Risks and Opportunities for Sustainability Science in Europe

Jill Jäger

1 Introduction

This chapter explores some of the issues around the topic of "sustainability science". In doing so, it attempts to draw a distinction between the wide variety of disciplinary and interdisciplinary research that can be called "research to support sustainable development" and an approach, here referred to as "sustainability science", that is much more strongly oriented towards the development of strategies and the implementation of measures to deal with problems of unsustainable development. Before discussing the different approaches, however, the chapter examines the need for this kind of research, which arises because of the increasing amount of evidence that despite international agreements and action plans at all scale levels, there has been no success over the past few decades in reconciling human development with the environmental limits of Planet Earth and in securing well-being for all people on this planet now and in the future.

The chapter then discusses a number of reasons why sustainability issues are hard to deal with. First there is the complexity of the problems, with multiple human activities as drivers of change as well as the complex interactions within the Earth System such as those between the atmosphere, the oceans and the land surface. Dealing with the problems involves many different stakeholders, both those whose activities are driving change and those who are affected by environmental and societal changes. Reconciling the perceptions and visions of all of these stakeholders is a major challenge. A further challenge is the immense uncertainty surrounding many aspects of problems of unsustainable development. While research can reduce or eliminate some uncertainties, some of the uncertainties will remain. In particular, uncertainties about how humans might behave in response to given stimuli will remain uncertain.

J. Jäger (✉)
Independent scholar, Vienna, Austria
e-mail: Jill.jager@speed.at

C.C. Jaeger et al. (eds.), *European Research on Sustainable Development*,
DOI 10.1007/978-3-642-19202-9_13,
Published by Springer-Verlag Berlin Heidelberg 2011

Given these challenges, the chapter then explores how a “sustainability science approach” could contribute to finding and implementing solutions to persistent problems of unsustainability, in particular through the design of processes of dialogue between all stakeholders, experimentation and learning. Examples are given of networks that are already attempting this kind of work and of the potential of this approach in Europe.

There are, however, also barriers to this kind of work and these are discussed in a further section of this chapter, which suggests that some major changes to the way that science is organized and funded are required for widespread use of sustainability science approaches. The chapter then uses examples from the Conference “Sustainable development: a challenge for European research”, several of which are included in the rest of this book, to explore how the challenges and barriers to sustainability science are being dealt with. Much research clearly includes important elements of sustainability science approaches, but there are only a few examples in which the approach is adopted fully.

Over the past decade, sustainability science has advanced in a rather ad hoc manner, with different approaches being tried in different places. Clearly there is a developing need for some consolidation through comparison of similar cases. At the same time, there is a need to address the institutional and other barriers to this kind of work. There are many opportunities to begin processes of transformation towards sustainability with the support of sustainability science. The risks lie in an inability to change the way that science is funded and evaluated, so that the potential of the approach cannot be demonstrated and the ad hoc nature of the endeavour leads to its dismissal.

2 Why Is Transformative Research Needed?

Research over the last two decades has documented that the Earth is undergoing major environmental and socioeconomic changes (see, for example, Steffen et al. 2004). The situation is dramatic, in particular because most of the driving forces of environmental change such as economic growth, consumption levels in industrialised countries, the size of the world population, resource use and energy consumption, continue to increase. In fact, as Steffen et al. (2004) have documented, there has been acceleration in the rate of growth of many of these driving forces since 1950. Population has been growing exponentially since industrialization began. Since 1950 the size of the world economy has increased by more than a factor of 15, inequality in wealth is also increasing and between 1960 and 1994 the ratio of income of the richest 20% to the poorest 20% increased from 30:1 to 78:1, world petroleum consumption has increased by a factor of 3.5 since 1960, and urbanisation increased tenfold in the twentieth century (Jäger 2009a). Since the middle of the last century there have been rapid and profound changes in almost every sphere of human activity. Many of these changes affect the environment and the pressure on the Earth’s resources and on the planet’s capability to assimilate wastes is intensifying sharply (Steffen et al. 2004).

The acceleration of human activities that affect the environment is already having observable consequences. Climate change, land degradation, deforestation, biodiversity loss and changes of water quality and quantity are prominent examples of global environmental changes. As Steffen et al. (2004) show, almost half of the earth's land surface has been transformed through human activities such as agriculture, urbanization, building of dams, deforestation etc. More nitrogen from the atmosphere is now fixed by the production of fertilizers and burning of fossil fuels than is fixed naturally. More than half of all accessible freshwater is now used by humans. The atmospheric concentrations of several climatically important "greenhouse gases", including carbon dioxide, methane and nitrous oxide, have increased significantly as a result of human activities such as the burning of fossil fuels and intensive agriculture. Coastal wetlands have also been noticeably affected by human activities, in particular through the removal of half of the world's mangrove ecosystems. The oceans have also been significantly affected by human activities, through, for example, depletion of fish stocks, ocean acidification, and various forms of pollution.

