REFRAMING THE PROBLEM OF

CLIMATE CHANGE

FROM ZERO SUM GAME TO WIN-WIN SOLUTIONS

EDITED BY
CARLO C. JAEGER, KLAUS HASSELMANN,
GERD LEIPOLD, DIANA MANGALAGIU
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Reframing the Problem of Climate Change

This book provides an evaluation of the science and policy debates on climate change and offers a reframing of the challenges they pose, as understood by key international experts and players in the field. It also gives an important and original perspective on interpreting climate action and provides compelling evidence of the weakness of arguments that frame climate policy as a win-or-lose situation.

At the same time, the book goes beyond providing yet another description of climate change trends and policy processes. Its goal is to make available, in a series of in-depth reflections and insights by key international figures representing science, business, finance and civil society, what is really needed to link knowledge to action. Different contributions convincingly show that it is time – and possible – to reframe the climate debate in a completely new light, perhaps as a system transformative attractor for new green growth, sustainable development and technological innovation.

Reframing the Problem of Climate Change reflects a deep belief that dealing with climate change does not have to be a zero sum game, with winners and losers. The contributors argue that our societies can learn to respond to the challenge it presents and avoid both human suffering and large scale destruction of ecosystems; and that this does not necessarily require economic sacrifice. Therefore, it is vital reading for students, academics and policy-makers involved in the debate surrounding climate change.

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Introduction
Beyond the zero sum game

From shirking burdens to sharing benefits

Carlo C. Jaeger, Klaus Hasselmann, Gerd Leipold, Diana Mangalagiu and J. David Tàbara

The zero sum fallacy

We have a climate crisis. We don't mean the danger that human modifications of the earth atmosphere will modify the earth's climate with grave consequences for people and the planet. Rather we see as the crisis the inadequacy of society's response to this threat.

Since the near collapse of international negotiations in Copenhagen 2009, the number of optimists believing in strong, global solutions to the climate problem is dwindling. Political leaders who made climate change a central plank of their agenda are slowly distancing themselves. Ban Ki-Moon indicated that he will concentrate on supporting the green economy and the growth of renewable energy and no longer be at the forefront of climate negotiations. President Obama did not even mention the words climate change in his 2011 State of the Union address. And the interest of the media is going down; only 1279 journalists registered for the Cancun meeting, well below the limit of 2000 set by the organizers (over 5000 journalists went to the Detroit Motor Show!).

Climate is a complex physical-biochemical-ecological system in itself. The effect of climate on culture, social organization and the economy and vice versa is even more complex. The complexity starts locally and extends to the whole globe. The world community has faced few – if any – such global challenges in its history: there are no precedents and few historic examples to draw upon.

In the light of such complexity, it is not surprising that no single actor possesses all the information, all the competence or all the authority to act comprehensively and decisively. Yet, with the common will to find solutions, and with the support of non-partisan scientific analysis, we are confident that optimal solutions to complex problems can indeed be found. We need to integrate multiple perspectives and skills and build on the adaptive and robust responses and learning of the many different actors that drive the global system and form policies.

The limitations of all actors leads to, at best, partial solutions: partial solutions that do not add up, partial solutions in which responsibility and blame is shifted onto others, partial solutions in which limited authority has led to limited action.

For the dispassionate observer, the wealth of activities and discussions over climate creates the illusion that we are engaged in a zero sum game. Although this is clearly not the case – we all will lose if nobody acts – we are behaving as though it were a game with winners and losers, in which one actor's gain is dependent on the losses of other actors.

We share a deep belief that dealing with climate change should not and need not be treated as a zero sum game. We see the pervading zero sum mentality as a consequence of the complexity of the situation, of institutions focused on national, regional and corporate interests, of actors unable to consider or overwhelmed by the complexity of the global system, of behaviour conditioned by conventional values and thinking – in short, in the failure of our institutions to understand the nature of climate change as an entirely new problem of global dimension that cannot be managed by the traditional techniques of regional bargaining or conflict resolution. It is a problem of the global commons. This requires an entirely new mindset.

