5 Transformative Science for Sustainability Transitions

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Abstract[4]

Sustainability Transitions require a knowledge production that contributes actively to the Grand Challenges of twenty-first-century societies. Scientific institutions play a key role in this domain in the transformation towards sustainability and peace. Against this background a Transformative Science is needed: a mode of science that not only analyses processes of transformation, but also actively supports and accelerates them. This chapter will introduce the concept of Transformative Science and its implications for (1) the methodologies of transdisciplinary and transformative research, (2) institutional capacity-building for facilitating such a research approach, and (3) the national science systems and national science policies that enable this new mode of knowledge production. The case of the German science system is introduced to describe an ongoing science system transition with special regard to the role of civil society organizations.

Keywords: Transformative science, science system transition, transformative research, transdisciplinarity, governance of science, civil society participation, Wuppertal Institute[5].

5.1 Need for and Definition of 'Transformative Science'

The concept of transformative science is closely connected to international debates about the 'Great Transformation' (WBGU 2011) or the 'grand challenges' announced by the EU (Reid/Chen/Goldfarb et al. 2010). The meaning of this concept and the new role it assigns to science and academia can only be fully comprehended against the background of these debates. Humanity in the twenty-first century is faced with massive upheaval and the challenge of guaranteeing a good life for nine billion people. Planetary boundaries (Rockström/Steffen/Noone et al. 2009) have been discovered that set clear limits for resource-intensive economies, for political systems that are not adequately oriented *towards* social welfare for all, and for the carefree continuation of today's lifestyles and

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5 The Wuppertal Institute for Climate, Environment and Energy was founded in 1991, when decision-makers around the world became aware of global climate change caused by humankind as a new global challenge. For more than twenty years now, the Wuppertal Institute has undertaken research and developed models, strategies and instruments for transitions to a sustainable development at local, national and international level. Sustainability research at the Wuppertal Institute focuses on resource-, climate- and energy-related challenges and their relation to economy and society. Special emphasis is put on analysing and stimulating innovations that decouple economic growth and wealth from natural resource use. The overall research focus is on transition processes towards sustainable development. Scientific research towards this end combines its approaches to generate practical and actor-oriented solutions. An overview of current projects of the Wuppertal Institute can be found at: <http://wupperinst. org/en/projects/>.

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patterns of consumption. The *German Advisory Council on Global Change* (WBGU) therefore claims in its flagship report *World in Transition* that a "great transformation towards a decarbonized society" is needed:

> Adding together all of these challenges involved in the transformation to come, it becomes clear that the upcoming changes go far beyond technological and technocratic reforms: the business of society must be founded on a new 'business basis'. *This is, in fact, all about a new global social contract for a low-carbon and sustainable global economic system* (WBGU 2011: 1).

At the international level, momentum is currently created by the UN's *Sustainable Development Goals* (SDGs). On the one hand, these address the slow progress towards more sustainable development (e.g. in the context of international climate negotiations about a binding agreement) and identify key fields of action. On the other hand, the SDGs serve as a new narrative that describes the necessary change processes; they offer a comprehensive framework for coordinating sustainable development efforts and strategies at regional, national and international levels, and for integrating them in a shared vision of a globally just and much less resource-intensive world society.

The emergence and steady growth of new fields of research, such as transition studies and related approaches focusing on a better understanding of complex system innovations, can also be explained as a phenomenon in this broader context. Current transformation challenges require radical change in infrastructures, institutions and lifestyles, and these have to be dealt with by different sectors and societal subsystems at different but interrelated levels.

In this transformation challenge, science and science policy plays a central—while often underestimated—role. Over the past years, science policy has come to be equated with innovation policy (Martin 2012) and this has contributed to the generation of unrestrained economic growth and the development and diffusion of technologies that have often caused severe and harmful side effects for society and the environment (Beck 1992). Therefore, achieving sustainable development crucially depends on the kind of knowledge that is produced in modern societies. Meeting the key societal challenges of today demands socially robust knowledge that can be applied under diverse, uncertain and unforeseeable conditions. The term *mode-2 science* (Nowotny/Scott/Gibbons 2001) emerged at the turn of the millennium and captures a new mode of scientific knowledge production, which facilitates and argues for a pluralization of the places where relevant knowledge is produced and of actors involved in the production of knowledge. A central claim in this debate is that a 're-contextualization' (Rip 2011: 5) of science in society is needed in order to accommodate the increasing demand for participation by non-scientific stakeholders and the growing complexity of knowledge production in the age of reflexive modernity.

In this context, transformative science is understood as a mode of science that not only analyses processes of transformation but also actively contributes to them: by developing new methodological approaches, and by explicitly focusing on the institutions shaping scientific knowledge production and science policy at the level of (national) science systems. The concept builds on successful experiences in the field of sustainability science, which has been established in the academic sphere from the early 2000s onwards (e.g. Clark/Dickson 2003; Kates/Clark/Corell et al. 2001). The WBGU has introduced the term 'transformative research' in its flagship report and defines it as research that analyses "transformation processes with regard to their causes, conditions and development" (WBGU 2011: 373) and actively contributes to "transformation processes through specific innovations in the relevant sectors" (WBGU 2011: 373).

