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Grand Societal Challenges as a Topic for Science Policy

Position Paper

Preliminary remarks

Grand Societal Challenges are the subject of an extremely heterogeneous science-policy discourse in which many different stakeholders have an interest. For example, the term "Grand Societal Challenges" |[1] is used in programmes for research and innovation funded by the EU and at state level to refer to the contributions of science for society as a whole, to identify areas of action that are of particular importance for science policy, to describe the rationale for public funding of science and to formulate the expectations associated with this funding for recipients. In addition, scientific institutions and universities use this term to emphasise the societal relevance and the profile of their research work and to support their claims for resources. Although this term appears to be intuitively plausible and although various stakeholders list similar challenges, it nonetheless has various meanings and is open to interpretation.

This topic of Grand Societal Challenges is increasingly significant in terms of science policy and the expectations on the part of science. In response to this and to the multiple interpretations of the term as well as to the contributions that are planned by parts of the science community, the German Council of Science and Humanities (Wissenschaftsrat) is taking the opportunity to clarify the orienting function of Grand Societal Challenges as a topic for science policy. Additionally, it formulates desiderata for the approach taken by science and science policy to Grand Societal Challenges.

The Council appointed a working group in July 2012 which completed its work in April 2014. The deliberations of this working group serve as a basis for this position paper. The Council would like to thank Stiftung Mercator for funding this working group and the subsequent work on this position paper. The Council owes a particular debt of gratitude to experts who are not members of the Council but also participated in this working group. It also thanks those experts from Germany and abroad who supported the working group with their opinions and insights. This position paper is the result of numerous lively

| [1] In the discussion that follows, statements that are made about the definition of this term or its everyday use are placed in quotation marks so as to emphasise the difference between discussions of the use of the term and the use of this concept as understood in this position paper.

discussions of the Council. The complexity of these discussions gives evidence to the contentiousness of this subject and to the necessity to clarity the openness and the resulting significant freedom of interpretation of the term for the differing interests of stakeholders in science, science policy, and also in the democratic public sphere and the media.

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A. Context and characterisation

A.I HISTORICAL CONTEXT OF THE DISCOURSE ON GRAND SOCIETAL CHALLENGES

The current discourse in science policy on Grand Societal Challenges originates in a number of issues. First of all, it follows on from developments in research and innovation policy. In the 1980s and 1990s, the focus of innovation policy shifted from selecting specific topics for funding to improving the characteristics of the innovation system in a subject-neutral way. The Organisation for Economic Cooperation and Development (OECD) played an important role in this debate by taking up the issue of national (and sectoral) innovation systems in innovation research. Around the turn of the millennium, thematic priorities received more attention again, although the topics were very broadly based and were not focused on individual technologies or major projects. One example here is the discussion concerning green growth, which initiated a focus on establishing strategies to promote environmental technologies in many national funding systems. |2 These strategies make use of many ideas and elements of the innovation system approach – such as the coordination of measures and activities along the entire innovation chain (from research funding through to market entry), the establishment of networks and the promotion of interactions between various stakeholders in the innovation process |3. Another root of the discourse about Grand Societal Challenges is the issue of climate change, which is increasingly perceived as a threat. As a response to this, climate research began to be established in the 1980s and quickly became a recipient of theme-oriented research funding. In addition, an intensive discussion about the relationship between science and society developed in asso-

| 2 For status information, cf. OECD (2012); JIIP (2012)

| 3 For the situation in Germany, cf. the first report of the Commission of Experts for Research and Innovation (EFI – Expertenkommission Forschung und Innovation, 2008) with its discussions of core tasks of the national research and innovation policy ("Solving general social problems") and the first edition of the "Hightech-Strategy"

ciation with climate research. At least since 2000, there has been a global discussion on how climate change and its consequences can be better mastered through increased or improved research funding or through specific changes in the relationship between science and society. The subject of this discussion was not just the question of suitable research and innovation policy strategies and instruments |[4], as a fundamental debate also developed on alternative research formats that explicitly target a new understanding of the relationship between science and society. This debate has some common ground with the contentious discussions regarding sustainability science, mode 2 knowledge production, transdisciplinarity and societal transformation processes. |[5] The "World in Transition" flagship report of the German Advisory Council on Global Change (Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen, WBGU) and the book "Transformative Wissenschaft" by Schneidewind and Singer-Brodowski can also be included in the context of this debate; both of these publications call for significant changes in the scientific system and in research practice. |[6] Grand Challenges in Global Health |[7], which was presented by the Gates Foundation in 2003, can also be regarded as pioneering in terms of the current science policy debate on Grand Societal Challenges; the term "challenges" refers here to very specific technological bottlenecks.

In 2008 and 2009, a number of innovation policy papers (cf. A.I.1) combined the various strands of this discussion with the new term "Grand Societal Challenges", which led to a comprehensive restructuring of European funding policy and, as a consequence, of various national funding policies. In 2012, these "Grand Challenges" were the subject of a comparative analysis by the OECD of the strategies and measures of various governments. |[8] Since then, support for contributions to addressing these challenges has been a target of research and innovation policy strategies and framework programmes for research in both

| 4 Cf. Mowery et al. (2010)

| 5 For information on the establishment of sustainability sciences, their core issues and research strategies, refer to Jerneck et al. (2011), Clark/Dickson (2003) and Kates et al. (2001). According to Gibbons et al. (1994), mode 2 knowledge production refers to a new form of scientific knowledge production that primarily aims to achieve robust knowledge that is of use to society. The fundamental thesis here is that knowledge is mainly produced in the context of applications nowadays and the boundaries between academic and other knowledge-producers are therefore blurring. Just like mode 2 knowledge production, transdisciplinary research is also associated with a focus by science on problems of non-scientific stakeholders. A critical examination of transdisciplinary and mode 2 knowledge production can be found in Zierhofer/Burger (2007).

