Chapter 3

Earth system analysis and taking a crude look at the whole

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Note: This chapter is a commentary on chapter 1.

Global change in the twenty-first century

The collective outcome of global humanity in action is, in our time, worldwide environmental degradation of a magnitude not seen before. Climate change and land-use-driven planetary deforestation are the two tips of a dangerous iceberg that signals a deep crisis in the relationship of humans to their material environment (see Fig. 1). These changes herald a transformation of Planet Earth that is on par with a number of major fluctuations, interruptions and transitions in the Earth's history. The root cause is the explosive growth of human material turnover and population (see Kohn, this volume) in the last several decades.

The question that largely remains open at this point is whether the Earth's transition to a new state of operation will be largely suffered by humankind (and with it a great many other species that share the planet), as a consequence of humanity's myopic focus on short-term advantages. Or whether, instead, humanity will be able to collectively influence the ongoing transition, at least to some extent, or even divert it in ways that would allow human societies and the greater environment to continue through the transition phase with considerable, but still manageable losses (see Fig. 2). In other words, the question is whether human societies will be able to develop the collective cognitive power to re-order their affairs in a manner that reflects an understanding of the interconnected workings of the planetary system, and whether they can come to a common understanding of major desired and undesired developments and the associated required revisions in the functioning of today's societies.

Should this challenge one day be successfully met, it would impressively testify to an ability of human cultures to produce, explain and justify collective responsibilities that reach beyond the present; a mental and cultural ability that, one could argue, is in many ways at the root of the differentiation of humans from other higher life forms. If the challenge is not met, however, the ongoing evolutionary experiment of rational intelligence may have reached its planetary limits.

The global anthropogenic transformation that has been set in train will have fundamental consequences not only for the state of the atmosphere, oceans and land surfaces, but equally for human societies (Costanza *et al.,* 2007). There is no particular reason to believe that social structures are more resilient to change under systemic forcing than the environment. They will be equally, if not more, affected. Tipping points that may cause state changes in characteristic parameters or spatial patterns are known to exist in the Earth's climate system and in the biosphere interacting with it (Lenton *et al.,* 2008). Similarly, tipping points can be expected to exist in the even more complex networked systems of societies. Currently, however, little is known about them.

A number of recent crises within the cultural, social and economic systems of

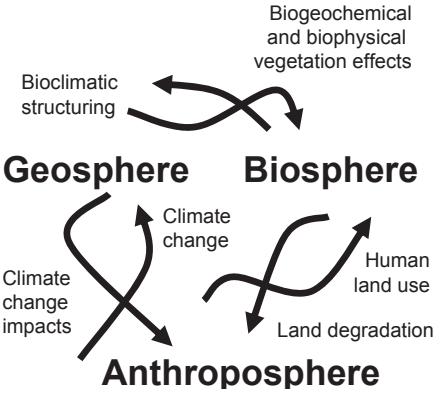

Fig. 1. Systemic interactions in the Earth system of the twenty-first century. (*Source:* W. Lucht)