While international agreements have been reached to deal with many of these problems, the implementation has not always followed and the problems have been tackled in isolation, rather than recognizing the major interactions between them. As a result, despite agreements reached almost 20 years ago at the UN Conference on Environment and Development in Rio de Janeiro, little has been achieved in putting the planet onto a sustainable track. We are faced by persistent problems of unsustainability resulting from an overexploitation of the planet's resources and ability to absorb wastes. Transformative research is needed so that sustainable pathways can be explored and taken.

3 The Challenge for Research

Several characteristics of persistent problems of unsustainability present serious challenges for scientific research. As Rotmans (2006)[1] has pointed out

> These problems are complex, ill-structured, involve many stakeholders, are surrounded by structural uncertainties, and are hard to manage.

For each of the different problems (climate change, land degradation, biodiversity loss, etc.) or problem sector (agriculture, energy, transport, etc.) the symptoms of unsustainability mask deeper underlying problems in our societal structures and institutions. Thus, as Rotmans (2006) underlines, they cannot be solved in isolation. The complexity arises because of the multiple and interacting drivers of change (e.g. agriculture requires land, water and energy), the interactions within the earth system (e.g. between the atmosphere and the oceans or between climate and vegetation), the interactions between levels of scale (local, regional global), time delays in responses and because of the massive complexities of human consumption

[1]http://www.matisse-project.net/projectcomm/uploads/tx_article/Working_Paper_4_01.pdf

and production systems. The persistence of the problems is because of what Rotmans (2006) refers to as "system failures" –

- *Institutional system failures* (e.g., dominance of institutions that block innovation)
- *Economic system failures* (e.g., inadequate market development or lack of investment capital)
- *Social system failures* (e.g., unchanged behaviour and habits)
- *Ecological system failures* (e.g., dominance of species or ecosystems that threaten biodiversity).

Uncertainty is also an inherent characteristic of persistent problems of unsustainability. There is much discussion in the scientific literature about sources and types of uncertainty (see, for example, references cited by van Asselt (2009)). The latter distinguishes between two sources of uncertainty: variability and lack of knowledge. Sources of variability uncertainty include the inherent variability of natural processes, value diversity as a result of differences of people's world views, behavioural variability (different responses by different people or discrepancies between what people say and what they actually do), societal variability (the unpredictable nature of societal processes) and technological surprises (new developments or unexpected side-effects of technology). Lack of knowledge is partly a result of the above kinds of variability but there are many other sources including : measurement errors, lack of observations or measurements, competing interpretations of available data. For many aspects of persistent problems of unsustainability uncertainty will never be eliminated. Some processes can never be fully predicted or determined.

The complexities and uncertainties, together with the fact that there are multiple stakeholders, mean that normal scientific research projects are ill-equipped to deal with persistent problems of unsustainability. The challenge is further compounded by the need to link knowledge production more closely with action.

4 Meeting the Challenge: Sustainability Science

In October 2000, a small international group of scientists met in Sweden to discuss the emergence of 'sustainability science' (Kates et al. 2001). In response to the kind of challenges discussed briefly in the previous section, it was agreed that approaches are needed that consider the human-environment system as a whole. Because of the need to bridge knowledge and action, the focus of the research must be on a particular place (and the human-environment interactions at that place but also with other places) or a particular sector (again taking into account the interactions with other sectors). It was recognized that fundamental advances would be needed in order to address such issues as the behaviour of complex, self-organizing systems, as well as the responses of the human-environment system to multiple and interacting stresses (Jäger 2009b).

Further discussions on sustainability science (ICSU 2002a) emphasized that research and development (R&D) priorities should be set and implemented so that science and technology contribute to solutions of the most urgent sustainability problems as defined by society, not just by scientists. ICSU (2002a) underlined many of the points raised in the previous paragraph: the focus of on the complex, dynamic interactions between nature and society, the 'place-based' or 'enterprise-based' nature of the work, and the need to consider cross-scale interactions. The bridging between knowledge and action, i.e. research leading to policy formulation and implementation was again emphasized.