| 6 For information on the debate on the concept of transformative sciences, refer to WBGU (2011), Schneidewind/Singer-Brodowski (2013), Stock (2014), Strohschneider (2014), Grunwald (2015)

| 7 Cf. www.grandchallenges.org/about/Pages/Overview.aspx (last accessed on 30/3/2015)

| 8 OECD (2012): "Innovating for global and societal challenges"

Europe and the United States. |[9] At the same time, the focus on Grand Societal Challenges has led to a range of changes in the German scientific system that go beyond establishing funding programmes and allocating funding. In the following discussion, the developments within European funding policy and in the German scientific system will be identified based on important innovation policy papers and the positions of central stakeholders. |[10]

I.1 Grand Challenges with focus on the European funding policy

I.1.a ERA Expert Group

A 2008 report by a European Union expert group on "Rationales for the European Research Area", which dealt with Grand Challenges as a motivation for European research and innovation policy and for corresponding investments, is regarded as particularly influential here. The report states: "The vision of the European Research Area presented in this report is founded upon the principle that the core objective should be to maximize the value contributed by research, today and into the future, to Europe's economic, social and environmental goals." |[11] and, later on, "[…] the growth of S&T in Europe becomes legitimate by demonstrating to the public and politicians that they make a key contribution to the problems that society recognises as central." |[12] According to the expert group, the challenges should be comprehensive and important enough to attract the attention of politicians and the public, to arouse the interest of science, industry and civil society, and to inspire young people. |[13]

I.1.b European Research Area Board (ERAB)

In 2009, the European Research Area Board (ERAB) |[14] first mentioned "an ERA driven by societal needs" and thus associated the creation of a European Research Area and the addressing of major "societal" challenges. In addition, the ERAB also identifies specific funding-policy goals: by 2030, the European Research Area should be structured in such a way that one third of public research spending is dedicated to research on Grand Societal Challenges and that 30 % of all researchers are trained in research fields relevant for these Grand

| 9 Cf. BMBF (2010), Bundesregierung (2013), Official Journal of the European Union (2013), Obama's 21st Century Grand Challenges (https://www.whitehouse.gov/administration/eop/ostp/grand-challenges) (last accessed on 30/3/2015)

| 10 For empirical information on this development, cf. Kallerud et al. (2013)

| 11 ERA Expert Group (2008), p. 8

| 12 Ibid., p. 36

| 13 Cf. ibid., p. 37

| 14 European Commission (2009)

Societal Challenges. The ERAB identifies the following Grand Challenges |[15]: "climate change, energy supply, water resources, ageing societies, healthcare"

I.1.c Lund Declaration

At around the same time as the ERAB paper, an important paper was approved under Swedish Council Presidency known today as the "Lund Declaration" |[16], in which science organisations, politicians and representatives from industry joined together to state that "Europe must focus on the Grand Challenges of our time". In this declaration, a range of demands are made that are still the subject of ongoing discussion: science must participate in the identification of these Grand Challenges and also in the search for solution strategies; all major stakeholders such as companies, public administration and civil-society organisations must be involved in this identification process; priorities in the funding of research and innovation should be based on Grand Challenges.

I.1.d Horizon 2020

In its proposal for the new Framework Programme for Research and Innovation, the EU Commission takes up the discussion on Grand Societal Challenges and restructures funding based upon three pillars: "Excellent Science", "Industrial Leadership" and "Grand Challenges". To emphasise the development in this strategy relative to previous programmes, the series is no longer being numbered sequentially – the last programme was referred to as the Seventh Framework Programme – and the Commission has called the new programme Horizon 2020. Of the overall budget of 78.6 billion euros – which will run from 2014 to 2020 – 29.7 billion euros, or almost 38 % |[17], have been earmarked for research to tackle Grand Societal Challenges; this line of funding thus has the largest share of the EU's overall research budget. Based upon intensive discussions with member states and numerous stakeholders in the European Research Area, Horizon 2020 |[18] identifies a very broad spectrum of topics as societal challenges: "Health, demographic change and wellbeing; Food security, sustainable agriculture and forestry, marine and maritime and inland water research, and the Bioeconomy; Secure, clean and efficient energy; Smart, green and integrated transport; Climate action, environment, resource efficiency and raw materials; Europe in a changing world, inclusive, innovative and reflective

| 15 European Commission (2009), p. 16

| 16 The Swedish EU Presidency Conference (2009)

| 17 http://www.kowi.de/Portaldata/2/Resources/Horizon2020/H2020-wp1415-Factsheet-budget-H2020.pdf (last accessed on 16/3/2015)

| 18 http://ec.europa.eu/programmes/horizon2020/en/h2020-section/societal-challenges (last accessed on 16/3/2015)

societies; Secure societies – protecting freedom and security of Europe and its citizens".

I.2 Grand Societal Challenges and the German scientific system

I.2.a The German Federal Government's High-Tech Strategy

Since 2006, the High-Tech Strategy has been the cross-departmental instrument for the coordination of the German Federal Government's research and innovation policy. It was first revised in 2010 with far-reaching changes. With its High-Tech Strategy 2020, the Federal Government aims to make Germany a leader in the solution of global challenges, which are described as the pressing issues of the 21st century. The focus on challenges and missions aims to provide impetus for stronger coordination of innovation-policy activities that go far beyond the confines of funding policy ("[translation by Wissenschaftsrat:] bundling of a variety of research and innovation activities across political fields and topics and across all departments" |[19]); this focus will also facilitate the implementation of this coordination in the political process. |[20] In the area of funding policy, the focus on missions has reinforced the already existing trend in favour of supplementing technology-specific initiatives with thematic framework programmes for research. The forward-looking projects represent a new feature in: taking societal needs and economic opportunities as their starting point. They aim to develop models and visions for future technological and societal developments. In turn, these models are intended to influence both funding policy and the independent activity of stakeholders in industry and science. Conventional processes involving laypersons or civil society are also among the instruments used by the German Federal Ministry of Education and Research (BMBF) in the area of these challenges. In the High-Tech Strategy 2020, the ministry identified the following global challenges: climate change, demographic developments, the spread of major diseases, securing the world's food supply, and the finiteness of fossil sources of raw materials and energy |[21]. These challenges serve as targets for the High-Tech Strategy. Also important for practical implementation purposes are the five areas of demand-