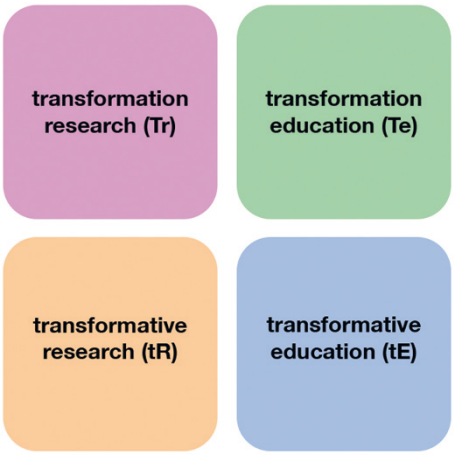
Transformative research aims not only at delivering analyses of complex and sustainability-related systems but also at supporting transformational changes in sustainability transitions (Wiek/Ness/Schweizer-Ries et al. 2012). This transformational agenda goes back to the beginnings of the debate about sustainability science (Clark/Dickson 2003: 8059), but in the practice of carrying out sustainability research it is confronted with many challenges (Wiek/Ness/Schweizer-Ries et al. 2012). For instance, engaging an extended peer community for research processes in post-normal science, as suggested by Funtowicz and Ravetz (1993: 752ff.), or concrete user engagement in sustainability research (Talwar/Wiek/Robinson 2011) require a completely new understanding of the role of researchers in the process of knowledge production (Wittmayer/Schaepke 2014). Researchers aiming at participatory knowledge production in complex und uncertain systems and transition processes (Loorbach/Frantzeskaki/Thissen 2011) will need a whole range of new competencies.

Building on strategies of 'transformative research' and introducing the broader concept of 'transformative science' highlights the crucial fact that knowledge production in a transformative mode is always embedded in the institutional context of the established sci-

Box 5.1: Four Transformative Pillars of the Knowledge Society. **Source**: German Advisory Council on Global Change (WBGU),2011: World in Transition: A Social Contract for Sustainability, Summary for Policy-Makers (Berlin: WBGU). This figure is licensed under Creative Commons BY-NC-ND; at: <http://www.wbgu.de/fileadmin/templates/dateien/veroeffentlichungen/hauptgutachten/jg2011/wbgu_jg2011_kurz_en.pdf>.

The German Advisory Council on Global Change (WBGU 2011) distinguishes four transformative pillars of the knowledge society:

- *Transformation research* focuses on "the basic principles, conditions and progression of transformation processes" (WBGU 2011: 351).
- *Transformative research* "supports transformation processes in practical terms", e.g. by developing relevant technological and social innovations, applying methods for facilitating inter- and transdisciplinary research processes, and by actively including non-academic stakeholders (WBGU 2011: 351f.).
- *Transformation education* "makes the findings of transformation research available to society" (WBGU 2011: 352).
- *Transformative education* encourages changes in actual social practices and focuses on creating awareness of concrete options for action and solution approaches (WBGU 2011: 352).



Typification of transformation research and education.

ence system, and this influences and bounds this specific quest for new forms of knowledge production.

Transformative science is not limited to research and education that focuses on analysing sustainability challenges and relevant systems; it goes beyond systems analysis and aims at catalysing and supporting transformation processes towards sustainable development through suitable forms of knowledge production and transfer. Consequently, the concept of transformative science has massive implications for (1) methodologies of transdisciplinary and transformative research, (2) institutional capacity-building for facilitating such a research approach in the field of sustainability science, and (3) national science systems, where this type of institutional change is the subject of controversial debate.

With regard to the methodological challenges discussed in the first part of this chapter, transformative research refers to the discourse on transdisciplinarity, which focuses on the development of research designs suitable for addressing sustainability-oriented research questions. A key aspect is the methodologically robust integration of the different forms of knowledge of different actors and stakeholders. Basic principles of transdisciplinary research have been adopted by global science programmes, such as Future Earth, by introducing concepts of 'Co-Design' and 'Co-Production' of knowledge, which explicitly provide a new role for non-scientific actors.

In addition, transformative science focuses on the institutional dimension regarding the places where knowledge is traditionally produced and reflects on the impact institutional structures have on the science–society interface. An institutional perspective is crucial because inter- and transdisciplinary research approaches have been faced with substantial barriers over the past years. Establishing such approaches requires institutional capacity-building that goes beyond project-based funding (Lyall/Fletcher 2013). In contrast to the methodological issues, the institutional dimension of the change envisaged in the science system remains understudied so far and will be discussed in the second part of the chapter.