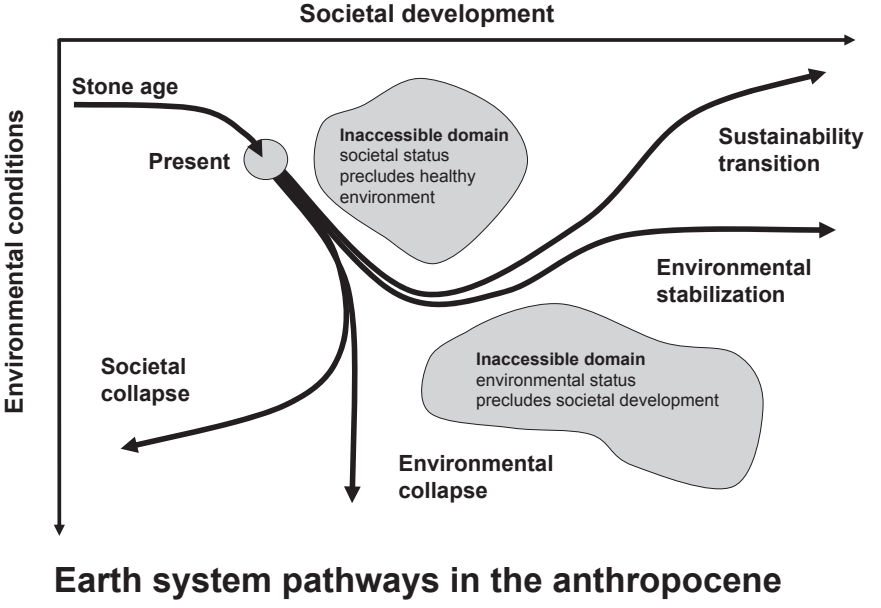

Fig. 2. Pathways in the future co-evolution of societies and the environment. (*Source:* W. Lucht, developed using ideas from Schellnhuber, 1999)

the world's societies have revealed intrinsic features of the self-organisation of these societies. In contrast, the influence of societies on the environment is still largely perceived as being external, and similarly the feedbacks of the ensuing changes on societies remain largely outside their self-reflection processes. The causal perception loop between societal and environmental dynamics is not closed in many important topical areas. However, thanks to recent efforts, the case of climate change is increasingly becoming a notable exception. The tipping points and disruptions that lurk in this loop are at the centre of the problems facing humanity in the twenty-first century.

Three prototypical solution pathways seem to be available and are supported by three strands of discourse: the technocentric, the value-oriented and the rationalistic-scientific strands.

Technological pathways

There is a widespread belief, or rather a hope, that technological progress will outpace growth in such a way as to make possible a breakthrough to clean, green, environmentally friendly technology without interrupting economic and material growth. This is the paradigm favoured in many current discussions about global change and the prospects of sustainable development. The ultimately technological causes of the great environmental problems currently at hand will, according to this school of thought, also lead in the medium term to means of surmounting them, if only technological developments are wisely steered in the right direction. According to this view, the currently observed biodiversity losses, climate change and environmental pollution are merely a dirty bottleneck through which human civilisation and with it the planet has to pass before a sustainable high-tech future unfolds. This argument is widespread: the most important debates on recycling, dematerialization, efficiency increases and semi-closed material loops all make use of it. Without this type of thinking, the world would already be in a much worse state. But in all of these scenarios, primary energy use is set to triple by the end of the century. How credible is it that the projected increase in available energy will lead to a decrease in the volume of materials used?

The fundamental problem is that there is little historical evidence that technological progress in material use and waste per produced unit has, on a large scale, been effective in reducing the overall material throughput of societies. Despite very substantial advances across the board in efficiency and in the material and energetic intensities of industrial processes, economic growth has up to now mostly outstripped these gains. Both the net harvest of materials from the environment as well as net waste flows into the environment have increased with time, often dramatically, when viewed across large regions and many sectors. Achieving a transition to a

lower level of socioeconomic metabolic turnover of materials would in fact be a first in human history; from hunter-gatherers to agricultural cultures to industrialized societies there has been a steady increase in the material throughput required to maintain, grow and reproduce human societies (Haberl and Fischer-Kowalski, 2007). History does not support the expectation that future technologies will, in their sum, be considerably more efficient and crucially less damaging to the environment in their production and implementation while economic growth continues. Such an expectation entails the crucial assumption that the future will somehow be qualitatively different from the past in this respect. This is almost completely speculative.

So while next-generation technology certainly will be an indispensable, immensely important factor in achieving a more sustainable future, unless the problem of growth is tackled it is very possible that a purely technological solution will, despite all progress, fall short. Since so much of the current world is based on growth, with the rich nations struggling to cope even with reduced growth, the rapidly industrializing nations greatly concerned about the robustness of their growth, and poor nations very justifiably aspiring to grow out of their poverty, this is a worrisome prospect.

The world of values

A second approach to the transition problem is embodied in the wide-ranging discourses on values, justice, and generic rights of the natural world. In this approach the solution is not sought primarily in technology but in the cultural power of humans: to frame their lives through cultural identity constructions and societal orders, built upon political and ethical systems, religious understandings and spiritual relationships to the world. At the core of this approach are central questions concerning who we are as humans, who we should and can be, and what our place in this world is.