In his classic paper 'The tragedy of the Commons', Garrett Hardin (1968) highlighted the basic dilemma of a group that jointly exploits a finite resource owned by all: each member of the group has a motivation to overexploit the resource, to the detriment of the group as whole. The obvious solution, that all members agree to limit their individual exploitation to a sustainable level, will work only if the agreement can be enforced. Ethical appeals alone, he argues convincingly, will always fail: nobody is willing to be duped by free riders. In the problem of global climate change there exist no effective means of enforcing compliance: all agreements on greenhouse gas emissions reductions are voluntary, based on an unstable mixture of trust and free-riding suspicions. Thus, without a change in the perspective of the participants, the failure of climate policy, following Hardin, appears inevitable.

Must we then resign ourselves to being for ever damned as the generation that destroyed the basis of human civilization as we know it today? The present state of climate negotiations as sketched above would appear to support this pessimistic view. Historical precedents of civilizations that collapsed due to their failure to prevent the destruction of the environment on which they depended (Diamond, 2005) are also hardly encouraging.

However, we are convinced that we need not be trapped in Hardin's logic. Not because we believe (although we would like to believe) that humans will necessarily place moral integrity above material gain – although there do indeed exist examples demonstrating the inherently social nature of humans and their ability to abide by ethical values for the common good without direct coercion (Ostrom, 2009). But rather, because the climate problem offers a simple solution to the 'Tragedy of the Commons' problem that was not foreseen by Hardin. Instead of reducing the exploitation of a finite common resource as the only option, we can switch to another resource that is unlimited, namely to renewable energy, and change our lifestyles accordingly. We argue in this book that the transformation process, if analysed carefully and implemented responsibly, can not only solve the climate problem, but also alleviate many other global problems, enhancing both

the average well-being of the human population as a whole and the welfare of each individual nation.

The role of science

The book is based on papers presented at the international conference 'Action for Climate – Beyond the Zero Sum Game' of the Global Climate Forum (formerly European Climate Forum) in Barcelona, April 2010. It is written *by* scientists, but not *for* scientists. Rather we address businesses, decision-makers, stakeholders of all sorts, and the general public. Our purpose is to generate a more widespread awareness of the opportunities and considerable benefits that the transformation to a green economy offer – beyond the immediate goal of avoiding dangerous climate change. Although our approach is that of the scientist, we attempt to develop a generalist view by drawing on the expertise from many disciplines, spanning the natural, economic, social and political sciences.

Climate science will continue to be the main source of knowledge with which to assess all climate efforts. It is the nature of all geophysical systems that their evolution can be predicted only with a limited degree of certainty. We have seen an ongoing improvement of climate science in recent years and have been able to narrow the uncertainty of the predictions and the range of expected temperature increases. Our knowledge about the climatic system will continue to improve, including our ability to better predict regional effects in addition to global temperature increase, such as rainfall patterns and extreme weather events. The reviews of Working Group 1 of the UN Intergovernmental Panel on Climate Change (IPCC, 2007a) can still be expected to provide on a regular basis the most authoritative review of the state of the art of climate science. However, in addition to the six-yearly reports of IPCC Working Groups 2 and 3 on adaptation and mitigation, respectively (IPCC, 2007b, 2007c), which are tied to the non-partisan 'policy-supportive but non-policy-prescriptive' mandate of IPCC, more timely – and, where necessary, policy proscriptive – assessments based on a continuous, close interaction between scientists and policy-makers will also be required (cf. Hasselmann and Barker, 2008).

Science will also help us to better understand the interaction and interdependence of the climatic system with the global social-economical-ecological system. Climate has a strong impact on water availability, agriculture and food production, and vice versa. Improving the understanding of the relationship between climate, water availability and agro-food systems, including the economic and political systems governing their dynamics, will be a necessary precondition for any move towards sustainable development.

The understanding of complex interactions of geophysical and ecological systems with human society is a particular demanding scientific challenge. While integrated modelling of interacting social and biophysical systems is still at an early stage, substantial progress has been made in understanding how to deal with complex systems (cf. Beinhocker, 2006) in relation to climate.

Essential for an improved understanding of the climate change problem leading to a recognition of the many benefits of foresighted climate policies is the identification and acceptance of the very different views as seen by different countries, and by different people within any given country. Thus a strongly actor-based view of the global socio-economic system must be developed (cf. Farmer and Foley, 2009).

Concurrent with this approach, we need to discuss and inter-compare alternative transformation paths promoted by the adherents of different schools, for example: the top-down versus bottom-up approach; the target versus free innovation approach; the emphasis on equal per capita emission rights versus equal carbon efficiencies; or the focus on absolute versus relative emission reductions.