In the meantime, a body of research has begun to accumulate that attempts to fulfil these aims. Journals on sustainability science have been established and books have documented some of the research.[2]

In Europe, in particular, sustainability science has evolved towards being strongly implementation-oriented in areas dealing with persistent problems of unsustainability that have a high level of complexity. This implementation orientation presents a number of challenges, in particular because it means that the researchers (or better the practitioners of sustainability science) focus on possible implementation within social, economic and culturally shaped environments. The sustainability scientists, as part of an iterative learning process with selected relevant stakeholders, have to think and act strategically.[3] In this respect sustainability science can be seen as a driver of societal learning and change processes (SLC). This intention to actively contribute to SLC processes distinguishes sustainability science from other approaches. The scientist leaves the "neutral position" as an observer and becomes an active protagonist as part of a process.

Clearly sustainability science is not a "mature discipline" but the discussions and projects over the past decades have begun to clarify its characteristics. It is important to note, however, that the paths taken in Europe, Japan and the USA have been different. While European practitioners have moved towards participatory, iterative processes with an implementation orientation, Japan started with a technology-based approach and has only recently begun to pay more attention to the human dimensions and the USA still prioritizes interdisciplinary research on complex human-environment systems.[4] Despite the differences in approaches,

[2]See for example, Moll and Zander (2006), Adger and Jordan (2009), Kasemir et al. (2003), Spangenberg (2008), Ehlers and Krafft (2006). Journals include Sustainability Science (http://www.springer.com/environment/environmental+management/journal/11625), the sustainability science section of the Proceedings of the National Academy of Sciences (http://www.pnas.org/site/misc/sustainability.shtml), Current Opinion in Environmental Sustainability (http://www.elsevier.com/wps/find/P09.cws_home/cosustnews).

[3]The MATISSE project (www.matisse-project.net) provides an example of the design and running of such a strategic process.

[4]This was confirmed by discussions at the International Conference on Sustainability Science in Rome, June 2010. The European approach was discussed at a small workshop in Brussels in October 2009 (http://ec.europa.eu/research/sd/pdf/workshop-2009/report_workshop_sustainability_science_october_2009.pdf#view=fit&pagemode=none). US research was discussed at a workshop in Airlie House, near Washington DC, in November – December 2009 (http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0955699)

there are clearly some crucial distinctive criteria of sustainability science, which have, for example, been listed by Kasperson (2008) and include the problem-driven nature of the work, the goal of looking at the system as a whole and tackling issues like complexity and uncertainty. The European approaches are further characterized by the focus on designing processes that are open, inclusive and goal-searching and that support learning and change through dialogue, experimentation and joint visions of a sustainable future.

5 Communities of Sustainability Scientists

As outlined in previous paragraphs, there is a growing interest in embracing sustainability issues in research and technology development. In Europe sustainable development has been introduced into a wide spectrum of scientific fields. The sustainable development website of the Directorate-General for Research of the European Commission[5] lists, for example, the following themes in which sustainable development research is carried out: energy, environment, food, agriculture, fisheries, biotechnology, health, information and communication technologies, nanoscience, security, space and transport.

The community actively pursuing sustainability science in Europe (but also globally) is highly diverse and changing. In fact some scholars have pointed to the risk of putting them into one "niche" – the great diversity of people, their backgrounds, expertise and work experience and the multi-, inter-, and trans-disciplinary nature of the institutions indirectly involved is essential and part of the specific strength of sustainability science in Europe (Jäger 2009c). There is no coherent overarching umbrella organization for the various strands of sustainability science work.

The small communities of sustainability scientists that do exist are often oriented towards specific topics e.g. climate change, development, water management, biodiversity, etc. and also technical or economic topics like consumption, production, logistics, and energy. There are few connections between these communities (apart from some individuals). The European Sustainability Science Group (ESSG)[6] is a first step in community building. The individuals in ESSG and the institutions they come from are a good starting point and a fair share of places where sustainability science is done in Europe at present, but the group is too small to fully represent sustainability science. A subset of the ESSG is working together with other colleagues in a working group on the "science-policy interface" of the ESF-COST Forward Look "Responses to Environmental and Societal Challenges for our Unstable Earth (RESCUE)". The goal of RESCUE is to develop a series of key recommendations aiming at improving the development and the impact of the RESCUE-related science community.

[5] http://ec.europa.eu/research/sd/index_en.cfm?pg=fp7-sustainability

[6] www.essg.eu

Other networks active in the area of sustainability science in Europe are listed in Table 1.

6 Opportunities for Sustainability Science in Europe

As highlighted on the sustainable development website of the Directorate General for Research of the EU Commission, the renewed EU Sustainable Development Strategy (EU SDS) adopted in June 2006 assigns an important role to research and development. The Seventh Framework Programme (FP7) for research responds to this challenge with an emphasis on delivering research to support the EU sustainable development objectives. Conversely, many recent major policy documents from the European Commission in areas relevant to sustainable development, ranging from marine policy to energy policy and technology policy, have underlined the importance of research.