Furthermore, the concept of transformative science is at the core of the political controversies that emerge when science actively assumes responsibility for societal developments. A number of controversial issues appear in this debate, for instance, the role of academic freedom versus the societal responsibility of academia, university autonomy versus university management, academic excellence versus transdisciplinarity, fostering innovation and ethics. Tensions in these fields are increased by the demands of external actors (e.g. civil society organizations) for a more open science system. By including a perspective on these issues, transformative science is positioned in the context of new theories of the governance of science, and the focus is explicitly on these negotiation and inter-

action processes. In the third part of this chapter, a discussion of these issues will be presented for the case of the German science system.

5.2 Methodological Challenges of a Transformative Research

A more detailed elaboration of the concept of 'transformative science' has to start by outlining transformative research, which is deeply intertwined with the discourse of transdisciplinarity and the basis of 'transformative science'.

Transformative research takes as its starting point various societal transformation challenges in the context of urban transitions, transitions to sustainable energy and transport systems, dealing with resource scarcity and the pressures caused by unlimited economic growth. The complexity of such transition processes can be illustrated by the example of the German energy transition ('Energiewende'), i.e. the nuclear phase-out and restructuring process of the entire German energy system, oriented towards increased energy efficiency and the development of renewable energies: This transformation not only includes the substitution of traditional technology but also supports social innovations between the affected stakeholders (companies, decision-makers, users etc.).

The energy transition is a typical example of a complex problem, in the sense that the object of study can hardly be separated from its context (Scholz/Lang/Wiek et al. 2006: 228). Such problems are deeply embedded in a complex system (Scholz/Tietje 2002). Most sustainability challenges can be described as 'wicked problems' which do not fit the disciplinary logic of academic problem definitions. Against the background of global unsustainable developments such as climate change, the term 'super-wicked problems' has been recently introduced. 'Super-wicked problems' are characterized by four key features: "time is running out; those who cause the problem also seek to provide a solution; the central authority needed to address them is weak or non-existent; and irrational discounting occurs that pushes responses into the future" (Levin/Cashore/Bernstein et al. 2012: 124). The urgent need to address these super-wicked problems using scientific approaches underlines once again the need for a transformational research agenda.

Nevertheless, transformative research basically draws on the methods developed in the field of transdisciplinary sustainability science, which emerged as a distinct field of research around the turn of the millennium (Clark 2007).

Transdisciplinarity can be defined as "a reflexive, integrative, method-driven scientific principle aiming at the solution or transition of societal problems and concurrently of related scientific problems by differentiating and integrating knowledge from various scientific and societal bodies of knowledge. This definition highlights the need for transdisciplinary research to comply with the following requirements: (a) focusing on societally relevant problems; (b) enabling mutual learning processes among researchers from different disciplines (from within academia and from other research institutions), as well as actors from outside academia; and (c) aiming at creating knowledge that is solution-oriented, socially robust (cf., for example, Gibbons 1999), and transferable to both scientific and societal practice." (Lang et al. 2012: 26f.).

This quotation summarizes the state of the art of the debate about transdisciplinarity and it shows that disciplinary approaches of defining relevant aspects of a broader research question and suitable methods for addressing these remain the core of good scientific practice. However, it is imperative that different disciplinary perspectives are connected and related to each other early in the research process, in order to be able to gain a comprehensive understanding of complex problems—and to cultivate a much deeper appreciation for the approaches and methods of other disciplines. In the case of transdisciplinary research processes, non-academic stakeholders are integrated as well, in order to provide relevant practical and transformation knowledge. Roland Scholz coined the simple yet ambitious phrase "disciplined interdisciplinarity in transdisciplinary processes" (Scholz 2011: XVII), which captures the central idea of the whole endeavour.

Thus, a disciplinary approach remains the essential starting point for transdisciplinary and transformative research. However, since sustainability science has to cope with complex systems and transitions processes, characterized by huge uncertainties and ambiguity (Kates/Clark/Corell et al. 2011, 641), there is an additional need for (1) cooperation in interdisciplinary teams and (2) participatory involvement of affected stakeholders (Loorbach/Frantzeskaki/Thissen 2011: 80f.). The basic idea is that such an approach leads to the production of socially robust knowledge.

5.2.1 Status Quo of Transdisciplinary Science?

An important milestone for transdisciplinary research was the conference "Transdisciplinarity: Joint Problem Solving among Science, Technology and Society" held in Zürich in 2000 (Klein/Grossenbacher-Mansuy/Häberli et al. 2001), which stimulated an intensive debate on the value, goals and processes of transdisciplinary research.

In transdisciplinary research processes, non-scientific actors are ideally integrated into all stages of a research process, i.e. from the formulation of the research question and the selection of methods to the discussion of findings and results. The basic aim is to arrive at a shared identification and systematization of the problem that is to be studied, and to ensure a continuous feedback process between researchers and non-scientific actors throughout the research process and the subsequent up-scaling of results (Hirsch Hadorn/Biber-Klemm/Grossenbacher-Mansuy et al. 2008). Following Jahn, Bergmann and Keil (2012: 7f.), this requires an integration of the perspectives of both actor groups at three levels:

1. at an epistemic level, the different kinds of knowledge (scientific knowledge and practical knowledge) of the involved actors need to be integrated;
2. at a social-organizational level, the varying interests and activities of involved actors need to be integrated;
3. at a communicative level, the different (professional) languages and forms of expression of the involved actors need to be integrated, in order to arrive at a shared understanding of the problem, the research process and the results; this also needs to be expressed in some form of language conversion.