| 19 http://www.hightech-strategie.de/de/13.php (last accessed on 30/3/2015)

| 20 Cf. EFI (2011), p. 29: "Under the High-Tech Strategy 2020, innovation policy receives a stronger orientation to 'missions'. This means that it is oriented more strongly to major priority areas, rather than to specific technologies and research programmes, the previous main orientation. In comparison to the High-Tech Strategy 2006, the newly oriented High-Tech Strategy lends itself to greater public awareness and transparency within the political process. And it further enhances interdepartmental co-operation between different ministries."

| 21 Cf. BMBF (2010), p. 3

derived from these challenges (climate/energy, health/nutrition, mobility, security, communication) as well as ten forward-looking projects. |[22]

With the new High-Tech Strategy, which was approved in September 2014, all aspects of a comprehensive research and innovation policy are to be considered in an integrated manner. In so doing, the German Federal Government is employing a broader understanding of innovation "[translation by Wissenschaftsrat:] that includes not just technological, but also social innovations and […] which involves society as a central stakeholder". |[23] In contrast with the High-Tech Strategy 2020, which was structured for the tackling of global challenges, the new strategy concentrates "[translation by Wissenschaftsrat:] on fields that are characterised by major innovative dynamics and which promise economic growth and prosperity. And […] where we can achieve contributions to the solution of global challenges and thus create a better quality of life for every individual." |[24] The forward-looking projects are equal to those in the previous High-Tech Strategy. Greater importance has been attached to processes involving laypersons or civil society, which are one of the five core elements of the new High-Tech Strategy under the heading "Transparenz und Partizipation" (dialogue and participation).

I.2.b State-level policies

The concept of "Grand Societal Challenges" and the demands that result from the sustainability debate have been addressed by the science and research policies of the governments of several federal states. One example here is the "Forschungsstrategie Fortschritt NRW", the research strategy for progress of North Rhine-Westphalia. |[25] Grand Societal Challenges are used here as the rationale for focussing funding on certain thematic priorities, also with the aim of facilitating links with European research. This strategy identifies the following Grand Societal Challenges: climate change, environmentally compatible and affordable energy supply and mobility, increasing scarcity of resources, demographic change, and the decline in societal integration, solidarity and security in the context of globalisation and the Internet. |[26] In its sustainability strategy "Wissenschaft für Nachhaltigkeit", Baden-Württemberg also makes reference to addressing Grand Societal Challenges. For example, the recommendations of an expert group appointed by the Minister of Science made explicit reference to the Grand Challenges defined in the EU's Horizon 2020 Framework Pro-

| 22 Cf. Bundesregierung (2012)

| 23 Cf. Bundesregierung (2014), p. 4

| 24 Ibid., p. 5. Cf. HGF (2012)

| 25 MIWF NRW (2013)

| 26 Ibid., p. 11

gramme for Research. |[27] One focus of these recommendations, which are currently being implemented, is the establishment of real world laboratories "[translation by Wissenschaftsrat:] the task of which is to stimulate and accompany transformation processes to achieve targeted sustainable development." |[28]

I.2.c Non-university research institutions

Non-university science organisations are demonstrating their respective strengths in working on Grand Societal Challenges. According to its mission statement, the Fraunhofer Society (FhG) conducts applied research to benefit private enterprise and to promote the economic development of our industrial society, with particular regard for social welfare and environmental compatibility. In recent years, the topic of sustainability has become increasingly important in the Fraunhofer Society's strategy. In its 2013 sustainability report, the FhG explicitly recognises sustainability as a component of its mission. It regards its responsibility as lying in the area of the development of proposed solutions "[translation by Wissenschaftsrat:] for the pressing issues of our time – climate change, security of food supply, demographic developments and resource scarcity". |[29] The Gottfried Wilhelm Leibniz Scientific Association (WGL) is structured in a broad, cross-disciplinary manner and, for a number of years now, has been combining the expertise of its own institutes and external partners on a thematic basis in various forms of scientific groups that also work on projects in the area of Grand Societal Challenges. The WGL regards the broad coverage of disciplines in its own institutes as a very good foundation for combining expertise in social, economic, natural and technological sciences precisely in the area of cooperation-based, transdisciplinary approaches. |[30] The Max Planck Society (MPG) has a central function in securing excellence in basic research across all disciplines. It has demonstrated that excellent basic research can also contribute to progress on Grand Societal Challenges.

The Helmholtz Association of National Research Centres (HGF) has the mission of supporting society in tackling Grand Societal Challenges by targeting its research strategy at the pressing problems and challenges of society, science and industry. |[31] The HGF's long-term-oriented research is organised in six research areas: Energy; Earth and Environment; Health; Aeronautics, Space and Trans-

| 27 MWK BW (2013), p. 15

| 28 Ibid., p. 9

| 29 Cf. Fraunhofer-Gesellschaft (2014), p. 7

| 30 See http://www.leibniz-gemeinschaft.de/forschung/leibniz-forschungsverbuende/ (last accessed on 16/3/2015)

| 31 Cf. HGF (2012)

port; Key Technologies and Structure of Materials. The HGF acts here within the framework prescribed by public funding bodies such as federal and state ministries, but it also has its own processes that are intended to give it the capability to anticipate new challenges and integrate them into the target system of its research portfolio. With its programme-oriented funding (POF), the HGF claims to be ideally prepared to play an important role in addressing Grand Societal Challenges. It provides major, organised research programmes that can include basic and applied research as well as interdisciplinary approaches in an integrated manner. It also acts as a point of contact for politicians in communicating societal needs in science and research, which in turn has implications for the role of the HGF in the scientific system.