EU Member States and Associated Countries have also begun discussions on how research contributes to sustainable development. The different approaches taken in individual countries were discussed at a workshop that took place in June 2007.[7] The participants agreed on a need to follow up on (1) reinforcing the synergies between national and European strategies for putting research at the service of sustainable development, (2) monitoring to what extent the sustainable development potential of FP7 will be translated into reality and (3) improving the role of research in policy making by introducing the idea of knowledge brokerage.

At the conference "Sustainable development: a challenge for European Research", upon which this book is based, one of the sessions discussed a background paper prepared by an expert group on research and development for sustainable development (RD4SD).[8] The RD4SD exercise aimed at discussing how European research can be harnessed for sustainability. The mandate required the expert group to explore the three following questions:

1. To what extent does sustainable development require changes in the way we carry out research?
2. To what extent does sustainable development require changes in the way we elaborate research policies?
3. Which indicators do we need to grasp the contribution of research to sustainable development?

All of these activities – the linking of the Seventh Framework Programme to the renewed EU Sustainable Development Strategy, the activities of Member States and Associated countries and the RD4SD exercise – largely represent a paradigm of

---

[7]Research for sustainable development – How to enhance connectivity. http://ec.europa.eu/research/sd/pdf/background_info/report_halfman.pdf

[8]The report is available at http://ec.europa.eu/research/sd/pdf/rd4sd/rd4sd_final_report.pdf#view=fit&pagemode=none

Table 1 Sustainability science networks

ESSG (European Sustainability Science Group) www.essg.eu	The European Sustainability Science Group – ESSG – consists of researchers and consultants in the fields of global change research and development research. Present. The overall vision of ESSG is a more implementation-oriented way of carrying out research projects for sustainable development: linking the worlds of science and practice – of knowledge and action.
Td-net (Network for transdisciplinary research) http://www.transdisciplinarity.ch/e/index.php	The network was launched in 2000 by the *Swiss Academic Society for Environmental Research and Ecology*. Since 2008 the *td-net for transdisciplinary research* has been a project of the *Swiss Academies of Arts and Sciences*.
TIAS (The Integrated Assessment Society) http://www.tias.uni-osnabrueck.de/	The Integrated Assessment Society (TIAS) is a not-for-profit-entity created to promote the community of inter-disciplinary and disciplinary scientists, analysts and practitioners who develop and use integrated assessment. The goals of the society are to nurture this community, to promote the development of IA and to encourage its wise application.
ESSP (Earth System Science Partnership) http://www.essp.org/	The ESSP is a partnership for the integrated study of the Earth System, the ways that it is changing, and the implications for global and regional sustainability.
The Resilience Alliance http://www.resalliance.org/1.php	The Resilience Alliance is a research organization comprised of scientists and practitioners from many disciplines who collaborate to explore the dynamics of social-ecological systems. The body of knowledge developed by the RA, encompasses key concepts of resilience, adaptability and transformability and provides a foundation for sustainable development policy and practice.
European Research Network on Sustainability Transitions http://www.ksinetwork.nl/conference2009/	The 1st European Conference on Sustainability Transitions in June 2009 brought together a rapidly growing community of researchers and practitioners interested in broad societal transitions towards sustainability. The common goal is to inform strategies for the governance of sustainability through a better understanding of the dynamics of transitions.
Forum: Science and Innovation for Sustainable Development http://sustainabilityscience.org/	The Forum on Science and Innovation for Sustainable Development is an attempt to outline the burgeoning field. The Forum focuses on the way in which science and innovation can be conducted and applied to meet human needs while preserving the life support systems of the planet. It highlights people and programs that are studying nature-society interactions and applying the resulting knowledge to create a sustainability transition around the world.

"science for sustainable development" in which science is carried out in a traditional mode and contributes to informed decision making. The reference in the 2007 workshop to "knowledge brokerage" provides a first hint of the need for sustainability science. The RD4SD exercise also refers to some elements of sustainability science but does not call for a major shift in the organization and funding of research to respond to the persistent and complex problems of unsustainability.

What could implementation-oriented sustainability science contribute to sustainable development in the EU? The renewed EU sustainable development strategy (SDS) identifies 7 key challenges:

- Climate change and clean energy
- Sustainable transport
- Sustainable consumption and production
- Conservation and management of natural resources
- Public health
- Social inclusion, demography and migration
- Global poverty and sustainable development challenges.