From these questions follow directions for societies. While many such systems have placed humans in a controlling, possessing position in the world, providing the ethical, religious, spiritual, tribal or national underpinning of environmental appropriations, many of the same and a number of alternative cultural systems, not only in indigenous cultures, emphasize respect for life in general, for the world and its inherited orders, for other humans and for the self as the best path towards a rich existence. In this view, the limits to growth are given where it impinges on the inherent rights of others, whether in this or a future generation, whether geographically close or afar, and whether in the human domain or in the wider domains of life. They are given where growth compromises the particular quality of the existence of the other. This world view appeals for a revision or even revolution of lifestyles, values and priorities driven by alternate cultural self-constructions. Justice is a core element of this debate.

There are two problems with such a value-oriented approach to achieving the reordering of human material relations to the world required for a sustainability transition. For one, history shows that for the mainstream of human cultures, appeals to become more responsible and to champion the good have too often lacked the power to overcome the material orders of societies, which people have often been reluctant to compromise. Humans seem disposed to put material wealth before mental well-being, though often the two are connected; a materially poor life is a happy one only with great difficulty, and often only in artificial monastic settings. Also, the strongly structured social orders characteristic of humans and most primates produce a close relationship between power and material control, making material production an element of deeply engrained social relations, and thus a difficult factor to overcome.

A second problem with this approach is that transforming value systems and thereby, to some extent, engineering a transition of cultural identities to a state that is compatible with sustainability is likely to conflict with the most fundamental of modern human values, that of individual freedom. Proactive cultural construction has too often been a tool of dictatorships and tyranny, with devastating consequences, for people not to be wary of consciously engineered value systems. Cultural construction is an ongoing human experiment that does not seem to be bound by a peaceful human inclination, once more for reasons probably rooted in the problematic but deeply constituting legacy of humans' primate past.

However, if a controlled transition in the interlinked social-environmental world system is to be achieved, transitional progress has to be made not just in the environmental domain, where the impacts have to be lessened, but also in the social domain, where the problems have their origin. The power of cultural re-invention should not be underestimated in this context. It is precisely what allowed humans to flourish in all corners of the world. When in the brains of early *homo sapiens* environmental and technological knowledge began to mix with their old and profound social intelligence, the foundations were laid for the experiment of nature unfolding in modern humans. Culture is elementary to our condition. Therefore, to ignore the powers of the cultural dimension in seeking solutions would amount to negating the core factor that has made modern humans what we are.

Perhaps for this reason, particularly in the American discourse, the solution for sustainability seems often to be sought in a combination of green technological breakthroughs and value changes (Raskin *et al.,* 2002). Unfortunately, as shown, technology probably will not be sufficient and value changes in a free world not a priority over material accumulation. This leaves this vision, despite the central position of culture for the human species, uncomfortably adrift of the workings of the real world.

Pathways through rationality

The third proposed avenue for engineering the collective sustainability transition rapidly is to rely once again on the hope that the rational side of the human intellect will in the end overcome the intricate webs of human societal and technological identity constructions. Admittedly, it is a hope that may be as questionable as that concerning values. The progress of rational thought since the Enlightenment has undoubtedly produced great improvements in the human condition, proving its power to transform, but it has also degraded the world by removing richness in cultural meaning and by tending to produce universalistic, dominating economic and technological structures. This has been called the totalitarian aspect of the dialectics of the Enlightenment (Horkheimer and Adorno, 1947). The hope is that, in the end, the intellect rooted in the human mind will understand the lock-in, transcend it, and, driven by the will to be something particular in the world, open up new avenues. We can question whether revolutions and cataclysmic crises are necessary to stimulate such breakthroughs. But certainly there is a deep conviction, particularly in European thought, that rational solutions to problems can be found, and implemented, even if the ultimate objectives of such rational action remain rooted in culturally formed self-understanding.

It is here that science enters the debate. Certainly humankind requires an analytical, diagnostic and prognostic science of the Earth system before the problems it faces can be adequately viewed and understood. Climate change is not a problem that can be described purely as socially constructed in the way some other aspects of human reality can; if emissions continue, climate change will occur irrespective of the prevalent social discourse. Planetary realities are impinging on the symbolic and discursive systems of humans in challenging new ways. It is only very recently that humans have even begun to see and appreciate the Earth as a physical, chemical and biological system. Concerning scientific insights into the world, it is worth remembering that a mere 200 years ago the meaning of prehistoric finds such as dinosaur bones or hand axes was unknown. Nobody knew how old the Earth was, that there were ice ages, where the sun obtains its energy from, or, how chemistry works. There was no knowledge of genes or epigenetics, no theory of evolution, and little to be called historical science.