I.2.d Universities

Many universities have incorporated the concept of sustainability into their mission statements, and a few have also included reference to tackling Grand Societal Challenges. Examples can be found in numerous institutional strategies to promote top-level university research in the second phase of the Excellence Initiative: most notably in Aachen (Meeting global challenges), and also in Heidelberg, Tübingen and Dresden. This term is used in institutional strategies to promote top-level university research to describe research excellence that is carried out in interdisciplinary projects primarily in the natural, engineering and medical sciences, is structured in a long-term manner and makes a claim to relevance for society. The links to specific Grand Societal Challenges are of varying degrees of closeness.

A.II CHARACTERISATION OF GRAND SOCIETAL CHALLENGES

The term "Grand Societal Challenges" |[32] is firmly established in science-policy language use, currently has an impact on funding policy influences the strategic orientation of scientific institutions and organisations in Europe. However, there is no unique or explicit definition of what is meant by "Grand Societal Challenges". In most cases, lists of examples with very different thematic ranges are used to illustrate this term. If one examines the lists of "Grand Societal Challenges" of various stakeholders in science policy, there are indeed common elements in these lists; an empirical study has shown that climate change, global warming and clean energy are among the most frequently cited examples |[33]. The term "Grand Societal Challenges" has also come to figure in the media and in everyday language use. It is used to signal that certain topics

| 32 Or related terms such as "grand challenge", "societal challenge" or "global challenge".

| 33 Cf. Kallerud et al. (2013)

have a large societal impact, are taken very seriously by a significant number of stakeholders |[34] and will require special efforts. At the same time, using this term also invokes particular needs in terms of strategic orientation and resources. In public perception, the risks associated with Grand Societal Challenges often receive more attention than the opportunities they offer. The broad opinion is that the emergence, course and consequences of Grand Societal Challenges are not unalterable. Instead, there is an expectation that they can be influenced and limited by human activity and steered onto a more manageable course by acting appropriately. To achieve this, comprehensive, deliberate and coordinated change processes are necessary in many areas of society. All in all, the risks and opportunities, and the potential responses and societal impact mean that these challenges are politically contentious issues. In addition to these three characteristics, Grand Societal Challenges have further typical features in form and content which set them apart from challenges in individual disciplines, challenges in the sense of specific technological projects or the challenges of individual political areas.

With regard to the form, many of the Grand Societal Challenges listed as examples are characterised by high levels of complexity, interdependency and polytely, and also by difficulty in defining them precisely. For this reason, Grand Societal Challenges have a lot in common with complex problems |[35] and also with so-called wicked problems |[36]. Thus Grand Societal Challenges have a large number of variables that must be taken into account when identifying and tackling them and that are also strongly interdependent. These include a range of phenomena and relate to various societal subsystems such as science, politics and industry, as well as to the interactions between these subsystems. They cannot be confined regionally, nationally or geographically, and are often located on a transnational or global level. Grand Societal Challenges are not well-defined problems with uniquely identifiable current and target states. Instead, the various levels of goal-setting, knowledge, strategy-development and action are mutually interdependent when addressing these challenges. Characteristic features include mutual dependencies between solution attempts and problem definitions, and the influence of (debatable and changing) normative valuations on the understanding and solution of these problems. Grand Societal Challenges have their own dynamics and can develop in often unpredictable manners even without external interventions. As a consequence, need for instant action can be necessary. At the same time, many items of in-

| 34 These include stakeholders from science, politics, industry, the media and the public.

| 35 In psychological problem-solution research, “complex problems” are characterised by complexity, interdependence, their own dynamics, intransparency and polytely. Cf. Dörner (1976), Funke (2003)

| 36 The term “wicked problems” originates in Rittel/Webber (1973) and was originally intended to explain the failure of rational planning in the solution of social-policy conflicts.

formation required when tackling Grand Societal Challenges have uncertainty associated with them or are not accessible at all. Numerous, sometimes contradictory goals may overlap with regard to Grand Societal Challenges, as these challenges affect a range of stakeholders with differing social backgrounds, heterogeneous bodies of knowledge and heterogeneous normative ideas. For this reason, it is necessary to set priorities and make compromises.

With regard to content, Grand Societal Challenges are characterised by the fact that societal problems are turned into scientific challenges. Science has always contributed to the solution of society's problems. In parallel, science policy has always regarded it as its task to promote scientific contributions to the tackling of societal problems and to communicate these to the public. With the global and transnational context of societal problems, however, Grand Societal Challenges present a new framework for understanding the role of science in society. In contrast to the coupling of science with economic innovation processes and in addition to the market introduction of product and process innovations, the development and supporting of social innovations that are based on a more comprehensive understanding of the common good are also important here. Accordingly, social and cultural studies – including normative sciences that deal with the interpretation and criticising of norms and norm systems – are called on here alongside the natural, engineering and life sciences in the context of tackling Grand Societal Challenges. In addition, coupling in this context means that transfer must operate not as a one-way transmission of knowledge, but rather as a feedback process between the scientific system and other function systems. The living conditions, quality of life and natural living environment of many people could change in the long term depending on the way that Grand Societal Challenges are dealt with, and therefore the tackling of Grand Societal Challenges is of great emotional and motivational significance.