Each of these challenges represents a set of complex issues, broken down into operational objectives, to which sustainability science can contribute through organising iterative processes in which stakeholders (including the research community) develop a common view about the scope of the problem, elaborate a common long-term vision for the future in this problem area and explore the possible pathways to achieve that vision using a variety of scientific tools and methods. Sustainability science can contribute both an approach to dealing with these challenges and support for decisions and implementation. Through structured dialogue processes that are perceived to be credible, salient and legitimate by all participants, sustainability science can make a robust contribution to implementation of the renewed SDS and thus to sustainability transitions.[9]

An even larger contribution of sustainability science would be to design and implement processes that lead to a reconciliation of the sustainable development agenda with the goals of economic growth and employment. This would lead to a reframing of dominant science-policy paradigms of growth and development and replacing them by a more science-based integrative paradigm that looks at human well-being and wealth creation–destruction from a perspective more embedded in the social-ecological system.[10]

Overall, sustainability science could provide examples of good practice of how science and technology can best contribute to finding and implementing sustainable solutions and could help to develop social networks and social capital to improve quality of life and well-being from a global systems and cooperative perspective. Sustainability science could provide some crucial insights for policy making about how to develop new patterns of socio-ecological systems structure formation that are more resilient and less vulnerable to global environmental risks, including potential shocks derived, for example, from resource scarcity, climate change or the emergence of new diseases.

There are two particular areas where sustainability science can make an important contribution: (1) dealing with complexity not by developing single solutions for single problems but considering interdependencies (and trade-offs); (2)

---

[9]For an example of such processes, see the MATISSE project (www.matisse-project.net)

[10]See, for example, http://www.seri.at/index.php?option=com_content&task=view&id=839&Itemid=408

providing a transdisciplinary approach that fosters joint production of solutions in a societal context that makes implementation more effective than other approaches tackling these challenges.

7 Barriers

The problem of unsustainable development was explained very clearly at the United Nations Conference on Environment and Development in Rio de Janeiro in 1992. Since then little progress has been made in solving the problems (UNEP 2007). Sustainability science, as articulated more than a decade ago and implemented in a relatively small number of projects compared to traditional research projects, has a potential to support transitions to sustainability but that potential can only be unleashed, if barriers are overcome.

Underlying several of the barriers is the belief within the scientific establishment (scientists, science policy makers and funders) that taking a strategic approach towards specific implementation is still considered by many to be going beyond the remit of science (Jäger 2009c). Therefore, scientists rarely have a mandate to engage in this kind of work and academic institutions rarely give credit for these "hands-on" strategic processes of engagement. Scientists who do become involved in processes that not only analyse problems and discuss possible solutions but also support both the selection and implementation of measures to deal with the problem are leaving the realm of analysis and assuming the role of an active stakeholder.

In general, current peer-review and project evaluation procedures generally do not support this type of work (see, for example Weaver and Jansen (2004)). Peer review of proposals still looks in most cases for traditional research projects that have a scientific objective with one or more central research questions, a methodology to approach these questions and a list of expected results. Implementation-oriented sustainability science cannot determine a specific objective *ex ante*, because the problem to be dealt with has to be agreed to first with the other stakeholders. Sustainability science is "goal-searching" and not "goal-driven" (see, for example, Weaver and Rotmans (2006)).

Project evaluation of iterative processes that incorporate internal evaluation, learning processes and adaptive management is also problematic. Normal criteria for the success of a project generally start with asking whether the goals of the project have been achieved, which is not possible if the goal or objective is not determined before the project starts. Furthermore, interim external evaluation of iterative sustainability science projects is ill-equipped to deal with the adaptive management explicitly build into the project to allow learning when mistakes have been made.

A substantial barrier to producing a body of experience with sustainability science is the absence of long-term funding to support iterative, participatory processes for a range of geographical contexts and persistent problems of sustainability. The kinds of projects that are necessary for building this body of experience do not fit in the normal mode of a 3- or 4-year project cycle.

The iteration and learning require a longer time and the processes as a whole require a funding commitment for such a period.

As a result of these barriers (although there are a few exceptions[11]) experience so far has been accumulated in an *ad hoc* fashion, with shorter term experiments in various places within a range of contexts and for a number of different issues (climate change, mobility, renewable energy transitions, etc.). The concepts, theories and methods of sustainability science need further development within a coherent framework (Jäger 2009c). While there are advantages in multiple, diverse approaches to finding solutions for persistent problems of unsustainability, current efforts are very diffuse and there is a need to begin a consolidation effort.

