The policy mix was not, therefore, designed from scratch, but evolved from existing bundled activities that were, over time, connected together more systematically against defined goals"* [19]. An assessment of the HTS found that "effective and substantial coordination among R&D policy activities of different agencies (i.e. Federal Ministries) as well as joint development of a policy strategy and measures that integrate existing policy actions can take place", in particular because of *"high-level political backing and additional funding: the initiative had backing from the Chancellor and was decided in the Cabinet"*; effective partnership between ministries and agencies; precise measures, clearly defined actions; effective links to other policy initiatives; and successful involvement of industry (Rammer 2009, 30) [20].

Relevant is also the priority setting approach of the European Innovation Partnerships, e.g. the one on Active and Healthy Ageing: ERAB Final Report, p.6: "*The governance and management of the organisations set up to drive Grand Challenge programmes will be crucial to ensure the commitment of all partners and the alignment of their instruments towards a common funding goal. In the same spirit as the debate on the establishment of European Innovation Partnerships (EIP), this should be the task of independent mission-driven agencies which are accountable for the agreed strategic objectives. These agencies should be run at arms-length from the EC and Member States, offering a platform where stakeholders engage in a real dialogue.*" The EIP website says: "*This will be realised in the three areas of prevention and health promotion, care and cure, and active and independent living of elderly people. The overarching target of this partnership will be to increase the average healthy lifespan by two years by 2020. The Partnership aims to achieve this by bringing together key stakeholders (end users, public authorities, industry); all actors in the innovation cycle, from research to adoption (adaptation), along with those engaged in standardisation and regulation. The pilot partnership provides these actors with a forum in which they can cooperate, united around a common vision that values older people and their*

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[19] See NESTA/MIoIR *"Compendium of evidence on the effectiveness of innovation policy"* (http://innovation-policy.org.uk/compendium/), here Report 19, "Innovation policy mix and instrument interaction".
[20] Quoted in NESTA/MIoIR Compendium Report 19, 30ff.

contribution to society, identify and overcome potential innovations barriers and mobilise instruments" (ec.europa.eu/active-healthy-ageing).

Concerted action is necessary to address Grand Challenges, and governments should play a role. But they are not the only ones to play a role. Thus, they can focus on their specific priorities and attempts to implement them. But they also have an overall responsibility, for example to create spaces in which a variety of actors can come together and address the Grand Challenges[21]. This combination of roles will not be easy to effect (and justify) because it goes against traditional roles of government. On the other hand, the need for such approaches is increasingly recognized. One could call it "directed facilitation". Such approaches are explored more widely, they are not specific to R&D and innovation policy[22].

3. Transformative system-wide changes: a scenario approach

Given our earlier considerations, and including the ERAB (2012) report's arguments, it is clear that addressing a Grand Challenge requires *concerted action*. It is not so clear, however, what the nature and constellation of actors in such concerted action could be, and how this will differ depending on the nature of the Grand Challenge. In addition, Grand Challenges are open-ended, and to address them, *tentative governance* rather than a master plan is the appropriate approach. This is all the more important because the transformative system-wide changes are not limited to what the Grand Challenges are about, but also apply to the R&D and innovation systems that are mobilised to address the Grand Challenges (the "other" Grand Challenge). As the RIF project has shown,[23] the landscape of science and innovation is changing, within the coming two decades quite likely even substantially. For example, there will be new sponsors of science. And science institutions and their disciplinary organisation might be replaced, partly because of new ICT possibilities, by new (and evolving) knowledge production communities. Here, a scenario approach allowed to address the multi-actor and multi-level complexity of trends, tensions, and (transformative) change.

One of the five RIF scenarios assumes that, in about 15 years from now, all kinds of knowledge claims are raised and negotiated worldwide in the so-called 'Knowledge Parliaments'. Knowledge parliaments prioritize research topics and provide 'trading zones' in

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[21] Op. cit. above.

[22] E.g. John Grin, Francisca Felix, Bram Bos, Sierk Spoelstra (2004): Practices for reflexive design: lessons from a Dutch programme on sustainable agriculture, *International Journal of Foresight and Innovation Policy*, 126-149.

[23] RIF project – Research and Innovation Futures 2030: From explorative to transformative scenarios, see http://www.rif2030.eu/. The RIF project concentrates 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 challenges & opportunities that need to be addressed if STI is to continue to play a key role for society. These tensions may be tackled within the confines of current institutional settings, but they may also require a substantial transformation of our STI systems as well as of our research and innovation practices. RIF suggests five transformative scenarios: (1) Open Research Platforms - Self-governance in a decentralized research landscape; (2) Knowledge Parliaments – The free negotiation of knowledge claims; (3) Grand Challenges for Real – Collective experimentation in socio-technical labs; (4) Knowledge Value Chains – Research for innovation in a specialized and stratified research landscape; (5) Researchers' Choice – Autonomous researchers go for self-fulfilment and wellbeing.

which actors with particular research interests, topics and epistemologies collaborate and compete for support. Not only the building of research consortia that incorporate citizens, a variety of other stakeholders and epistemic cultures (e.g. lay and indigenous knowledge), but also the research processes and conceptions of research quality are freely negotiated by the power of the argument. Thus, neglected or under-represented research topics and unconventional knowledge domains can be brought to the fore.[24] Whether this scenario will come true is not relevant, but what we can see with the help of this reasoning is that priority-identification and priority-setting in research and innovation policies can take other ways and forms than known today: Relevant 'knowledge claims' and related needs for action and investment become co-defined, in a more or less dedicated way, by actors beyond classical research and innovation policymaking.