The three levels of integration show that transdisciplinary knowledge production requires organizational framework conditions that facilitate cooperation between researchers and non-scientific actors at eye level. At the same time, creating acceptance and the conditions for epistemological pluralism and reflexivity is a central aim of institutional change for sustainability-oriented knowledge production (Miller/Munoz-Erickson/Redman 2011: 188f.). Researchers who have been successful in current science systems for a considerable amount of time have to develop this kind of reflexivity, because otherwise they tend to rely on their academic routines and action strategies (e.g. using highly specialized professional languages), making communication with non-scientific stakeholders extremely difficult.

Discourses on transdisciplinarity have gained substantial momentum over the past ten to fifteen years. Important impulses have been created by the discussion of suitable quality criteria for this new mode of science. Quality criteria have been defined for the different phases of a transdisciplinary research process: "problem identification and systematization, participative generation of solution-oriented and compatible knowledge, re-integration and application of the generated knowledge" (Vilsmaier/Lang 2014: 101). Most experts in the field of transdisciplinary research (Jahn 2008; Lang/Wiek/Bermann et al. 2012) have defined similar quality criteria for the different phases of the research process.

Most recently, the idea of transdisciplinarity has gained a prominent position in the redefinition of 'Global Change Research'. In the newly constituted programme of Future Earth Science, the concepts of Co-Design of research questions and processes and Co-Production of knowledge play a key role. The discourse on transdisciplinarity has successfully entered the field of science and science policy.

However, an overview of transdisciplinary research projects shows that there is still a large gap between the aspirations of an ideal-typical transdisciplinary sustainability science and the reality of actual research projects: "there is a gap between 'best practice', transdisciplinary research as advocated, and transdisciplinary research as published in scientific journals" (Brandt/Ernst/Gralla et al. 2013: 5). Furthermore, transdisciplinary research is currently still a niche discipline in the science system as a whole. The academic mainstream is firmly based on traditional disciplinary quality criteria. Central questions thus remain: what institutional framework conditions are needed to facilitate transdisciplinary research, and what are the differentiation criteria delineating the boundaries between transdisciplinary research and transformative science?

5.2.2 From Transdisciplinary Research to Transformative Research

The outline of the basic principles of transdisciplinary research presented above (cf. also Jahn/Bergmann/Keil 2012; Lang/Wiek/Bermann et al. 2012) shows that a new relationship between researchers and non-scientific actors is central. This new relationship is built on the acceptance of the different epistemological backgrounds of the involved scientific and non-scientific research partners and it aims at the generation of knowledge that is socially robust and solution-ori-

ented. The concept of transformative research further stresses this aspiration: it contributes to the generation of different forms of knowledge and actively catalyses concrete transformation processes.

In addition to the principles of knowledge integration developed in the field of transdisciplinary research, a central element of transformative research is active intervention in a specific field of research. Such an interventionist character is described by the WBGU in its conceptualization of transformative research:

> It supports transformation processes in practical terms through the development of solutions and technical and social innovations, including diffusion processes in economy and society, and opportunities for their acceleration, and demands, at least in part, systemic perspectives and inter- as well as transdisciplinary procedure methods, including stakeholder participation (WBGU 2011: 351f.).

The aim of transformative research is to actively generate impulses for change in society and to intervene in concrete transformation processes by scientific means and in the course of a research process. It contributes to an Experimental Turn in the social sciences, which has been observed in political science as a "significant change in perspective" (Morton/Williams 2010: 3) towards a focus on experiments as a suitable method for studying causality in complex real-life settings (Greenberg/Shroder 2004). This experimental turn includes a move away from abstract modelling approaches that are independent of specific contexts and introduces a new focus on analysing systems through 'real-world experiments' (Groß/Hoffmann-Riem/Krohn 2005). The aim of real-world experiments is to identify characteristic patterns in transformation processes and to generate 'pattern languages', which provide orientation to concrete actors involved in transformation processes (Schneidewind/Singer-Brodowski 2014: 73).

The interventionist character of transformative research also requires a more explicit focus on (sectoral) societal subsystems and on catalysing, accompanying, analysing and reflecting on complex system innovations in these systems. In this way, an active contribution to transformation processes is generated. Knowledge generated in these types of research processes is socially and scientifically robust. From a methodological point of view, this research mode is similar to the field of 'action research'. Together with the focus on societal systems, this makes research in real-world laboratories a suitable strategy (cf. Schneidewind/Scheck 2013).