Most of the barriers to a major, consolidated effort in sustainability science will not be removed without far-reaching institutional change.[12] The existing institutions that support science and technology in the current governance structure for knowledge require major adjustments in order to improve the links between science, policy and society. Thought still needs to be given to the kinds of institutions that can best support the necessary dialogue and science-practice partnerships to contribute to solutions of sustainability problems. A particular institutional challenge is posed by the need to build partnerships with the business and industry sectors. Institutional changes that enhance capacity building in sustainability science are also required. There are some important opportunities for institutional change in the area of sustainability science. As Tàbara (2009) has argued, two key opportunities for institutional innovation are: (1) the risks of climate change and the struggle to reach international agreements on mitigation and adaptation; and (2) new initiatives to reduce poverty and global resource/ environmental degradation inequality/inequity by a supporting a new 'global deal' of North–South (and East–West) cooperation.

One important area of institutional change referred to in the last paragraph is in the area of capacity building. Changes in the educational system to strengthen or even introduce training for sustainability scientists are necessary. Some universities (e.g. Lund, Maastricht, Arizona State, Tokyo) have introduced schools/departments for sustainability science, but the number remains very small compared to the perceived demand for practitioners with the mediation skills and systems approach needed for the processes described above. On the other hand there is no point providing training in such skills, if there are no long-term career perspectives for this kind of work, so attention to providing career incentives is also necessary.

An interesting aspect of capacity building was raised in a panel at the 2005 AAAS annual meeting regarding the lack of opportunities for young scientists to engage in and learn from work that directly links knowledge with action in the area of sustainable development. As Clark (2005) reports, the panel consisted of half a dozen young environmental scholars and development activists from China, India

[11]Probably best exceptions are transitions research networks in the Netherlands detail and at least as a model the LTSER expand

[12]A conclusion also reached by the working group on the Science-Policy Interface of the ESF RESCUE project (www.esf.org/rescue)

and Brazil. Their discussions emphasised the need for more recognition by the scientific community of the value of problem-driven work and more support by society in undertaking such work. One very interesting proposal that was generated through the panel discussion is the recognition and support of volunteer efforts by scientists to work 'in the trenches' on pressing problems. In other professions, this kind of volunteer work has long been supported (e.g. in the legal and medical professions). This would contribute to capacity building and to the accumulation of experience. As Clark (2005) points out, setting up a successful programme of scientist volunteers for sustainability would require, above all else, 'that the scientific community and its gatekeepers formally acknowledge the importance of such volunteer work in professional careers'.

8 Meeting the Challenges and Removing Barriers

Using examples from the Conference "Sustainable development: a challenge for European research" (Brussels, 26–28 May 2009) organised by the Research DG of the European Commission, this section explores how the challenges and barriers discussed above are being dealt with. Based on material discussed in previous sections, some important elements of what can be called "sustainability science" are:

- Taking an integrative view of the human-environment system;
- Using a participatory approach;
- Developing a common vision of the future and exploring possible pathways;
- Discussing trade-offs between pathways;
- Linking across scale levels;
- Integrating different forms of knowledge; and
- Fostering learning.

8.1 Taking an Integrative View of the Human-Environment System

Probably the best examples of this element of sustainability science are the papers that won awards at the conference and are included in this volume. Topics such as climate change, energy scarcity and water resources management clearly require an integrative view of the human-environment system since these problem areas arise because of the interaction between human activities and natural systems. Importantly, the papers show that the integration requires methodologies and approaches that differ from traditional research approaches, often involving stakeholders as discussed in the next paragraph.

8.2 Using a Participatory Approach

In recent years, there has been increasing recognition of the value of participatory approaches in dealing with persistent problems of unsustainability (see, for example, Siebenhüner 2004; van de Kerkhof and Wieczorek 2005; Whitmarsh et al. 2009). Even in the conference session largely oriented to the natural sciences ("Interactions and feedbacks between ecosystems and climate change") the presentation on the impact of ocean acidification on marine organisms and ecosystems indicated the inclusion of a "Reference User Group". Participation also played an important role in projects on sustainable cities and the session entitled "Yes, We Did" pointed out that dissemination, a traditional component of research projects, is moving towards co-creation of research outputs. That is, participation of stakeholders is expanding to include the design and use of research results. One session at the conference also focussed on the contributions of civil society organizations to research for sustainable development, pointing out that in addition to technological solutions there must be changes in mindsets but also concluding that civil society organizations have not been much involved in this kind of research so far.

8.3 Developing a Common Vision of the Future and Exploring Possible Pathways

In many of the implementation-oriented processes tackling sustainability issues, it has been found important to include a step in which all participants develop a joint vision (see, for example, Weaver and Rotmans 2006). This helps the participants to become much more innovative in thinking about possible solutions to problems of unsustainability. Developing a vision is not practiced in a large number of projects, but it was demonstrated in projects with a transitions-research approach (see, Chapter 7 in this volume) and in papers from the spatial planning perspective.