We also need to recognize and address the limitations of a purely science-oriented analysis of climate change issues. While science will always be a key driver of the necessary technological innovation, it is not the sole answer to the climate challenge. Other social, cultural and institutional aspects also need to be taken into account. This includes the questioning of conventions and general beliefs in the possibility of maintaining business-as-usual trajectories, the role of selective incentives or sanctions, and the unveiling of options to modify existing patterns of individual and collective behaviour. In particular, in the era of the internet, the potential of mobilizing wide public and consumer support for the realization of win–win policy options is a powerful weapon for overcoming the combination of inertia and vested interests that are currently blocking progress towards more enlightened climate policies.

Following this line of reasoning, we investigate in the following first the origin of the present climate policy blockages, then the various socio-economic transformation trajectories that have been proposed to overcome the blockages and create a sustainable green economy; and, finally, the changes in perspectives and regulatory measures that are needed to accomplish the transformation. We foresee that the growing evidence of the negative impacts of unabated global warming, amplified by the media and disseminated by the modern powers of the internet, will sooner or later bring about the required widespread change in perspective. Countries that anticipate these trends and lead in the development and implementation of low-carbon technologies will then stand to gain most from the future enhanced quality of life of the world as a whole.

The subsequent chapters of the book will investigate in more detail the various aspects of the problems and solutions that we can only briefly summarize in this introductory overview.

Current blockages in climate policy

The breakdown of climate negotiations since the failure of the Copenhagen conference is most evident in the glaring contradiction between the acceptance by the conference of the 2°C global warming limit, while at the same time the conference participants failing to agree on shared commitments that could actually achieve this goal. The non-committal reduction goals offered by individual

countries would, in sum, produce an estimated global warming by the middle of this century nearly twice as high as the accepted limit. This is of the same order of magnitude as the warming that occurred since the last ice age. But instead of 20,000 years, society would have only one generation to adapt to the change.

The origin of this blockage lies in the aforementioned inability of the world's policymakers to deal with genuine problems of the global commons. These cannot be resolved in the zero sum tradition of conflict resolution. The only comparative problem of global dimension is the danger of nuclear war. However, the two problems differ in one essential aspect: in the dependence on time. The defusing of the nuclear threat can be simply postponed to a later day in the hope of future enlightenment (in the hope also that no nuclear exchange has meanwhile taken place). But the resolution of the climate problem suffers no delay. Without mitigation policies, global warming will continue to increase, and the costs of ultimate remedial action, if feasible at all, will continue to rise inexorably.

To overcome the blockage, we must first identify the different goals and value systems of the actors that have led to the blockage.

Perhaps the most fundamental divergence of views lies in the interpretation of equity with respect to the amount of CO_2 emissions allowed to each person. At present, the global average per capita CO_2 emissions are about 5 tons per year. This is comparable with the per capita emissions of China, while the corresponding values for Europe and Japan (10 tons per year) or the US (20 tons per year) are twice or four times or as high, respectively. The per capita emissions of India, Brazil and other emerging economies, and still more so of the less developed countries, are significantly lower than the world average (www.ucsusa.org/global_warming/science_and_impacts/science/each-countrys-share-of-co2.html). Many countries with low per capita emissions argue that every person should have the same emission rights, and that until per capita emissions have equalized, the burden of climate change mitigation should be borne by the countries with the highest per capita emissions. The industrialized countries argue, on the other hand, that their high per capita emission levels are simply an expression of their higher levels of production per capita, which every country is free to emulate. The relevant yardstick should be the carbon efficiency, that is, the value of the goods produced per unit of emissions. All countries should strive to achieve a common carbon efficiency target, which could be continually raised to comply with the prescribed reduction of global CO_2 emissions. This would also resolve the question of whether emission reductions should be assessed in absolute terms or relative to the level of production.

Between these two contrasting viewpoints there exist, of course, many gradations, as well as other general aspects of fairness. These concern, for example, the special rights of developing nations aspiring to achieve the same living standards as the developed nations, or the historic responsibility of the developed nations for the past emissions produced in achieving their own living standards, or the asymmetries between nations adopting strong and those adopting laissez-faire population-growth policies.