A.III INTERIM SUMMARY

The term “Grand Societal Challenges” has become firmly established in the discourse on science policy in recent years. In the political and public spheres the expectation abounds that “science” will contribute to the tackling of these challenges. In view of the difficulty of defining this term and the heterogeneous uses and differing interests associated with it, the Council believes that it is necessary to critically question the use of this term in both science policy and everyday language use in order to develop a transparent usage of the term “Grand Societal Challenges” and to identify the requirements that result for stakeholders in science and science policy within the context of the addressing of these “Grand Societal Challenges”. The analogy with complex problems and wicked problems and the coupling of science with other function systems in society as significant characteristics of Grand Societal Challenges present starting points for these tasks. The complexity, dynamics and long-term nature of

major societal problems require scientific treatment that goes beyond one-dimensional, mono-disciplinary analyses and solution approaches and that takes into account the interaction between subject areas and also between science and other function systems in society.

Many researchers are also motivated in their work by the fact that they are convinced of its benefit to society. Accordingly, they participate in the public discourse and regard it as their personal task to contribute relevant findings and to ensure they are visible and effective for society as a whole. In the light of the complexity of the challenges and societal expectations, however, the Council still identifies a joint responsibility of scientific and political stakeholders to improve the contribution of science and science policy to the identification, analysis and tackling of Grand Societal Challenges. The aim here is to foster the potential of the scientific system in a reasonable manner and to take into account society's legitimate demands without raising unattainable expectations. Against this background, desiderata will be formulated here for the debate in science and science policy on Grand Societal Challenges and their contribution to dealing with the challenges that have been jointly identified. The Council does not make any claim here to state concrete recommendations in the sense of developing a set of instruments; instead, it is aiming to formulate a fundamental position in the present paper and to identify desiderata that are intended to contribute to the resolution of the science-policy discourse on Grand Societal Challenges.

B. Desiderata

B.I IDENTIFYING GRAND SOCIETAL CHALLENGES IN OPEN AND PLURALISTIC PROCESSES

Referring to a problem area as a Grand Societal Challenge corresponds to an act of setting societal and political priorities, even if no clearly delimited problems are defined in this way. For this reason, the term "Grand Societal Challenge" can be used to exert pressure on political institutions or on the scientific system. After all, scientific knowledge always plays a central argumentative role in dealing with these challenges in view of their complexity, dynamics and long-term character. At the same time, possible framework programmes for research and innovation to tackle Grand Societal Challenges create incentives for interest-led use of this term. The Council requests that future Grand Societal Challenges should be identified in open-ended discourses where access is structured in as open a manner as possible so as to ensure the participation of a plurality of stakeholders and positions.

The recognition and understanding of complex interdependencies and developments that have impacts far into the future is a prerequisite for identifying future Grand Societal Challenges as such. The scientific system with its various subject areas, institutions and organisations and its international networking can help to identify global trends and interdependencies as a type of early-warning mechanism. They can also push to adapt these challenges into the political agenda of governments and help to become more aware to the public. Science can contribute to the recognition and understanding of Grand Societal Challenges; however, the establishing a societal consensus on the significance of these challenges is a separate task. In this regard, political, scientific and other societal stakeholders |[37] must work together in identifying new Grand Societal Challenges. To initiate the necessary changes, decisions need to be taken that provide long-term orientation and encourage coordinated action. Ultimately, these decisions are necessarily political resolutions that a society agrees upon. However, as these resolutions can only contain an incomplete and temporary formulation of the problem statement and the targeted state, it is

| 37 Depending on the problem area and challenge to be addressed, examples here include civil-society organisations, citizens, affected societal groups, consumers, users and employees.

necessary to renegotiate the related differences of opinion and conflicts again and again in the light of changing situations and valuations. In the context of finite resources and differences in perceived urgencies, the decision as to which Grand Societal Challenges should be tackled requires that priorities are being set. This type of deliberation should be based on the current state of scientific knowledge and can be supported by normative reflections on the values introduced by various stakeholders; however, this deliberation must then result in political decisions that should be taken with the broadest possible participation of the interests and parties affected.

B.II COMBINING SCIENTIFIC KNOWLEDGE FROM VARIOUS SOURCES

A science-based contribution to the addressing of a Grand Societal Challenge could consist in analysing the behaviour of affected complex systems, developing scenarios and evaluating possible responses. For this purpose, knowledge of the various natural, technical, social and cultural aspects and components of the systems and their behaviours on a range of spatial and temporal scales must be combined. These bodies of knowledge are established within the scientific system in various disciplines and at different times. In order to improve the contribution of science to the tackling of Grand Societal Challenges, processes and structures for the combination and integration of these bodies of knowledge must be developed.

Knowledge relating to the ecological, technological, social, cultural and economic aspects of a given transformation process must be bundled and recombined in a flexible manner in order to identify and cope with Grand Societal Challenges. For this reason, these challenges cannot be defined in a discipline-specific manner, nor can they be successfully tackled by contributions from a single scientific discipline. Instead, interdisciplinary research approaches and transdisciplinary forms of cooperation that act across disciplinary boundaries are also an essential prerequisite for successful work here. |[38]

The contributions of science to the addressing of Grand Societal Challenges do not represent another category of research of its own kind alongside knowledge- and solution-oriented research; however, they are also not limited to the development and investigation of new technologies, production processes and products. In fact, the contribution of science should be interpreted significantly more broadly and can receive input from all parts of the existing scientific system. For instance, science delivers knowledge about interdependencies and

| 38 Transdisciplinarity is interpreted here in line with the definition of Mittelstraß as research "[translation by Wissenschaftsrat:] that frees itself of its disciplinary boundaries, that defines its problems in a cross-disciplinary manner and solves them independently of disciplines" (see Mittelstraß, 1998, p. 44 f., cf. also Stock (2012) and Mittelstraß (2012)) and not in the sense that stakeholders outside of organised science are involved in the research process (cf. B.VI).