However, the interventionist character of transformative research is a controversial issue in the field of transdisciplinary research, because it implies a redefinition of the role of science in society, where science is no longer just a provider of objective and neutral knowledge to politics, economy and society. Mittelstraß stresses that transdisciplinary research is in fact a new 'scientific and research principle', but that it does not have a direct impact on scientific standards of rationality (2003: 22). Jahn, Bergmann and Keil (2012: 2) also stress that transdisciplinarity is a "research approach, not a theory, methodology or institution". Nonetheless, the institutional consequences of transdisciplinarity 'between mainstreaming and marginalization' are spelled out clearly: "the true challenges of transdisciplinary collaboration are underestimated and [that] those who take them seriously become marginalized" (Jahn/Bergmann/Keil 2012: 1). Yet still, the necessity of associated forms of institutional change is only hinted at. A discussion of the institutional consequences of a new mode of sustainability science expands the focus of transformative research and calls for developing a broader notion of transformative science.

5.3 Institutional Challenges of a Transformative Science

It has been shown that, in principle, transdisciplinary research is possible and it has developed fruitfully over the past years as regards methods and fields of application. However, why has its diffusion in actual research practice and across concrete research projects been relatively slow? It is argued here that this is mainly due to the lack of a focus on an institutional perspective. In order to facilitate inter- and transdisciplinary as well as transformative research, new institutional framework conditions in universities and other scientific organizations are needed. A number of arguments are relevant in this context:

1. Transdisciplinary and transformative research is in conflict with the established disciplinary organization of science. A brief look at the field of science studies shows that the science system follows a distinct logic of functioning which is detrimental to transdisciplinary and transformative aspirations: scientific communities can be described in terms of epistemic communities that tend to develop within disciplinary boundaries and focus on specialization within their specific fields of research. They withdraw from non-scientific perspectives, from the

political regulation of science and thus also from societal expectations (cf. e.g. Gläser/Lange 2007: 441). "The autopoietic nature of disciplines assures their perennial and, in principle, their unlimited regeneration, growth and differentiation" (Weingart 2014: 163). Efforts towards the establishment of transdisciplinary and transformative research thus remain an uphill battle, if they do not explicitly include an institutional perspective, because they are in conflict with the deep structural principles of scientific communities. The disciplinary organization of science (especially within universities) limits the possibilities for designing research projects that are motivated by concrete societal challenges from the outset.

2. A closely connected argument is related to established reputation-building and qualification mechanisms in the science system, which is firmly placed within the disciplinary logic of academia. Over the past decades, scientific impact has emerged as the key criterion for assessing the quality of research as well as of individual researchers. Science policy instruments are also geared towards increasing scientific impact—together these factors prove to be a disincentive for engaging in transdisciplinary research. Scientists focusing on transdisciplinary research early in their career face major barriers in their further academic career. Therefore, identifying measurable indicators of societal impact (e.g. Bornmann 2013) are decisive for the further development of sustainability science. Additionally, institutional framework conditions need to be established within universities (specific research groups, institutes, faculties) that offer a protected space for discussing societal quality criteria for transdisciplinary research and developing career pathways in accordance with such criteria.
3. Adopting a perspective on real-world problems that guides the research process and organizing research based on transdisciplinary and transformative principles questions the self-conception of science and individual researchers. Tensions emerge in the related debates about autonomy versus freedom of research and lead to massive controversies in the realm of science policy. It can safely be assumed that scientific self-conceptions represent the most prominent barriers to institutional change because they touch upon the issue of freedom of research, which is argued to be at risk where science focuses more explicitly on societal challenges. It is feared that science as a whole will be increasingly politicized (Shinn 2002), if external expectations are entering the safe haven of academia. A common accusation thus centres on the 'normativity' of transdisciplinary and transformative research. However, this criticism in fact applies to any field of research that avoids making inherent norms and values transparent and hides behind seemingly 'objective' data. Again, the field of science studies provides an important contribution to this debate, showing that social negotiation processes within science have always shaped the generation of new (and only allegedly objective) knowledge (Felt/Nowotny/Taschwer 1999: 136ff.). A crucial example in this context is the current state of economic research, which has focused on objective calculations and thereby failed to predict dramatic developments during the financial crisis, and up until now has ignored substantial foundations of economic activity, such as natural capital, which are not included in common economic models and calculation methods. In contrast, transdisciplinary and transformative research make different forms of knowledge (e.g. the target knowledge of societal stakeholders regarding desirable futures) explicit and integrate it into a cooperative research process—in this way being fully transparent and thus complying with the most fundamental requirement of good scientific practice (Schneidewind/Singer-Brodowski 2014: 380). While debates about normativity and academic freedom are often avoided in the sustainability science community, they are a central element in the concept of transformative science.