While the moral principle of equal per capita emission rights as a long-term goal has many adherents, the short-term need to increase the carbon efficiency of rapidly growing economies still largely dependent on fossil energy, particularly coal, is equally persuasive. To accommodate both viewpoints, a climate agreement would need to envisage a rapid reduction of per capita emissions of the developed countries, allowing the emerging and less developed countries to increase their per capita emissions for a short period before decreasing also their emissions, such that the per capita emissions of all countries converge finally to levels compatible with the prescribed global warming limit of 2°C. The distribution of emissions between different countries in the converged long-term limit is then an equity issue that must be resolved politically. However, the rate of reduction and the acceptable very low final level of the total emissions is not an open question but is clearly specified scientifically, once the 2°C global warming limit has been accepted.

Thus the central challenge of international climate negotiations is to agree upon the rate of contraction and convergence of the per capita emissions of all countries – an approach that was first discussed in the 1990s and has meanwhile become a basic pillar of UNFCCC (cf. for example, Kuntsi-Reunanen, E. and J. Luukkanen, 2006, or IPCC, 2007c).

However, along with this basic problem of equity are numerous further issues. These include: the role of greenhouse gases other than CO_2, such as methane, nitrous oxide, CFCs, HCFCs and HFCs, which together contribute nearly 40 per cent of the total greenhouse warming (IPCC, 2007a); the release of CO_2 as well as other negative environmental impacts due to deforestation; or the morally mandated transfer of capital and technology from the industrialized countries, the principal originators of climate change, to the emerging and less developed countries, the countries with the least resilience to climate change. Transfers are needed both for investments in climate change mitigation and for adapting to climate change. Although economic analyses indicate that it is more effective to invest in the longer-term abatement of greenhouse gas emissions than to adapt to the climate change that one has failed to prevent, the costs of adaptation can nevertheless not be ignored, since some degree of global warming will be unavoidable.

Finally, the problem of climate change cannot be divorced from other global problems. These include widespread poverty, malnutrition, increasing rich–poor gradients within and between regions, and the many global challenges summarized in the millennium development goals. For example, the increasing use of bio-fuels as substitute for fossil fuels can lead (and has led) to a direct conflict with food production. Climate mitigation policies also cannot be pursued without consideration of the widely differing forms of government of the participating countries, with their inherent tensions and potential sources of conflict. These clearly have a direct impact on the relative values and priorities accorded by different countries to climate change policies. Thus, climate policy must be pursued as an important, but only one, component of an integrated global policy approach.

The strong interdependence of climate change and global welfare has been explicitly recognized by the recent creation by UN Secretary-General Ban Ki-Moon of the Global Sustainability Panel, consisting of 21 high-level representatives of countries worldwide (IGBP, 2011). However, the Global Sustainability Panel must develop policies in a world of many influential actors, with widely differing values, perceptions, beliefs, goals and strategies.

Against this real world background, we review now some of the proposals that have been put forward for achieving the transformation of our present fossil-based socio-economic system to a sustainable decarbonized system.

Transformation trajectories

While the optimal transformation path and the means by which it should be pursued are the subjects of considerable debate, there exists general agreement that, in principle, the basic technologies to achieve the desired transformation are available, and that the transformation can be achieved within the finite time window afforded by the 2°C global warming limit. However, it is also widely accepted that this represents a major technological and economic challenge that cannot be met by relying on market forces alone, but requires effective government intervention to stimulate the necessary large scale innovation efforts and investments.

Before entering into the debate, it is useful to recall some basic physics. We focus on CO_2, which accounts at present for about 60 per cent of the total greenhouse gas emissions, and is projected to account for a still higher fraction in the future, driven, among other factors, by the rapid increase in the use of coal in China and India. CO_2 has a mean residence time in the atmosphere of well over 100 years. Thus for a rough estimate of the global warming impact of the CO_2 emitted within the first half of this century, it is sufficient to consider the total sum of the emissions, neglecting the removal from the atmosphere through storage in the oceans and the biosphere. According to climate models (IPCC, 2007a), the 2°C warming limit implies that the total emissions over the next 50 years should not exceed 1000 GT (1 Giga Ton = billion tons) CO_2, or about 150 T CO_2 per person.