suggested solutions for specific problems and produces new information and methods, which can serve as the basis for societal debates, evaluations and decisions. It describes interdependencies between individual phenomena in a systematic manner and reflectively investigates target concepts and solution approaches that are regarded as promising. Knowledge- and solution-oriented research are therefore equally relevant for the identification and addressing of Grand Societal Challenges. As a result, strengthening the contribution of science means regarding the task of meeting Grand Societal Challenges in a comprehensive manner and taking full advantage of the potential of a differentiated scientific system. This also involves the development of additional incentive systems that promote cooperation across disciplinary boundaries. Thus cooperations across disciplinary boundaries for addressing Grand Societal Challenges require cross-institutional and cross-sectoral alliances, in the opinion of the Council. These cooperations require methods and concepts in order to combine not just heterogeneous bodies of scientific knowledge from various disciplines, but also practical knowledge. These methods and concepts must reflect differences in understanding with regard to research subjects, goals and working strategies and must create transparency by means of normative decisions, with the aim of defining a common task and developing high-level solution approaches. For this reason, they must be structured in a long-term manner.

The lengths of time over which Grand Societal Challenges retain their significance can be difficult to estimate; in this context, correspondingly long-term, cross-disciplinary research can lead to a merging of specific technologies, processes, methods and instruments, resulting in a new research field being created. |[39] In this regard, orientation based on Grand Societal Challenges can also have impacts on the internal organisation of universities and non-university research institutions, on the structure of courses of study and on career paths in science.

B.III RECOGNISING AND COMMUNICATING THE LIMITS OF SCIENTIFIC KNOWLEDGE

Knowledge about Grand Societal Challenges is often particularly uncertain because the affected systems are exceptionally complex, the relevant processes are non-linear and either the procedures for the integration of knowledge from various sources have not yet been tested or else experimental testing is not possible under controlled conditions. In addition, new knowledge needs to be generated and applied in many cases, but this knowledge has not yet been scientifically tested and proven to a sufficient extent. Contradictory findings and interpretations are discussed in public at an early stage to a much greater extent than

| [39] MIT White Paper (2011)

in many other research fields as a result of the major relevance of the topics involved. For this reason, researchers need to communicate the limits of scientific knowledge and the uncertainty involved in its application when they make statements – either personally or in the name of organisations – on the identification or evaluation of Grand Societal Challenges and on possible responses. They should describe in a transparent manner how uncertainties in bodies of knowledge and data can affect the conclusions that can be drawn. As there is always a danger of interest-led interpretation of research findings, the researchers should declare any possible conflicts of interest.

In their scientific work, researchers are used to dealing with incompletely specified problems that develop during the research process and also with complexity and the uncertainty that results from complexity. However, new uncertainties can develop when dealing with Grand Societal Challenges because conflicts exist with regard to values or goals, the societal framework conditions change quickly and heterogeneous bodies of knowledge from various disciplines and societal stakeholders have to be combined. At the same time, researchers are confronted with an expectation in the political and media spheres that they should provide sound scientific findings as a basis for structuring long-term societal development processes. The resulting pressure of expectation demands not just critical evaluation and clear communication of scientific findings and of the interpretation of these findings, but also a high degree of self-reflection and academic integrity when dealing with the diverse and significant uncertainties in the identification of Grand Societal Challenges and the contributions of science to tackle these challenges. It is important not to yield to demands from the media or the public for the single or "best" solution to a supposedly clear-cut problem if this is not justified from a scientific viewpoint. The contribution of science should go beyond the development and evaluation of scenarios and should also communicate the methodological prerequisites and uncertainties of scientific knowledge, render transparent the target conflicts, different understandings of challenges and different discipline-specific viewpoints, and also make a case for potential opportunities to try out uncertain strategies. Science is also responsible here for providing support for societal change processes – by means of data collection, analyses and reflection processes, for example. The aim should be to support the various participating stakeholders from the fields of politics, industry and the media and citizens too in entering into a dialogue about the understanding and evaluation of Grand Societal Challenges and about the various strategies for tackling these challenges; the aim should also be to help these parties engage in this dialogue in an informed and considered manner. The media have a particular responsibility to monitor and ensure the quality of their reporting.

Scientific contributions to the tackling of Grand Societal Challenges are generally not based on clearly delineated task descriptions, which means that conventional planning and project-management instruments are either poorly suited or not at all suited for this work. In addition, scientific strategies and political decisions must remain capable of being revised in the light of the uncertainties, long periods of time, continuously growing knowledge and changing evaluations that are involved. The establishment of a central, comprehensive coordination and monitoring structure would constrain the flexibility that is required here and is thus not a suitable solution. Project management is an appropriate coordination mechanism only in the case of partial problems that are well understood. Indirect coordination mechanisms and a variety of instruments and perspectives in terms of funding are better suited for the overall task of addressing Grand Societal Challenges.

The tackling of Grand Societal Challenges cannot be adequately described as a transition from a current to a target state, as the current state often cannot be uniquely defined and the target state cannot be clearly specified. Accordingly, the necessary steps cannot be defined in advance for the overall research process or divided into isolated work packages. In addition, cross-disciplinary cooperation and intensified interaction have an effect upon a range of stakeholders with cognitively and normatively heterogeneous opinions and goals; for example, these opinions and goals differ between researchers of various disciplines, between researchers and industrial partners, and also between various ministries that have to take into account cross-disciplinary interdependencies within the framework of their funding policy. For this reason, the establishment of a central, comprehensive coordination and monitoring structure is not appropriate for the research processes relating to a Grand Societal Challenge. Instead, various coordination mechanisms are necessary that allow for coordinated action among heterogeneous stakeholders if interaction and cooperation are to be successful. Project management is an appropriate coordination mechanism only in the case of partial problems that are well understood. Hierarchical coordination with separate work packages, monitoring and project management can even be counterproductive in subject areas that are characterised by uncertainty and conflicts in terms of goals and understanding; such an approach tends to favour currently preferred solution approaches and to limit alternative thought.

