Responding to Climate Change

Knowledge and Insight Required to Act under Uncertainty

Focusing on Robust Findings

Bert Bolin

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STOCKHOLM ENVIRONMENT INSTITUTE

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Rainwater harvesting and terracing in Gansu Province, China. Courtesy of Professor Qiang Zhu, Gansu Research Institute for Water Conservancy, Lanzhou, Gansu, China

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Abstract

To communicate scientific findings to politicians for action requires care and insight in what really matters to people. The scientific process tends to focus on uncertainty and issues about which we have limited knowledge, since these naturally are topics for continued research. Solid and well-established facts are rather what should be in focus to support political actions. Uncertainties should of course be fully recognised but must not be the prime message.

We know quite well about past increases in atmospheric greenhouse gases and also the change of the radiative forcing of the climate system that they now are bringing about. The inertia of the system implies that only part of what we have done so far has yet been realised as a change of climate. In addition, air pollution partly hides the warming that otherwise would have occurred, but air pollution will eventually be reduced to protect human health. Also, a climate change due to enhanced greenhouse gas concentrations in the atmosphere is next to irreversible. These statements are quite robust.

Preventive actions concern the development of a sustainable energy supply system for the world. The emissions must be limited and possible sinks (e.g. storage of carbon dioxide underground) be utilized. Reducing net emissions will just about have begun by 2010, but further major decreases will be required in order to avoid a major change of the global climate. The aspirations for industrialisation and a decent lifestyle in developing countries implies rapid increase of fossil fuel use and increasing emissions of greenhouse gases. This will in turn mean that industrial countries will have to take the lead in emissions reductions. Global inequities, the slow response of the global socio-economic system and unwillingness to take the warnings of a forthcoming change of climate seriously, still stand in the way for major mitigation efforts. This inertia of the global society must be overcome and in the long run costs will be less the sooner major measures are taken.

Most of these facts have been known for a decade or more. A rapid change in attitudes towards global climate change among people and politicians is necessary if the industrial and developing countries are going to secure sustainable development.

The Challenge

The assessment by the Intergovernmental Panel on Climate Change (IPCC) of the climate change issue has provided a detailed and authoritative analysis of what we do know and what we still are uncertain about regarding the ongoing change of the global climate. The global mean temperature has increased by 0.6 ± 0.2 ºC during the 20th century, which cannot be explained unless the contributions due to human emissions are included. A large majority of the scientific community therefore accepts the notion that a human induced climate change is on the way. Some still maintain an opposite view, but their scientific arguments are generally inconclusive. The view that remaining uncertainties justify delaying preventive actions is hardly convincing.

There is, however, still a significant uncertainty about the sensitivity of the climate system to the disturbances that human activities on earth bring about. Nor are we able to spell out more in detail what the characteristics of this change might be or how quickly, where and to what extent it will have a major impact on our well-being. Similarly, the impacts of a forthcoming climate change are also uncertain. It is of course most essential to analyse these uncertainties more carefully, but there are in any case reasons that justify early actions. The main theme of this report is to bring home the message that even though the climate change issue is fraught with uncertainty, a number of quite firm conclusions can be drawn. These should serve as a basis for action. Uncertainties should of course be fully recognised but must not be the main message. The final judgement about the urgency remains a political issue and will necessarily to some extent, be subjective.

Some Key Features of a Human-Induced Climate Change

The following features of the climate system are particularly important when developing a strategy for handling the climate change issue because there is little controversy about these findings (IPCC, 2001a):

- The enhanced greenhouse effect (including also the role of methane, nitrous oxide, and the three minor constituents considered in the Kyoto protocol) so far means an increase of the equivalent atmospheric carbon dioxide concentration by about 55% yielding an enhanced radiative forcing of about 2.7 Wm^{-2}. This forcing corresponds to an enhancement of the atmospheric carbon dioxide concentration to about 440 ppmv (parts per million) as compared with a pre-industrial concentration of about 280 ppmv. The carbon dioxide concentration in 2003 was about 373 ppmv.