A final reason for the slow development of transdisciplinary research over the past years has to do with the lack of 'transformative' infrastructures, i.e. the arenas in which sustainability scientists can discuss such fundamental questions and at the same time have the opportunity to develop new methods for and approaches to a more interventionist research process. The decisive impact of favourable structural conditions can be shown for the case of the Leuphana University of Lüneburg, where the foundation of the Faculty of Sustainability has allowed for the integration of approaches from the natural and social sciences. As a result, the Faculty of Sustainability has not only emerged as an important think tank in the German field of sustainability science, it also plays an important role in the education of a new generation of young scientists thinking and working in a transdisciplinary fashion.

Transformative science calls for an institutional revolution if it is to contribute to the mainstreaming

of sustainability science. This distinguishes transformative science from other concepts (post-normal science, action research, intervention research, transdisciplinary research), because they call for an alternative form of doing research (for sustainability) and the changing roles and competencies of researchers in the concrete research processes. However, they lack a perspective on the institutional framing, which is needed to provide additional space and resources for transformative research, as well as suitable incentives and structures, which reduce the risk for sustainability researchers of being permanently overburdened.

The necessary institutional change depends not only on the various academic institutions themselves (universities, non-university research institutes, departmental research in government ministries, that should enable research processes across single disciplines and in cooperation with non-academic stakeholders), but also on those agencies shaping the framework conditions for academic knowledge production, such as administrative agencies, scientific policy advisors and other relevant political authorities (that are called to facilitate these non-conventional research approaches with a focus on a societal impact). Finally, change is needed at the deeper level of implicit routines, self-conceptions and paradigms in the science system, which has been shaped by the institutional framework conditions.

Transformative science actively contributes to societal transformations towards sustainable development and is itself subject to a continuous transformation process, where new interrelations between specific national or regional science systems and other societal subsystems are forged. This affects also the level of the curriculum and higher education, which should be oriented more towards societal challenges and foster education for sustainable development.

The interplay of change towards transformative science approaches and the related institutional change has been defined in terms of a mode-3 science (Schneidewind/Singer-Brodowski 2014: 103ff.). It builds on the concept of mode-2 science (Nowotny/Scott/Gibbons 2001) and further develops it as a concept of continuous self-reflexion of science and an opening-up of the science system with a view to societal transformation challenges. Mode-3 science is further based on the concept of third-order change or higher-order learning as developed in system theory (Sterling 2003: 127 ff.), which goes beyond the reflection of implicit routines during learning processes, and conceptualizes epistemic change, "a corrective change in the system of alternatives from which choice is made" (Bateson 1972: 293). This type of change can be fostered by actively including civil society actors, because civil society organizations can function as an external corrective with a critical perspective on the 'blind spots' in the science system. Defining transformative science in terms of mode-3 science includes basic principles such as "plurality, heterodox thinking and inclusion of civil society. At the same time the normal-science-mode is not negated but transcended" (Schneidewind/Singer-Brodowski 2014: 123).

Sophisticated approaches to delineating a mode-3 knowledge production have described it in terms of an advancement of the triple helix (i.e. the interplay of science, politics and industry) to a quadruple helix that also includes civil society (Carayannis/Campbell 2012). "The Mode 3 Knowledge Production System architecture focuses on and leverages higher order learning processes and dynamics that allow for both top-down government, university and industry policies and practices and bottom-up civil society and grassroots movements initiatives and priorities to interact and engage with each other towards a more intelligent, effective, and efficient synthesis" (Carayannis/Campbell 2012: 3).

Mode-3 science places academic knowledge production in a context of societal challenges and broadens the set of relevant scientific actors to also include civil society, and it discusses the related institutional implications with regard to relevant forms of knowledge, scientific organizations and quality criteria for research.

5.4 Achieving Institutional Self-transformation: Towards a 'New Governance of Science'

5.4.1 From Science Policy to Governance of Science

A focus on institutional mechanisms is instructive with regard to the science system as a whole, and especially in the context of its political framework conditions. The way in which political framework conditions for a specific field of research have developed is regularly discussed, particularly by researchers as the concerned parties who have to react to new emphases in research funding programmes. Apart from this, these issues have been analysed in the field of 'science policy research', where the political steering processes of the science system are studied. Relevant questions in this field deal with issues of the

effectiveness of science policy, science policy as innovation policy (Martin 2012), and the changing role of steering committees. New science policy instruments have internationally contributed to a strengthening of decision-making power by university boards and thus to greater flexibility and responsiveness towards external demands (Jansen 2010: 47). Science policy research also studies the changing interplay between industry, politics and science, i.e. the triple-helix model (Etzkowitz/Leydesdorff 2000).

Based on the current state of research in the field of science studies, it can be shown that the science system is confronted with dynamic change processes and shifting boundaries, where new demands are voiced by industry or civil society actors and media penetration is increasing. These changing conditions also have a massive impact on science policy itself, as well as on research carried out in this field. "These transformations require ... a fundamental change in perspective in science policy: from traditional 'science-policy making' to the 'governance of science' which is currently taking shape" (Grande/Jansen/Jarren et al. 2013: 19, translation by authors).