Indirect coordination mechanisms such as mission-statement processes, reciprocal observation of knowledge production and investigation findings, and competition are inherently better suited for the overall task of addressing Grand Societal Challenges. It should be considered here that the number of stakeholders affected can lead to difficulties within the framework of self-coordination processes. It therefore remains an important task to repeatedly guide the societal discourse on goals towards as binding a consensus as possi-

ble and to establish transparency with regard to contributions already completed by or to be expected from individual stakeholders. In the Council's opinion, this is the responsibility of the political institutions. The need to preserve a variety of instruments and perspectives in funding requires both comprehensive funding programmes as well as area-specific funding programmes along with discipline-oriented research and a differentiated portfolio of funding formats. Particular requirements with regard to coordination result less from the scope of the challenges to be addressed than from the fact that these challenges are positioned right across the areas of responsibility of political stakeholders, research-funding organisations, scientific institutions and scientific disciplines. For this reason, appropriate mechanisms are required in order to ensure reciprocal transparency with regard to strengths, weaknesses and strategies. The alternative scenario that threatens is an undifferentiated concentration on fashionable topics by all stakeholders, instead of a diverse and coordinated system of science and research. A systemic perspective on the interactions between the various areas of responsibility is important in both department-specific funding programmes and single-discipline research approaches.

B.V INCREASING THE DIVERSITY AND SELF-CORRECTING CAPABILITY OF THE SCIENTIFIC SYSTEM

In the light of the flexibility demanded by a focus on Grand Societal Challenges, it is a good idea to deliberately preserve and promote diversity in the scientific system, as this improves the system's robustness and its ability to react in a dynamic manner. At the same time, the self-monitoring and self-correcting capabilities of the scientific system should be expanded beyond institutional boundaries. Particularly suitable here are up-to-date, scientifically grounded analyses of individual challenges that describe the status of scientific knowledge across disciplines, the possible future actions for science, politics, industry and citizens, and other relevant unresolved issues.

The overall organisation and financing of scientific institutions and activities must be structured in such a way that the diversity and freedom of science are preserved and fostered. An integral component here is funding for that type of research that is not in itself targeted at reflecting on societal challenges and making these challenges the subject of research efforts. The funding of basic research and sufficient basic funding for scientific institutions are foundations for addressing Grand Societal Challenges in an appropriate manner.

Funding of targeted contributions to the identification, evaluation and tackling of Grand Societal Challenges and acknowledging these in evaluation and other incentive systems are useful additions to independently controlled research and contribute to the diversity and multidimensionality of the range of capabilities of science. In return, the guaranteed diversity and freedom of research demands a high degree of responsibility from researchers, scientific institu-

tions and organisations that they should contribute to the tackling of Grand Societal Challenges to the best of their abilities in cases where they have appropriate knowledge and skills.

"Science" must improve its self-monitoring and self-correcting capabilities and thus also its collective ability to learn in order to react successfully to the major complexity and diverse uncertainties that are involved here. It would be helpful here to identify the status, relevance and outlooks for the research significant for a particular challenge and for its implementation across subject boundaries. Corresponding status analyses should be carried out in a transparent process with the broadest possible participation, in which alternative positions are documented and uncertainties are clearly identified. These analyses can serve as a basis for state action and can support researchers and scientific institutions in the classification and orientation of their research strategies. Status analyses also have an important function in the dialogue between science and the public sphere and therefore have to be formulated and communicated in a manner suitable for a broad public audience.

B.VI TESTING INSTRUMENTS FOR THE PARTICIPATION OF STAKEHOLDERS OUTSIDE OF SCIENCE

Grand Societal Challenges cannot be addressed through local changes or new technologies alone. Far-reaching transformations in society are always necessary in order to tackle these challenges. For many people, this means changing their way of living – by using new technologies and by other approaches too. Instruments that allow those affected to participate in the designing of research programmes and the development of solution approaches can deliver results that are easier to implement and also improve people's willingness to change their behaviour.

The tackling of Grand Societal Challenges aims to achieve comprehensive societal transformations that are predicated on the creation of awareness and, in certain cases, changes in values and that can include technical and social innovations. In the context of the complexity and range of Grand Societal Challenges, all potentials for the development and implementation of innovative solutions should be used and – alongside industry – other non-scientific societal stakeholders should also be involved in research and innovation activities and the initiation of these activities. Taking into account the specific bodies of knowledge, interests and values of various groups of societal stakeholders increases the diversity of perspectives and broadens the knowledge basis with regard to the development of research agendas and funding programmes and to the definition and practical implementation of research projects (particularly the collection of data and interpretation of results). This results in a justified interest on the part of non-scientific societal stakeholders to participate in research and innovation processes. In addition, there is an expectation associated

with the participation of societal stakeholders that the legitimacy and transparency of the selection of research topics and the acceptance of research findings will improve as a result. In the context of Grand Societal Challenges, dialogue between scientific and other societal stakeholders is therefore very important, particularly when this dialogue is not just limited to the communication of research findings, but also allows the various societal stakeholders opportunities to participate in the formulation of and, where applicable, work on research issues. |[40] Nonetheless, the unity of decision-making and responsibility must be preserved here.

Instruments for participation by societal stakeholders have recently been refined within the context of transdisciplinary and transformative research. The term transdisciplinary research has emerged since the 1980s, mainly in connection with sustainability and climate research. In this regard, those processes and arenas of knowledge production are referred to as transdisciplinary where researchers trained in given disciplines work together with non-academic producers of knowledge from companies, associations or civil society, for example. |[41] This approach was taken up by the German Advisory Council on Global Change (WBGU) in its "World in Transition – A Social Contract for Sustainability" flagship report under the heading of transformative research |[42] and refined in the form of the concept of transformative science. |[43] This approach is currently the subject of contentious discussions. |[44] In particular, critics regard the shifting of the frame of reference for scientific knowledge production as a threat to the autonomy of universities, the freedom of science and the epistemic autonomy of science.