Applying the equal emission rights principle, this implies that if the present per capita emission rates quoted above remain unchanged, people in the US, Europe and Japan, or China would exhaust their personal total CO_2 emission contingent in about 7, 15 or 30 years, respectively. The last figure is representative also for the 'average person' of the world (in rounded numbers, ignoring increases in population, the removal of CO_2 from the atmosphere, and uncertainties of the order of +/- 50 per cent in the relation between CO_2 concentrations and global mean temperature).

The simple budget calculation highlights the challenge we face in implementing contraction and convergence paths of CO_2 emissions under the total budget constraint. To treat the negotiations over the distribution of the permissible finite amount of CO_2 emissions between different countries as though we were engaged

in the zero sum exercise of dividing up a finite cake ignores the fact that the cake is being continually devoured by a few voracious appetites. We cannot afford the losses of time incurred in the zero sum bargaining sessions of the latest climate negotiations. On the other hand, we can – and must – use the limited time available to bake another cake – in the form of renewable energy.

Typical transformation paths computed under the budget constraint implied by the 2°C global warming limit yield total emissions peaking around 2020, decreasing rapidly thereafter to very low values by the middle of the century. The later the emissions peak, the more rapid and challenging the required subsequent rate of decrease. To satisfy realistic contraction and convergence criteria, the emissions of the industrialized countries need to start decreasing immediately in order to accommodate longer emission growth phases for the emerging and less developed economies.

The existing voluntary emission reductions of the signatories of the UN Framework Convention on Climate Change (UNFCCC) fall far short of these goals. Nevertheless, economic analyses indicate that the goals are achievable at an acceptable cost of the order of 1 to 2 per cent of GDP (Azar and Schneider, 2002; Weber et al, 2005; Stern, 2007). This corresponds to a delay in the BAU (business-as-usual) economic growth path of the global economy over the next 50 years of a few months to a year – surely an acceptable price to avoid the risks of dangerous climate change! In fact, we argue in the next section that weighing 'costs' is the wrong view of the problem: the transformation process will create considerable net benefits, which are not considered in the standard discussion of incurred and avoided costs.

Views diverge, however, on which are the best transformation trajectories and how they should be realized. Renewable energies cannot compete economically with fossil fuels without internalization of the external costs of future climate change through government intervention. However, the optimal mix of market forces and government policies is much debated. Governments have essentially three instruments at their disposal: (i) imposition of a carbon price ('stick' policies); (ii) direct government support, either in the form of research and development, or for new technologies ('carrot' policies) and (iii) direct regulation measures (for a more detailed breakdown of mitigation instruments, see IPCC, 2007c).

A carbon price is the most direct way of internalizing the costs of future climate change. It can be imposed either through a carbon tax, or through a cap-and-trade system. It is an effective instrument for bringing renewable technologies that are close to becoming competitive into the market. However, for renewable energies that hold considerable long-term promises but are currently relatively costly – such as concentrated solar power, an essentially unlimited resource – governmental support is essential in order to launch the technologies on to the learning curves and the economy-of-scale benefits that will ultimately make them competitive, especially since the full costs of fossil fuels and nuclear power are not internalized. Parallel government support for public or private research institutions developing innovative technologies for renewable energy, or new methods for improved energy and carbon efficiency, is also an important component of

government-sponsored innovation. Finally, direct regulation is necessary in many sectors in which market forces are ineffective, for example, in the purchase of consumer goods (automobiles, homes, household appliances) in which affluence overrides frugality in determining consumer preferences.

A major cause of the blockage in climate negotiations is that each country has different concepts regarding the optimal mix of instruments that should be applied to achieve a given emissions reduction trajectory, yet individual national policies are unavoidably interlocked through the global nature of the socio-economic system and climate change. This is not necessarily a disadvantage. Different policies in different countries can be more effective than a common policy applied indiscriminately to all countries. However, there needs to be a common will to harmonize the different approaches. There exist two schools of thought of how to arrive at an effective solution. These may be characterized generally as the top-down and bottom-up approach.

Adherents of the top-down approach argue that the global interdependencies mandate global solutions in the form of binding international climate agreements. The most straightforward way to realize equitable contraction and convergence trajectories, for example, would be to apply a 'stick' policy in the form of a global cap-and-trade system – generalizing various regional or national cap-and-trade systems, such as the European Emission Trading System (ETS), or similar schemes in the US.