It is only on the basis of this newly created scientific image of the Earth, rather than the earlier cosmological, religious, cultural images of the Earth, that a warning can now be sounded, perhaps just in time, about the consequences of human action on the planet; only computer models built with the knowledge of Earth system science are now able to project climate change and land-use scenarios and the resulting impacts on the world's ecosystems in a way that will affect political action. It is the system of rational analysis that has contributed this crucial element to

human reflection. Despite the large remaining uncertainties and gaps in knowledge, what has become known is significant enough to have triggered the current global debates on climate change, land use and sustainability.

The question now is whether the expectation that rational insights have the power to influence and ultimately transcend cultural and economic practices is warranted. That is, whether the powers of the collective human brain will allow a narrow escape from the predicament by steering the tools of culture, economy and social relations in directions that sustainably support a future free of unmanageable tipping point transitions in either the environment or in societies. Is this a realistic prospect? Realities around the world are more strongly shaped by cultural and economic forces than by rational analysis. The deeper challenge, therefore, is how to integrate the findings of the sciences into the sometimes fast-changing, sometimes sluggish societal self-constructions that dominate human processes. If this is not successful, rational analysis will remain a marginal activity in the government of human affairs, its power of insight and foresight wasted.

Looking at the Earth as a system

Murray Gell-Mann argues that a way forward might best become apparent if we take a 'crude look at the whole' as our starting point (Gell-Mann, this volume). This formulation encapsulates his analysis that relevant Earth system processes are firmly interconnected and that the 'whole' includes identifiable macroscopic properties, including transitional behaviour. His proposal is based in science, the rationalistic vein of analysis, but goes far beyond it by building on the realization that, in the end, it is the human mind that has to come to conclusions and has to find ways to bridge the gaps between the realities of social structures, cultures and sciences, and bring it all together in a mentally adequate manner. It is for this reason that the disciplinary segregation inherited from the history of science is not suited to the problem of climate change. A more comprehensive approach to applying the intellect to the problems of the world – a crude look at the whole – is needed.

Alexander von Humboldt championed a similar approach, depicting the complexities of world landscapes that he encountered by describing their natural history, geology, ecology and human colonization in narratives composed of well-selected details, arranged to provide insight into the larger whole (von Humboldt, 1807). They were meticulously accurate and highly selective in their depiction, and formed a whole of consciously aesthetic quality, as a means of facilitating the incorporation of scientific knowledge into the human mind.

James Lovelock (2003) has argued in a closely related vein against reductionism in Earth system science. He writes that reductionist disciplinary approaches, despite their indisputable successes, are fundamentally unsuited to explaining the major

systemic interconnections that form the whole of the planet; and hence make it more difficult, if not impossible, to understand the change underway in that whole. By drawing analogies between the planetary and the human body Lovelock observes that just as the human phenomenon cannot be understood from the mere sum of its biochemical states, so the Earth as a whole cannot be understood from a merely reductionist summation of its physical and chemical states. He then describes the Earth as a self-regulating system in which humans are in danger of marginalizing themselves through their own actions.

Hans Joachim Schellnhuber (1999) has described the emergence of the modern scientific enterprise as a series of revolutions that have signalled the advent of systemic reflection in the life of the planet; the original Copernican revolution, looking out into the heavenly world, has been followed by a recent 'second Copernican revolution', looking inward into the workings of the planet. In both cases, optical instruments led the way, producing essential images that helped establish a coherent new science. The insights gained were not initially of immediate relevance to daily lives, but subsequently shifted perceptions of human identity in a most profound manner while also opening up new methodological avenues. Building on new knowledge, and using the tools of scientific Earth system analysis, humankind is now in the process of forming a disembodied, networked collective Global Subject that is attempting to order its affairs in the world while struggling with the intimidating complexity of the task.