In general, a governance approach provides a perspective on negotiation processes and the interdependencies of actors in a specific field. Governance theories adopt a social science perspective and analyse patterns of handling interdependencies between actors (Schimank 2007: 29). The term governance depicts the interplay of "all co-existing forms of collectively regulating societal issues: from the institutionalized self-regulation of civil society, to the different kinds of interaction between public and private actors, and the sovereign actions of state actors" (Mayntz 2003: 72, translation by the authors). The following characteristics of governance approaches are identified by Grande, Jansen, Jarren et al. (2013: 20, translation by authors):

1. 'Emphasis on non-hierarchical forms of providing public goods,
2. a critical perspective on the nation state as the exclusive provider of public goods,
3. a non-hierarchical integration of private actors in the provision of public goods,
4. the complexity of political action in a world of blurred boundaries and, following from this,
5. the 'necessity of coordination (of action) and, beyond that, of cooperation (between different actors)'.

The governance debate has over the past years spread out into an increasingly differentiated field. A prominent strand of research has developed around the concept of reflexive governance, which describes governance processes and policy analyses as "interlinked with and open to feedback from broader social, technological and ecological changes, both in terms of innovative action and structural change" (Voß/Smith/Grin 2009: 280). The field of transition studies has also built on the concept of governance (Chappin/Ligtvoigt 2014: 717) and explicitly emphasizes the importance of reflexive approaches.

The theoretical positioning of transformative science in a context of 'governance of science' emphasizes a move away from top-down steering processes; it takes up the impulses from science politicians and statistically analyses their effects. The theoretical approach of science governance includes a more diverse set of actors and external demands (e.g. by civil society) in its analyses, since they have begun to influence academic knowledge production (Jansen 2007).

The role of civil society as an increasingly active agent in science policy shows the value of such a broadened perspective. In current discussions of science policy and in the field of science studies, the analysis of negotiation processes and the handling of interdependencies between researchers and civil society actors play only a minor role. In the following section, the case of Germany shows the increase in dynamics caused by the more active involvement of civil society organizations in science policy.

5.4.2 The Role of Civil Society in the Governance of Science

Organized civil society has not entered the field of science policy as an independent stakeholder so far. Apart from a few exceptions, theoretical analyses of civil society as a stakeholder in the field of science policy are hardly to be found (Wehling/Viewhöver 2013). At the same time, civil society organizations do play a key role in fostering societal transformation processes. However, they can only fulfil this role adequately if they can rely on scientific expertise in sustainability-related challenges.

Transfer of knowledge and expertise has traditionally worked well in specific cases in Germany, where civil society organizations such as the large environmental associations were well connected with academic partners in specific types of universities. "Together with the growing environmental movement, a large number of reform universities were founded in the 1970s. In these universities, controversially discussed issues such as environmental protection played an

important role and many professors were appointed who focused on research questions close to the concerns of environmental associations" (Schneidewind/Singer-Brodowski 2014: 309). Such a pattern of transferring knowledge between civil society and science has not been broadly diffused beyond the issue of environmental protection throughout the science system as a whole, but this is nonetheless a valuable example of successful cooperation.

This type of close cooperation deteriorated with the changes in the science systems sketched above. "The generation of professors appointed in the 1970s is resigning. Many of their professorships are not reappointed or with severely changed denominations. Environmental associations suddenly experience the ... results of a self-reducing science system that solely focuses on inner-academic disciplinary expertise" (Schneidewind/Singer-Brodowski 2014: 309). Pressing questions voiced by civil society are not matched with sufficient amounts of research funding. Therefore, the large environmental associations, such as BUND,[6] have published their own science-political position papers over the past few years (e.g. BUND 2012). These position papers highlight the discrepancies between the funding priorities of the Federal Ministry of Education and Research and the research questions that, from the perspective of civil society, are decisive for achieving sustainable development: for instance, instead of spending billions of euros on technological innovation and the development of e-mobility, research projects should rather focus on the development of new concepts of mobility.

Another large environmental association in Germany, NABU,[7] has intensively dealt with the science-political strategy of the German government in the field of 'bio-economy' and has, in 2011, published a study on the specific focus of the research programme on 'bio-economy', worth two billion euros (NABU 2011). The study showed that the adopted research strategy focuses almost exclusively on technological solutions and basically ignores the position of civil society. NABU is also the first environmental association that has established among its staff the official position of an advisor for research and science policy, whose task it is to integrate the different policy fields within NABU with the field of science policy.

The various science-political activities of the German environmental associations have increasingly emerged as an important catalyst for a more sustainability-oriented science policy (similar initiatives at an international level are presented in box 5.2). In this way, they support the role of other large stakeholders, such as the independent sustainability research institutes and students, who are actively involved in the transformation of the science system and of universities. In 2012, concerted activities resulted in the foundation of a common platform, 'Forschungswende' ('Research Transition'), which independently voices their demands, such as the integration of civil society issues in the conceptualization and calls for new research programmes. These demands were taken up in the coalition agreement of the new German Government (2013 – 2017). Organized civil society has thus become established as an important new player in the field of science policy and its participation demands have contributed to an opening-up of science policy towards the great societal challenges. Such initiatives are not limited to environmental lobby groups but also include stakeholders in other fields directly and personally affected by (a lack of) research, such as patient associations and consumer organizations (cf. Wehling 2012). Ober (2014) argues that involving civil society actors can contribute to a democratization of science policy, because the increasing tendency to make science-political decisions in expert commissions that are not democratically elected has led to an exclusion of citizens in this policy field.