In the approach proposed by Wicke and Dürr-Pucher (2006), for example, each country would be assigned a total number of emission permits proportional to its population, in accordance with the principle of equal per capita emission rights. Countries with low per capita emissions would then be able to sell their initially surplus emission rights to countries with higher per capita emissions, thereby achieving two important objectives: (i) global investments would be attracted into the most effective channels for reducing emissions; (ii) capital and technology would be transferred from the industrial countries to the emerging and less developed countries. Thus the resultant contraction and convergence trajectories would be economically optimal, generate transfers from industrialized countries to emerging and less developed countries, and be consistent with the principal of equal per capita emission rights. Each country would furthermore be able to implement its own individual policies for reducing emissions, for example, by auctioning its national contingent of emission permits and using the income for subsidies for renewable energy, or by introducing additional emission regulations. The basic principle of equal per capita emission rights would need, of course, to be adjusted to allow for different regional climates, different access to natural resources, etc., and would also need to be augmented by further global agreements on non-CO_2 greenhouse gases, on deforestation, etc.

However, Copenhagen and Cancun have demonstrated that the world is not governed by a benevolent global authority, but by a distributed system of players pursuing national interests, in which short-term regional interests can override longer-term global goals – even existential goals of future human existence. Rather than despairing over the frustration of trying to create a Grand Plan for future

human civilization based on justice – whether based on some version of a global cap-and-trade system or some other global agreement – adherents of the bottom-up approach argue that efforts to achieve a transformation to a sustainable socio-economic system should focus on opportunities within individual countries or regions (Jaeger et al, 2011). Frustration with the current blockage of the Grand Plan approach is no reason for not pursuing partial solutions, for supporting regional approaches and promoting the many bottom-up actions that are springing up in impressive variety.

Indeed, it is only through the active participation in the innovative governance initiatives of the innumerable regional and bottom-up actions that we can gain the necessary experience and create the political conditions needed for a global solution. The prospect and persistent pursuit of a top-down Grand Plan will, in its turn, provide guidance and motivation to this wealth of bottom-up activities. Thus, a coordinated bottom-up and top-down approach offers the most promising prospect of reducing the probability of dangerous climate change.

However, an essential condition for overcoming the present hindrances of climate policy will also be a fundamental change in our view of the functioning of the socio-economics of climate change.

From shirking burdens to sharing benefits

One of the strongest influences on the present public and political understanding of the economics of climate change was the review of the same title by Sir Nicholas Stern (Stern, 2007). Stern emphasized that 'Greenhouse gas emissions represent the biggest market failure the world has ever seen'. Stern's analysis – as the analyses of most economists – focused on the costs of future climate change. He pointed out that, although uncertain, these would undoubtedly greatly exceed the estimated costs (of the order of 1 per cent of GDP) of the necessary mitigation measures to avoid dangerous climate change.

Unfortunately, the focus on weighing costs against each other has led in the political arena to discussions over appropriate schemes for 'burden sharing'. In view of the prevalent zero sum mentality of negotiators, this has resulted in the dominance of strategies for shirking rather than sharing burdens. We argue that the correct view of the desired socio-economic transformation process is not one of incurring present costs to avoid future costs, but rather one of investing today to reap significant benefits both today and tomorrow (cf. Chapters 4–11).

The cost perspective arises from the misconception that the business-as-usual trajectory represents an optimal reference growth trajectory. The societal costs incurred by climate change are simply ignored. Any departure from the BAU path is seen as an incurred additional cost. This misconception, in turn, derives from the traditional economic assessment of production solely in terms of the Gross Domestic Product (GDP), i.e. in terms of the cost of production. Relevant for the evaluation of economic production, however, is what is referred to in Chapter 7 as the Human Value of Production (HVP) (see e.g. Stiglitz et al, 2009 and the references cited there for a detailed criticism of GDP and proposed alternative

human-welfare relevant measures of production). HVP represents a weighted sum of both monetary and non-monetary values, such as job security, health insurance, social institutions, the state of the environment, and the impact of the production process on the legacy of the present generation for future generations. It is clearly a subjective, strongly actor-dependent value measure, but nevertheless the measure that determines the behaviour of economic actors. In standard economic general equilibrium theory, GDP and HVP are not differentiated. It is implicitly assumed that market forces will effectively monetarize HVP, leading to an equalization of HVP and GDP.