Earth system analysis

So how, then, can a crude look at the planetary whole be achieved? Based on Schellnhuber's analysis, three elements support an adequately reflective consciousness. First, a highly developed, comprehensive science of Earth system analysis is required, using medium-complexity computer simulation as an important synthetic tool for projecting the joint dynamics of geosphere, biosphere and anthroposphere into the past and into the future. Second, a comprehensive, global-scale Earth observation system is needed to provide the essential empirical links between the past or present states of the planet (including the many local realities in its regions), and theoretically constructed macroscopic images of these states. And third, a globally networked, multi-hubbed system of communication, negotiation and goal-setting is required to enable distributed, multifaceted communication, understanding and then management of a considerable number of processes relevant to the basic functioning of the Earth system. Together, these elements will constitute the distributed, collective, networked global consciousness that may steer planetary processes out of dangerous territory by influencing the powerful dynamics of the anthroposphere.

Current medium-complexity Earth system modelling already provides to some extent crude looks at the whole. Profound insights have been generated in the past 30 years about the functioning of the Earth system and its many interlinked biogeochemical cycles, geophysical balances and system feedbacks. Nonetheless, these models still treat the main cause of today's disruption of global biogeochemical and energetic balances – human action – as largely external. Neither the deeper social drivers nor the impacts of the change on these drivers are yet part of most modelling systems, partly because the processes of the anthroposphere cannot yet be systematically computerized. Again, one of the deeper reasons for this deficiency lies in the disciplinary structure of the sciences, out of which Earth system science has grown.

A similar gap is evident in current global Earth observation, which is required to provide humankind with sensory feedback on the Earth's history and current state. Current observations focus strongly on non-human systems. With the notable exception of global economic and related national statistics, the all-important human dimension is subject merely to weak, largely unsystematic or under-evaluated observation. A more comprehensive observation of the whole, particularly of the exchange processes between human societies and their environment, is urgently required if a crude look at the whole is to be achieved. One of the greatest challenges in sustainability research is to develop methods to identify the details on the basis of which a crude look at the Earth system and its interactions with humans can be achieved. The challenge is to bring local realities into the framework of global interconnections. That process involves more than creating a loose mosaic by reductionist summation of separate parts.

In terms of communication and decision-making structures working with crude looks at the whole, the global transitions to be managed in this century are of a magnitude that will require coordinated international, though not necessarily unified, approaches. Bodies such as the Security Council of the United Nations may recognize that it is in their remit to pro-actively anticipate the geopolitical dangers resulting from mismanagement of the looming food, climate, energy, industrialization, population, and resource crises. In order to avoid, limit, channel, or manage these dangers the world will need coordinated optimization of resource use, adherence to agreed bottom-line standards of international justice, joint financing of overarching countermeasures, stimulation of education and innovation, and the sustainable regulation of many resources that, under the prevalent economic and political paradigms, are not coherently managed. If the impending change is to be managed rather than suffered, human societies will need to adopt self-engineered paths to sustainability. These will have to lead to substantial reductions in worldwide human material extraction, emission and waste flows.

New cosmologies

In summary, there is still widespread failure to appreciate that the methods of the twentieth century are not fully adequate to address the transformative crisis at hand. The assumption persists that somehow societies will be able to more or less continue on their current paths, with some adaptation to environmental changes, but little or only gradual alteration in basic functions. This may turn out to be one of the greatest misconceptions of our time. The adaptive powers of societies are certainly strong, but most likely are too slow to keep pace with environmental changes, and even at a slow pace they will likely transform societies. The challenges of the twenty-first century will be fundamentally different in quantity and quality from those of the twentieth century because the fundamentals of the problems to be tackled are very different. The question now is whether an investment can be made – intellectually, financially, and culturally – in finding pathways that will allow a future based on sustainable use rather than profligate consumption of resources.

It is only for this reason of urgency that we can probably not avoid adopting the very uncomfortable word 'engineering': the world can no longer avert dangerous change unless human societies actively engineer, or manage, a rapid way out of their predicament. This engineering or management will engage multiple sectors: technological engineering (as in new energy and production technologies), societal engineering (as is currently happening in the form of a politically agreed transition in the world's energy systems and in the creation of international institutional structures), environmental engineering (as in the world system of human-controlled nature reserves), and perhaps even – as a very last resort that is better avoided – limited, targeted geoengineering. Engineering, however, is by definition built on a rationalistic basis, and is subject to the fundamental cultural risks associated with that. To be truly effective it must pay particular attention to matters of design: it must by design be deeply embedded in a social and value-based analysis looking at consequences and pitfalls.