This scenario is about knowledge production (scientific and more broadly). The scope of the 'Knowledge Parliaments' could be extended to include Grand Challenges The approach required to identify and to address Grand Challenges is to "assemble", to create a more inclusive, socio-technical system-oriented approach, embedding policy action in society. This can be achieved in several complementary ways. First, by making sure that key actors are involved, which implies that actor consortia should be public-private, including charitable foundations playing a key role, because they are free to move, and tend to go for public interest goals. Second, economic and social aspects and changes are a key part of addressing Grand Challenges, so social innovation must be included. Third, intermediary organisations and spaces for interactions are important to enable and improve concerted action without having a master plan. In the course of such developments, existing organisations may transform themselves. For example, research funding agencies may play more than their traditional role of funding research proposals, now adding reference to a Grand Challenge. They could adopt a central role in defining and/or managing a concerted action (there are precedents, including the way US universities can have contracts with the Department of Defense to manage a public research lab of the Department). Such a role would require new capacities/competencies, so learning and transformation would be necessary.

As an illustration of the approach, we offer a scenario. The starting situation is one where existing ST&I policies and instruments are mobilised to address Grand Challenges in the new public management style of specifying objectives and monitoring performance. The responsibility to address Grand Challenges is seen to ly with governments (at different levels) and their funding and supporting of ST&I. The present version of EU's Horizon 2020 exemplifies this. Other actors are included as needed for the necessary concerted action, but governments remain accountable for the progress in addressing the several Grand Challenges.

Governments cling to this approach, and for good reasons, but already in the first few years it becomes clear that they cannot meet the essential complexities of Grand Challenges (it is not a matter of setting priorities and have them implemented), and are also faced with transformations of science: re-contextualization of science in society, and the growing importance of new sponsors of science. The first-round response of governments worldwide, under pressure to limit expenditures because of the continuing crisis, was to give up on

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[24] See RIF Deliverable D2.1: *Modular Scenario Report – Synthesis New ways of doing research: from explorative to transformative scenarios* (http://www.rif2030.eu/wp-content/uploads/2013/09/RIF-D2-1-Scenario_Report-Synthesis-20130515final-2.pdf; approached Jan 13, 2014).

major funding of ST&I. There were additional arguments about 'government deficit' and the importance of delegation to relevant actors, the key push was to further reduce public funding of STI. This then opened up new ways to enact responsibility for addressing Grand Challenges. The Grand Challenges can be implemented through public-private set-ups, charitable foundations and some firms, joining consortia for Grand Challenges.[25] Ongoing changes in the research and innovation landscape kicked in, in particular how research organisations (funding agencies supporting concrete research, public research organisations and even universities) shifted their focus to include research assemblage (e.g. towards a societal need) rather than just performing research. Compare the move in the automotive manufacturing sector to assemble cars to as a service to customers. Governments articulating goals/priorities and trying to get them implemented can assemble what they consider important and making a difference, rather than trying to select and support research performance. Following this scenario, by the late 2010s, addressing Grand Challenges had moved from a government responsibility to an integral part of the functioning of R&D and innovation systems – which had been transformed themselves, including new sponsors and new performing actors.

In view of such a scenario it becomes clear that major public-private initiatives aiming to cope with the transformative potential of a Grand Challenge need a 'tentative' concept of governance: Governance is tentative "when it is designed, practiced, exercised or evolves as a particularly dynamic process to manage interdependencies and contingencies in a non-finalizing way; rather prudent (e.g., trial and error, or learning processes in general) and preliminary (e.g., temporally limited) than prescriptive and persistent. 'Tentative governance' plays with flexibility and acts incrementally (…). The notion of 'tentative governance' typically aims at creating spaces of openness, probing and learning instead of trying to limit options for actors, institutions and processes (…). It answers political and organizational complexities and uncertainties with explorative strategies, instead of relying only on orthodox or preservative means."[26]

4. Policy options and recommendations

There are no straightforward recommendations, because addressing Grand Challenges is open-ended and part of overall changes. Systemic and tentative policy mixes, in a way patchworks including other actor's activities rather than just those of policy makers, are called for. And these will be different for different Grand Challenges.

One should go for appropriate tentative policy mixes, also facilitating system changes where relevant (for a particular Grand Challenge). The mixes may draw on classical priority setting and implementation approaches, on transformation in science (systems) or breakthrough innovation, and demand-side and procurement policies, but will have to focus on system-oriented strategic interventions, tentative and experimental in design, including out-of-the-box approaches like new combinations of actors and alliances.

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[25] The European Joint Technology Initiatives could be seen as a precedent, even if these focus on STI supply rather than societal needs.

[26] Kuhlmann et al. (2012), op.cit.. See also Lindblom, Ch.E./Woodhouse, E.J. 1993: *The Policy Making Process*. Prentice Hall; Hoppe, R. (2010): *The Governance of Problems—Puzzling, Powering and Participation*. Bristol; Voss, J.-P., et al. (eds.) (2006): *Reflexive Governance For Sustainable Development*. Cheltenham: Elgar

Addressing Grand Challenges includes what we called the other Grand Challenge of transforming R&D and innovation systems. By now, it is clear that there is a further Grand Challenge: reconsidering the role of policy and policy actors. In the scenario presented in Section 3, the change towards a more distantiated and tentative role was made because predicated on other considerations (the need to withdraw from financial commitments). The further (final?) Grand Challenge then is to make this move independently from solving a budgeting problem.