- The greenhouse warming is counteracted by enhanced concentrations of atmospheric aerosols (air pollution), the presence of which is also a result of human activities. The IPCC considers that **the northern hemisphere greenhouse gas warming therefore at present may well be reduced by 30-50%.** A value of -1.3 Wm^{-2} in 1990 has been assumed when constructing the IPCC future climate change scenarios. The global greenhouse gas warming is thus partly hidden as a result of the enhanced concentrations of atmospheric aerosols.

- Because of the damaging effects of aerosols on human health and the acidification of freshwater systems and soils that they also bring about, industrial countries have reduced this kind of pollution markedly in recent years, but air quality in developing countries has been and still is deteriorating.

- Because of the wish to protect human health, more stringent measures will be required, particularly in developing countries, to reduce air pollution. Since aerosols stay in the atmosphere merely weeks or perhaps a month, while greenhouse gases have life times of decades to centuries, the long-term greenhouse gas warming will emerge more fully and clearly, if and when air pollution is generally reduced.

- The warming due to human emissions is also delayed because of the considerable inertia of the climate system, primarily because of the associated warming of the top layers of the oceans. Only about 80% of the ultimate warming due to the enhanced radiative forcing that the emissions of greenhouse gases and aerosols so far have brought about, has as yet been realised.

- The observed warming during the 20^{th} century, about 0.6 ºC on average (about 0.8 ºC over land areas and about 0.5 ºC at sea) might therefore plausibly be even less than 50% of the expected ultimate warming as a result of **the enhanced greenhouse concentrations so far.** This means that the sensitivity of the climate system to human interference is likely to be at least 2.5 ºC for a doubling of the carbon dioxide concentration, even though a smaller value cannot be excluded.

- There are signs that the frequency of extreme events has increased during the latest few decades, but it has not yet been possible to tell conclusively to what extent the ongoing warming has caused this increase. We know, however, that a warmer atmosphere means more water vapour in the air, which in turn is the major energy source for storms and violent weather. The notion that there may be more extreme events in a warmer world therefore seems plausible.

- People respond slowly to the possible threat of a climate change, both in developing and industrialised countries and efforts aimed at reducing emissions have so far been modest (see further below). In spite of the agreement reached in Kyoto in 1997, the carbon dioxide emissions have continued to rise in most countries and will probably do so through the first commitment period, 2008-2012 and for quite some time beyond, although at a somewhat slower pace than at present.

- A stabilisation of greenhouse gas concentrations will not be achieved until emissions have been **reduced substantially below present emission levels**. Therefore, a change of climate will be with us during most of this century, probably well into the next. Thus, seen in a social/political context a global climate change is inevitable and next to irreversible. The key questions therefore become: To what extent will we be able to keep a climate change within reasonable bounds and what does “reasonable bounds mean?” Adaptation to a changing climate will in any case be a necessity but differently so in different parts of the globe.

- The search for predictable regional features of the ongoing change is obviously the key to improved understanding of the human-induced future changes of the Earth’s climate. This understanding is required in order to assess the impacts on human activities and our well-being. Such efforts should be given priority in ongoing research. It will, however, take time to provide more reliable results and some changes may well remain unpredictable because of the non-linear characteristics of the climate system. Uncertainty may be reduced somewhat, but will not be eliminated.