8.4 Discussing Trade-offs Between Pathways

Again, this element of sustainability science is standard practice in the transitions-research community and not common in other research projects. An example during the conference was provided by the paper on a transition to sustainable materials management in Flanders.

8.5 Linking Across Scale Levels

Making the linkage between human-environment interactions at the local level and processes at the regional and global levels presents numerous methodological challenges but is essential when sustainability is being assessed. Similarly, linkages between the near-term and the long-term future also have to be considered, not only because of time-lags in the system but also given the possibilities of "tipping points" or thresholds. Linking across geographical scale was exemplified in the work on sustainable primary health care in the session on enhancing global sustainability through international cooperation. Linking across temporal scale was not covered in any detail during the conference.

8.6 Integrating Different Forms of Knowledge

The recognition that scientists are not the only people who can contribute knowledge in implementation-oriented research is, of course, linked to the call for participatory processes, as discussed above. In particular, for solutions-based research, traditional or indigenous knowledge (ICSU 2002b) could play a significant role. The sessions and papers at the conference did show some evidence of the use of different sources of knowledge. In the session on international cooperation the use of indigenous knowledge in Arctic research was discussed. In the session on economics, employment, behaviour and territorial dynamics there was discussion on improving the interface between quantitative and qualitative discourses, while the session "New Imaginings" discussed systems of knowledge governance.

8.7 Fostering Learning

This is one of the central elements of sustainability science. The design of processes that support learning by all stakeholders, including the scientific community, about the causes and consequences of, as well as possible responses to, persistent problems of unsustainability is a necessary part of implementation-oriented research. The learning both about the perspectives on the issue of other actors as well as about the process itself and possible improvements in the next iteration contribute to effective processes (see, for example, Tuinstra et al. 2008).

At the conference the topic of "learning" was raised in several diverse sessions. The session on "Cash and Theory" noted the importance of changing awareness of Chief Executive Officers and employees. Several of the winning papers in this volume also include discussions of learning. Importantly, in the session "Yes, We Did" participants noted the need to provide space for reflexivity in projects and to support the learning of researchers by including a step (or, steps) of self-conscious evaluation within the research process.

8.8 Linking knowledge to Action

One of the dominant themes throughout the conference was the need to link knowledge with action. This was often posed as a question: "What do we need to do to make better linkages?" Or, in the "Fix It" session, "What do we need to do to get widespread implementation of a radical innovation?" Clearly the above seven elements are extremely important in improving the linkages between knowledge and action, as shown in other research and analysis (see, for example, Farrell and Jäger 2005; Cash et al. 2003). Overall, what they point to is the central significance of the design of processes and it was even noted that the researcher can benefit as much from the process as from the final product.

9 Reflection

A number of characteristics distinguish sustainability science from other research endeavours. These have been used in the previous section to examine the content of the conference on research for sustainable development held in Brussels in 2009. We find that each of the characteristics was present in papers presented in the conference, but not all presentations encompassed all of the ingredients of sustainability science. In fact, most of the presentations did not have all of the ingredients. Most of the research presented is certainly "science in support of sustainable development" but does not use the iterative, participatory and implementation-oriented approaches of sustainability science (at least as at is practiced in Europe). To further the use of sustainability science approaches, the barriers discussed in Sect. 7 must be removed.

First, there is a need for more funding mechanisms for the goal-seeking, iterative and integrative approaches to address the complex issues of sustainability. Second, and related to the first need, the review mechanisms for proposals and projects must be modified to deal with the special characteristics discussed in the previous section. Evaluation criteria are required that allow for a continued learning process with stakeholders. Finally, there is a need for improved incentive structures for scholars who wish to engage in implementation-oriented work, where credit could be as much for designing an effective process as for concrete results in the form of a scientific publication.

As noted above, sustainability science is not a mature discipline with shared conceptual and theoretical components. As shown by the other contributions to this book and the discussion above, we find multiple sciences addressing a common theme – the reconciliation of societies' development goals with the planet's environmental limits over the long term (see Clark and Dickson 2003). Sustainability science is heterogeneous in scope and practice. Over the coming years, considerable effort will be needed to begin a consolidation effort. With the removal of barriers it should be possible to demonstrate the huge potential of this approach to stimulate transitions to sustainability.

References

Adger, W. N., & Jordan, A. (Eds.). (2009). *Governing sustainability*. Cambridge: Cambridge University Press.

Cash, D. W., Clark, W. C., Alcock, F., Dickson, N. M., Eckley, N., Guston, D. H., et al. (2003). Knowledge systems for sustainable development. *Proceedings of the National Academy of Sciences of the United States of America, 100*, 8086–8091.