In this manner, the three strands of technological, value-oriented and rationalistic-scientific approaches are interwoven in this process of Earth system management and are not mutually exclusive. All of them must be applied in order for humankind to turn a potential dead-end into a bottleneck that in turn may lead to a sustainable opening. In fact, closer analysis shows that these three approaches operate on different levels. The rationalistic-scientific approach deals with understanding the control problem at hand. The technological and value-oriented strands have to do with means for exercising the necessary, albeit surely very partial, control in the technological and social domains. In addition, the value-based approach is concerned with the question of what the operating principles and directions should be, beyond merely avoiding the worst.

The global transformations now under way are the latest expression of a transformation that probably began with the advent of symbolic information processing in the brains of humans, or more precisely in the brains of the latest species of humans, *homo sapiens,* some 100 000 years ago. Ever since that transformation the human domain has been structured according to ideas of culture, religion, language, tribe, nation, place, personal identities and histories, leading ultimately to the still somewhat mysterious processes of agriculture and industrialization that are now causing such dangerous systemic side effects. In that sense, many of the dynamics of the anthroposphere are a cultural phenomenon. The ultimate root causes of the global transformation will be found in these intrinsic, still poorly understood processes of human culture. Ways forward will therefore, ultimately, have to also be anchored in social and cultural dimensions.

Environmental feedbacks from human action have always been an integral part of societal dynamics, but for the first time they now have to be considered on a global scale. For the first time in human history, a systemic understanding of the Earth system needs to enter cultural processes. Therefore, the crude narratives of the whole to emerge from this process will inevitably need to depart from sociocultural narratives if they are to be effective since they must ultimately aim at affecting societal structures. Taking a crude look at the whole in this sense puts an immense responsibility on the human mind to develop well-founded narratives that are in full resonance with the latest scientific findings (Lucht and Pachauri, 2004).

The process of constructing such views is not without dangers. Human history is replete with societal visions of nature and the natural that have clouded the practice of human interaction with the environment. It takes a culturally embedded and reflective, yet highly capable science to prevent such misguided approaches. This will be all the more difficult as comprehensive, fundamental theories of ecological systems are not yet available (if they even exist). Attempts at a theoretical explanation of the historical evolution of human societies and their interactions with the environment are fragmentary at best and the underlying assumptions deeply controversial among historians, economists, sociologists and anthropologists. We lack guiding theories of society-environment interactions, let alone of society-environment co-evolution. Yet such insights are required to form a framework upon which new interpretations of the human as well as the planetary condition can be formulated.

I therefore propose that the key factor in taking a crude look at the whole is a belief, maybe even merely a hope, that the human mind – in this case the collective mind of networked humanity – will be able to construct mental images of the whole that are more than mere figments of cultural or scientific projection. Rather, they must be equally founded in rational analysis and cultural production. These mental images have to take the form, I propose, of new cosmologies, cosmologies that

blend cultural narratives of the position of humans in the world with the findings of Earth system analysis, encompassing both the natural world and the human condition in its cultural expression. These new cosmologies will do one thing: they will once more describe the place of humans in the Earth system.

The required sustainability transition will certainly not happen by accident. It will not merely emerge – by chance or by necessity. Achieving it will require a collectively conscious societal effort based on a reflective Earth system science that takes into account the full extent of the human experience, expressed in new cosmologies. Such a transformation will likely open up interesting new pathways for human societies on our planet. It will require that humankind applies its unprecedented scientific knowledge determinedly to the problems facing the world, and shows a great openness to renewed discourses on values, priorities, justice and self-images, with consequences that will structure societies, through the power of narratives. Such societal self-engineering is not a small intervention, however the consequence of inaction will be equally transforming. It is, in the end, a question of identity because the damage done will be largely irreversible.

The ultimate question, I suggest, is: What will we do with our freedom? This question can only be answered by the human mind. This is what is meant by taking, through a science of Earth system analysis that is comprehensively embedded in sustainably re-empowered cultural practices, a crude but well-defined and essential look at the whole.

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