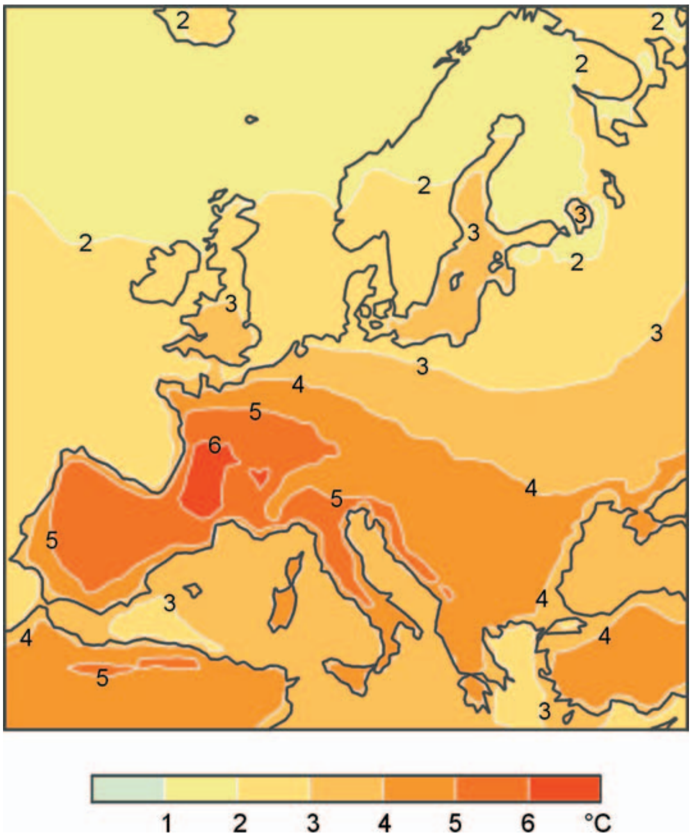

Figure 1. *Projected average temperature changes for the summer (June-August) over Europe from 1961-1990 to 2071-2100 based on the IPCC Scenario B2 (IPCC, 2000), making use of the regional climate model developed at the Rossby Centre at the Swedish Meteorological and Hydrological Institute in Sweden (see SWECLIM, 2003).*

- Some progress however, may be expected. The extraordinary heat wave that struck major parts of southern Europe during the summer of 2003 (as well as similar extreme events elsewhere) with serious damages, is the kind of evidence that deserves further analysis. As a matter of fact both the excessive heat and associated extended droughts that occurred show distinct similarities with the expected long-term regional changes that have been deduced by several research groups in Europe; see Figure 1 (SWECLIM, 2003). One may indeed question if southern Europe may have a more desert-like climate in the future with serious implications for the livelihood in this region. A similar change towards drier conditions may be expected in many regions poleward of the subtropical belt in both the northern and southern hemisphere, e.g in the southern US, India, South Africa and Australia.

In summary, the fact that a global human-induced climate change has begun, acknowledging the inertia and the next to irreversibility of the climate system, and the likeliness that the response by the global community will not be quick, are strong arguments for concluding that the ongoing change of the climate might be a more serious matter for the future than so far has generally been considered to be the case. Considerably more far-reaching measures during the next commitment period after 2012 than agreed in Kyoto are likely to be necessary in order to avoid serious consequences of a change of climate. This might be good reason for adopting a precautionary principle. Before returning to a discussion of mitigation, a few comments on the issue of impacts and adaptation are provided.

Impacts and Adaptation

We do not know very well how severe the impacts of climate change on our natural environment and society might be, but the conclusions in the previous section already imply that it still might be prudent to take steps for adaptation to a changing future already now and to make more serious efforts in order to slow down and ultimately stop the ongoing human-induced climate change. Expected impacts deserve attention (IPCC, 2001b).

- Changes of the hydrological cycle are particularly important. We are fundamentally dependent on the availability of water. Projections by many scenarios of future changes of the climate show increases in annual mean stream flow at high latitudes and in Southeast Asia but, on the other hand, decreases in central Asia, areas around the Mediterranean, southern Africa and Australia. Today approximately 1.7 billion people live in areas that are water stressed. This number is, according to the IPCC, projected to increase to several billions by 2050.

- The magnitude and frequency of floods could increase markedly in many regions as a consequence of increased frequency of heavy precipitation events that increase runoff but may, on the other hand, also recharge groundwater in some floodplains.