Clark, W. C. (2005). A new social contract for science? *Environment, 47*(3), 1.

Clark, W. C., & Dickson, N. (2003). Sustainability science: The emerging research program. *Proceedings of the National Academy of Sciences of the United States of America, 100*(14), 8059–8061.

Ehlers, E. A., & Krafft, T. (Eds.). (2006). *Earth system science in the anthropocene*. Heidelberg: Springer.

Farrell, A. E., & Jäger, J. (Eds.). (2005). *Assessments of regional and global environmental risks: Designing processes for the effective use of science in decision-making*. Washington, DC: Resources for the Future Press.

ICSU (International Council for Scientific Unions). (2002a). *Science and technology for sustainable development*. ICSU Series on Science for Sustainable Development, No. 9. Paris: International Council for Scientific Unions.

ICSU. (2002b). *Traditional knowledge and sustainable development*. ICSU Series on Science for Sustainable Development No. 4 (p. 24). Paris: International Council for Science.

Jäger, J. (2009a). *Our planet: How much more can earth take?* London: Haus Publishing.

Jäger, J. (2009b). The governance of science for sustainability. In W. Neil Adger & Jordan Andrew (Eds.), *Governing sustainability*. Cambridge: Cambridge University Press.

Jäger, J. (2009c). *Sustainability science in Europe*. Paper prepared for DG Research, European Commission, Brussels. Available at: http://ec.europa.eu/research/sd/pdf/workshop-2009/background_paper_sust_science_workshop_october_2009.pdf#view=fit&pagemode=none (accessed May 28 2011).

Kasemir, B., Jäger, J., Jaeger, C. C., & Gardner, M. T. (2003). *Public participation in sustainability science*. Cambridge: Cambridge University Press.

Kasperson, R. E. (2008, October 29). *Closing the science-practice gap and the role of sustainability science*. Colloquium given at the Institute of Environmental Science and Technology, Autonomous University of Barcelona,Barcelona.

Kates, R. W., Clark, W. C., Corell, R., Hall, J. M., Jaeger, C. C., Lowe, I., et al. (2001). Sustainability science. *Science, 292*, 641–642.

Moll, Peter, & Zander, Ute. (2006). *Managing the interface. From knowledge to action in global change and sustainability science*. Munich: oekom.

Rotmans, J. (2006). *Tools for integrated sustainability assessment: A two-track approach*. Working Paper 4, MATISSE Project. Available at http://www.matisse-project.net/projectcomm/uploads/tx_article/Working_Paper_4_01.pdf (accessed May 28 2011).

Siebenhüner, B. (2004). Social learning and sustainability science: Which role can stakeholder participation play? *International Journal of Sustainable Development, 7*, 146–163.

Spangenberg, J. H. (Ed.). (2008). *Sustainable development – past conflicts and future challenges*. Münster: Verlag Westphälisches Dampfboot.

Steffen, W., Sanderson, A., Tyson, P. D., Jäger, J., Matson, P. A., Moore, B., III, et al. (Eds.). (2004). *Global change and the earth system: A planet under pressure*. Berlin: Springer.

Tàbara, J. D. (2009, July 10). *What is sustainability science and what it is not*. Speech given at the Catalan Polytechnic University, Barcelona.

Tuinstra, W., Jager, J., & Weaver, P. M. (2008). Learning and evaluation in integrated sustainability assessment. *International Journal of Innovation and Sustainable Development, 3*(1/2), 128–152.

UNEP. (2007). *Global environmental outlook*. Nairobi: United Nations Environment Programme.

van Asselt, M. B. A. (2009). Uncertainty management in integrated regional assessment. In C. G. Knight & J. Jäger (Eds.), *Integrated regional assessment of global climate change*. Cambridge: Cambridge University Press.

van de Kerkhof, M., & Wieczorek, A. (2005). Learning and stakeholder participation in transition processes towards sustainability: Methodological considerations. *Technological Forecasting & Social Change, 72*, 733–747.

Weaver, P. M., & Jansen, J. L. (2004, July). *Defining and evaluating "science for sustainability"*. Paper presented at the international conference on sustainability engineering and science, Auckland. [Online] Available from: http://www.nzsses.auckland.ac.nz/conference/2004/Session5/63%20Weaver.pdf (accessed May 28 2011).

Weaver, P. M., & Rotmans, J. (2006). Integrated sustainability assessment: What is it, why do it and how? *International Journal of Innovation and Sustainable Development, 1*(4), 284–303.

Whitmarsh, L., Swartling, Å., & Jäger, J. (2009). Participation of experts and non-experts in a sustainability assessment of mobility. *Environmental Policy & Governance, 19*, 232–250.