Including civil society in science policy can develop an additional potential. Wehling and Viehöver (2013) describe a double participation of civil society in science. On the one hand, it can offer welcome contributions in agenda-setting processes, which often play a role in politically sensitive fields (e.g. nuclear technology, genetic engineering) and where civil society involvement can contribute to greater societal acceptance of new technologies. On the other, it can also offer "unwelcome civil society participation", for instance, in cases where patient organizations successfully demand research on rare diseases and through continuous lobbying achieve the establishment of new research programmes. It is argued that "civil society organizations can play an important role for the governance of science, especially when they proactively and in self-organized ways contribute to the

6 Friends of the Earth Germany (Bund für Umwelt und Naturschutz Deutschland, BUND) is an environmental NGO with currently more than 480,000 members and supporters in Germany. More information can be found at: <http://www.bund.net/ueber_uns/bund_in_english/>.

7 The *Nature and Biodiversity Conservation Union* (Naturschutzbund Deutschland, NABU) is one of the oldest environmental associations in Germany with currently more than half a million members and supporters (see at: <http://www.nabu.de/en/nabu/>).

Box 5.2: Global Efforts towards Transformative Research and Civil Society Participation. **Source:** The authors.

'Future Earth' is a global research programme and coordinating platform for inter- and transdisciplinary research on transformations towards sustainable development. It was launched by the UN (including UNESCO, UNEP, and UNU), the *International Council for Science* (ICSU), the *International Social Science Council* (ISSC), and the Belmont forum of funding agencies. It is not only a platform for connecting scientists; its explicit aspiration is to generate knowledge together with societal partners in co-design and co-production processes. For more information see: <http://www.futureearth. org>.

The ISSC has developed a global social science research agenda on global environmental change: *The Transformative Cornerstones of Social Science Research for Global Environmental Change* (see chapter 14 by Arizpe/Price/Worcester in this volume). This agenda originates from the idea that co-designing research processes and co-producing knowledge together with civil society is imperative for addressing sustainability challenges in a solution-oriented way and for achieving actual societal impact. It also calls for institutional change in the global science system, since there are no adequate funding structures for this type of research (see at: <https://igfagcr.org/sites/default/files/news/issc_transformative_cornerstones_report.pdf>).

development and design of research and technology" (Wehling/Viehöver 2013: 213, translation by authors).

Thus, external demands by civil society can be included in theoretical analyses in the field of the governance of science—in contrast to research approaches with a more traditional focus on science policy—and the concrete impact of civil society on the science system as a whole can be studied in theoretically differentiated ways. Furthermore, a governance approach is suitable for capturing all the relevant negotiation and interaction processes that have an impact on the science system. In this context, the demands for participation and the necessary processes play an important role. A perspective on the science system and science policy against the background of the century's major challenge of achieving sustainable development can be captured in terms of 'governance of science' as a comprehensive concept that is close to reality and that facilitates the analysis of the complex interdependencies in the science system. Transformative science is positioned in this exact context.

5.5 Conclusion

Humanity is facing massive challenges. The important role of science in contributing to sustainability transitions is so far only partially being recognized. This chapter has introduced the concept of transformative science, which aims at catalysing the necessary processes through suitable forms of knowledge production. The concept of transformative science emerges from three specific strands of thought:

1. Transformative science is based on debates about transdisciplinary/transformative research and emphasizes the aspirations of scientists to intervene in complex systems and adopt a new mode of research carried out in real-world laboratories.
2. Transformative science not only focuses on the problem dimensions of sustainability science, but also adopts a perspective on the necessity for institutional change, in order to build the framework conditions for better sustainability science.
3. Transformative science also focuses on the science system as a whole, which is itself facing massive transformations. Building on theoretical approaches of the 'governance of science', it argues for non-hierarchical forms of organization in science and the acceptance of external actors (such as organized civil society), which are playing an increasingly important role in national science policy.

Change processes that have contributed to an opening-up of the science system have briefly been sketched for the case of the German science system (Schneidewind/Augenstein 2012). Science system transformations, in the larger context of transitions to sustainability, require a process of reflection on the institutional conditions for a broadening and a quality enhancement of sustainability sciences as a whole. A science system transition presents a complex challenge, but it is not a lost cause. The German example shows how reform processes extending over twenty years have prepared the ground. Even though the German case cannot be directly compared with other countries, it can be assumed that structural similarities can be observed in other cases. This has been illustrated by examples of global initiatives such as the Future Earth programme and the global change research agenda of the International Social Science Council.

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