In recent years, diverse formats for the participation of stakeholders from industry and society have been developed such as citizens' dialogues, citizen science and real world laboratories. The Council regards the investigation of the conditions and potential of various forms of participation and the creation of experimental environments for these as an important contribution by science to the addressing of Grand Societal Challenges. With regard to the locations and forms of societal participation, methodological and epistemological clarifi-

| 40 In the context of transdisciplinary research, these forms of participation are referred to as co-design and co-production of the research process.

| 41 This approach is to be distinguished from the transdisciplinarity concept applied by Mittelstraß, which refers to (science-internal) processes and arenas of knowledge production where conventional discipline-specific identities are dissolved (cf. B.II).

| 42 The WBGU applies the term transformative research to research that "supports transformation processes in practical terms through the development of solutions and technical as well as social innovations, including economic and social diffusion processes and the possibility of their acceleration, and demands, at least in part, a systemic perspective and inter- and cross-disciplinary methods, including stakeholder participation" (WBGU (2011), p. 322).

| 43 Schneidewind/Singer-Brodowski (2013)

| 44 Cf. ibid., Stock (2014), Strohschneider (2014), Grunwald (2015)

cation and a discussion of the relationship between participative instruments and research freedom are still required. In this context, the relationship of "transdisciplinary" and "transformative" research with "knowledge-oriented" and "solution-oriented" research and with the capability dimension of transfer must also be determined. The Council reserves the right to make a statement on this issue at another point in time.

B.VII STRENGTHENING THE GLOBAL PERSPECTIVE

Grand Societal Challenges often have a global character and affect stakeholders across national and geographical boundaries and across social and cultural differences. Global social and ecological challenges such as climate change, energy supply and ageing societies can only be addressed by cross-border cooperations and on the basis of scientific expertise; in this regard, they also touch upon important issues in global governance.

The tackling of Grand Societal Challenges with a global character is a multilevel problem. As a result, very different responses must be found on a regional basis for global challenges. Scientific contributions to the solution of global challenges will primarily be developed in scientific systems that are structured and financed mainly on a national basis. From a German perspective, an important role is also played by European funding programmes such as the Horizon 2020 framework programme for research. Higher-level international research funding that is comparable in terms of scope with national or European funding does not exist. In the light of its cross-border impacts, the transnational response to global challenges must take into account socio-cultural diversity and must include global agreement on the legitimate interests of third parties, i.e. of other members of the global community. In this way, issues of global justice and responsibility are also addressed here. Thus the inclusion of interested and affected parties at a global level is particularly important for the formulation of research issues and the development of proposed solutions, but also represents a particularly difficult problem. The disparate distribution of resources, capabilities and population numbers in the global community also presents significant demands for capacity building in science, technology and innovation – particularly in developing countries.

To complement a diverse range of national funding opportunities, the Council particularly recommends that differentiated agenda-setting processes and formats be developed in relation to research funding that take into account the global character of Grand Societal Challenges. |[45] Science could make an im-

|45 The international "Future Earth: Research for Global Sustainability" programme is currently being established. Alongside scientists from relevant fields, its initiators include various organisations from the areas of research funding and international research cooperation. Future Earth aims to shift the perspective of re-

portant contribution to the tackling of Grand Societal Challenges by investigating the conditions and organisational potential of global governance and formulating relevant recommendations.

search from the recognition and understanding of global problems to the development of problem solutions with the aim of supporting transformation processes for responses to global challenges.

C. Summary

In recent years, tackling Grand Societal Challenges has developed to become an additional science-policy goal that complements the approach of promoting basic research as a driver of progress and of supporting innovation processes. This science-policy goal has far-reaching implications for scientists and for scientific institutions that take on this task: they must establish cooperations in a cross-disciplinary manner; they must regard and promote interaction with stakeholders from other parts of society as a particularly important task in this context; they must develop mechanisms for self-coordination of stakeholders with various interests together with science policy; and they must ensure that the goals, mission statements and understandings of challenges are regularly reconsidered. A long-term master plan cannot be specified for the tackling of major challenges or for the contribution to be made by science here. Instead, diverse scenarios need to be developed in both science and science policy; appropriate responses need to be developed, which themselves must be regularly updated in order to take current knowledge into account. In the Council's opinion, this can best succeed if a variety of autonomous institutions work on the analysis of Grand Societal Challenges and the development of specific strategies in a decentralised manner; transparency with regards to aims and the contributions of individual stakeholders should be an overarching principle here. The importance of other science-policy goals and of basic research and the promotion of innovation will not be reduced by adding the tackling of Grand Societal Challenges as a new goal.

BMBF	Bundesministerium für Bildung und Forschung (German Federal Ministry of Education and Research)
EFI	Expertenkommission Forschung und Innovation (Expert Commission on Research and Innovation of the German Federal Government)
ERAB	European Research Area Board
EU	European Union
FhG	Fraunhofer-Gesellschaft (Fraunhofer Society)
HGF	Helmholtz-Gemeinschaft Deutscher Forschungszentren (Helmholtz Association of German Research Centres)
MIWF	Ministerium für Innovation, Wissenschaft und Forschung (Ministry of Innovation, Science and Research of the state of North Rhine-Westphalia)
MPG	Max-Planck-Gesellschaft (Max Planck Society)
MWK	Ministerium für Wissenschaft, Forschung und Kunst (Ministry of Science, Research and the Arts of the state of Baden-Württemberg)
OECD	Organisation for Economic Cooperation and Development
WBGU	Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen (German Advisory Council on Global Change)
WGL	Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz (Gottfried Wilhelm Leibniz Scientific Association)
WR	Wissenschaftsrat (German Council of Science and Humanities)

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