However, that this is not the case is clearly demonstrated by the impact of the information provided by IPCC. Prior to the publication of the second, third and fourth IPCC reports (IPCC, 1996, 2001, 2007a), which presented successively stronger evidence for a significant human impact on climate, the BAU scenario could be accepted as a reasonable representation of an optimal economic growth path, without making any distinction between GDP and HVP. After the fourth IPCC report, however, only very few people chose to ignore the evidence presented by the overwhelming majority of climate scientists. (Unfortunately, the formally 'unconvinced' nevertheless still represent a majority in the present republican dominated US Congress, a disturbing reflection on the powers of special interest groups and the effectiveness of disinformation campaigns, cf. Hoggan, 2009; Dunlap and McCright, 2010.) For most people, the climate evidence resulted in a collapse of the HVP-curve relative to the GDP-curve for the BAU trajectory (cf. Chapter 7). The magnitude of the collapse depended on the separate weights assigned by individual actors to the different components of their subjective HVP function. It depended, among other factors, on their concern over the impact of future climate change. But it occurred, with varying intensity, for all people who accepted the scientific evidence.

Concurrent with this change of perspective, most people today support climate mitigation policies (cf. Chapters 3 and 6). They are consequently disappointed and disillusioned with the outcome of the latest climate conferences. But rather than mount public protests, the more common reaction has been to suppress the disappointment and turn to more positive aspects of daily life.

The media sensed the public disillusionment and, responding to the lost interest of the public, reported less on climate issues. Thereupon politicians, always sensitive to media trends, also backed away from the climate issue.

How can one break the vicious cycle? We argue that it can and will be overcome by embracing a longer-term perspective while providing feasible, attractive and mutually beneficial options in the short term. In the long term, our civilization has no other choice than either to become trapped in the conflicts arising from climate change or to mount more vigorous efforts to transform our socio-economic system. How long will it take for the public, the media and policy-makers to accept this simple fact?

It took 30 years for climate scientists to convince the public of the reality of human-induced climate change. This was based on global mean data, such as global mean surface temperature, mean atmospheric temperature profiles, mean

upper-ocean temperatures, etc. The more important negative effects of climate change on regional scales (cf. Chapters 1 and 2), in the form of increasing frequencies of floods, storms, droughts, etc. are only just beginning to appear above the 'noise' of the natural climate and weather variability. It can be anticipated that in the next 10 or 20 years the increase in extreme events will become ever more evident, and the public demand for political action, amplified by the networking power of the internet (cf. Chapter 6), will become increasingly strident. Countries that have a long record of blocking climate policies and denying the overwhelming evidence of leading academic institutions worldwide are likely to lose credibility and international influence – or even face increasing hostility by less fortunate countries that have come to fully realize that they have been seriously short changed in their efforts to prevent climate change.

In contrast, countries that are able to demonstrate that their socio-economic systems have been successfully transformed to a sustainable decarbonized system, with many clearly visible benefits (cf. European Commission, 2011, Chapter 5), will be the countries that will lead the way to a more stable global society. The benefits will not be limited to direct climatic impacts (cf. Chapters 1, 2) and the socio-economic sector (cf. Chapters 3–10), but will affect all aspects of life on this planet. Reforestation, for example, not only removes CO_2 from the atmosphere, but also can convert arid areas to pleasant and productive environments and increase water availability through enhanced rainfall (cf. Chapter 11).

The transformation will not be easy. We will need to change much of our thinking and behaviour and conduct many experiments, not all of which will succeed. However, we are confident that the transformation will succeed. Our confidence rests on the wealth of actions of citizens, civil society, companies and local, regional and national governments, all of which demonstrate the willingness of actors to assume responsibility for their actions on the global environment. Concerns are occasionally expressed that independent decarbonization efforts of individual countries or regions will necessarily place these at a comparative disadvantage relative to countries that continue with business-as-usual policies. However, these can be readily overcome by applying a combination of stick-and-carrot policies. A carbon tax or regional cap-and-trade system combined with support for affected sectors can remove trade distortions (a less controversial approach than imposing emissions-dependent import tariffs) without weakening the motivation to reduce CO_2 emissions.

Since these insights are relatively straightforward, it may be anticipated that as soon as they are recognized and seriously pursued by a few foresighted countries, other countries will quickly follow, transforming the present vicious cycle into a virtuous cycle.

References

Azar, C. and Schneider, S.H. (2002). 'Are the economic costs of stabilising the atmosphere prohibitive?', *Ecological Economics*, vol. 42, pp73–80.

Beinhocker, E. (2006). *The Origin of Wealth*, Boston, MA: Harvard Business School Press.

Diamond. J. (2005). *Collapse: How Societies Choose to Fail or Succeed*, London: Penguin.

Dunlap, R.E. and McCright, A.M. (2010). 'Climate change denial: sources, actors and strategies', in Lever-Tracy, C. (ed.), *Handbook of Climate Change and Society*, Abingdon, UK: Routledge, pp240–259.

European Commission (2011). 'Roadmap for moving to a competitive low-carbon economy in 2050', http://ec.europa.eu/clima/policies/roadmap/index_en.htm.

Farmer, D. J. and Foley, D. (2009). 'The economy needs agent-based modelling', *Nature*, vol. 460, pp685–686.

Hardin, G. (1968). 'The tragedy of the commons', *Science*, vol. 162, pp1243–1248.

Hasselmann, K. and Barker, T. (2008). 'The Stern Review and the IPCC fourth assessment report: implications for interaction between policymakers and climate experts', editorial essay, *Climatic Change*, vol. 89, pp219–229.

Hoggan, J. (with Littlemore, R.) (2009). *Climate Cover-Up. The Crusade to Deny Global Warming*, Vancouver, BC, Canada: Greystone Books.

IGBP (2011). 'Planet under pressure', *Global Change: International Geosphere Biosphere Programme*, vol. 76, January.

IPCC (1996). *Climate Change 1995: The Science of Climate Change, Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change*, Houghton, J.T., Meira Filho, L.G., Callander, B.A., Harris, N., Kattenberg, A. and Maskell, K. (eds), Cambridge, UK and New York: Cambridge University Press.

IPCC (2001). *Climate Change 2001. The Scientific Basis*, Houghton, J.T., Ding, Y., Griggs, D.J., Noguer, M., van der Linden, P.J., Dai, X., Maskell, K. and Johnson, C.A. (eds), Cambridge, UK and New York: Cambridge University Press.

IPCC (2007a). 'Summary for policy makers', in *Climate Change 2007. The Physical Scientific Basis, Contribution of Working Group 1 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. and Miller, H.L. (eds), Cambridge, UK and New York: Cambridge University Press.

IPCC (2007b). *Climate Change 2007. Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and C.E. Hanson (eds), Cambridge, UK and New York: Cambridge University Press.

IPCC (2007c). *Climate Change 2007. The Mitigation of Climate Change, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Metz, B., Davidson, O.R., Bosch, P.R., Dave, R. and Meyer, L.A. (eds), Cambridge, UK and New York: Cambridge University Press.

Jaeger, C.C, Paroussos, L, Mangalagiu, D., Kupers, R., Mandel, A. and Tàbara, J.D. (2011). *A New Growth Path for Europe. Generating Prosperity and Jobs in the Low-Carbon Economy*, ECF Synthesis Report, info@european-climate-forum.net, www.european-climate-forum.net.

Kuntsi-Reunanen, E. and Luukkanen, J. (2006). Greenhouse gas emission reductions in the post-Kyoto period: Emission intensity changes required under the 'contraction and convergence' approach. *Natural Resources Forum*, vol. 30, pp272–279, DOI: 10.1111/j.1477-8947.2006.00119.x.

Ostrom, E. (2009). 'A general framework for analyzing sustainability of socio-ecological systems', *Science*, vol. 325, pp419–422.

Stern, N. (2007). *The Economics of Climate Change. The Stern Review*. Cambridge: Cambridge University Press.

Stiglitz, J.E., Sen, A. and Fitoussi, J-P. (2009). Commission on the Measurement of Economic Performance and Social Progress (www.wikiprogress.org/index.php/Commission_on_the_Measurement_of_ Economic_Performance_and_Social_Progress).

Weber, M., Barth, V. and Hasselmann, K. (2005). 'A multi-actor dynamic integrated assessment model (MADIAM) of induced technological change and sustainable economic growth', *Ecological Economics*, vol. 54, pp306–327.

Wicke, L. and Dürr-Pucher, G. (2006). 'Beyond Kyoto 2012: No prevention of dangerous climate change without an internationally acceptable "Beyond Kyoto" global cap-and-trade system', *International Review of Environmental Sciences*, vol. 6, pp63–91.