- Many coastal areas will experience increased levels of flooding, accelerated erosion, loss of wetlands and mangroves, and seawater intrusion into freshwater sources as a result of climate change.

- Appreciable costs will accrue in coping with increasing climate-induced yield losses and adaptation of livestock production systems. When agronomic adaptation is included, assessments indicate that the projected climate change will generally lead to positive responses in mid-latitude crop yields at less than 2 ºC warming, but negative responses for more warming than that, especially in already hot climates. Droughts in particular are threats to agriculture.

- It has been established, although as yet incompletely so, that climate change, mainly through increased extreme events and temporal and spatial shifts, will worsen food security in Africa, where it already today is inadequate in many regions.

- The severity of storm impacts, including storm-surge floods and shore erosion, is likely to increase.

- Most changes of climate as foreseen are damaging, e.g. more heat waves and droughts in semi-arid regions, more flooding in temperate and wet regions, rising sea level, and also probably an increased risk for stormy weather. Nevertheless some limited regions, particularly at high latitudes in the northern hemisphere, might benefit from changing climate conditions, e.g. parts of Canada, Scandinavia and the Russian Federation. A warmer climate might for some time to come be advantageous for forestry in these regions.

- On the whole, however, the negative effects will be dominating and more so in a perspective beyond a few decades. On the other hand, changing the present course in a major way may take half a century or more, if the present slow response to a call for action by most countries of the world is not soon markedly changed.

- Adaptation to the impacts of climate change is much dependent on local conditions as well as institutional capacity and capability to cope with future modifications of the prevailing climate. Obviously developing countries are at a disadvantage, because lack of resources often prevents necessary steps to be taken for protection of people and infrastructures. The need for adaptation to a climate change should therefore influence decisions regarding assistance to developing countries.

Mitigation, Opportunities and Limitations

What can then be done, what are the opportunities and limitations? Which are the prime indications that show the needs for urgent actions?

Mitigation of climate change concerns reduction of emissions, and/or enhancement of sinks for greenhouse gases in a long-term optimal manner.

Reductions of Emissions

Since carbon dioxide is the most important greenhouse gas and primarily produced in providing energy for human needs, the issue of emissions reduction is intimately coupled to the establishment of a long-term sustainable energy supply system for the world.

- People respond slowly to the possible threat of a climate change, both in developing and industrialised countries and actions aiming at reducing emissions have so far been modest. In spite of the agreement reached in Kyoto in 1997, the carbon dioxide emissions in most industrial countries have continued to rise.

- The Kyoto Protocol aims at reductions by industrial (Annex 1) countries by about 5% from 1990 to 2010, while no specific targets were specified for developing (Non-annex 1) countries. Perhaps the EU may reduce their emissions slightly but hardly by 8% as specified in the Kyoto Protocol, while the other OECD countries probably on average will increase their emissions by more than 10% in particular because of the increasing emissions in USA. The countries in economic transition have, however, reduced their emissions by 25-35% since 1990, because of major changes in the infrastructure and a decline of the production, but a turning point seems now to have been reached. Industrial countries may totally reduce their emissions somewhat until 2010, but then primarily because of the decline of emissions in the countries in economic transition and most likely not by 5 % as aimed at in the Kyoto protocol. **The efforts to stabilise carbon dioxide concentrations in the atmosphere will just barely have begun at the end of the first decade of this century.**

- It is not likely that the Kyoto target will be reached, but the figures given above also imply a major redistribution of the emissions between industrial countries. Assume, as seems likely, that the global emissions will increase by about 20% from 1990 to 2010 and that the trends as described above will continue during the first decade of the 21st century. The USA was responsible for about 36% of the total emissions by industrial countries in 1990, and is then likely to contribute about 42% in 2010. Other OECD countries continue to be responsible for about 32%, while countries in economic transition probably will have reduced their part from 32% to about 26%. In addition developing countries will probably increase their emissions by 30-40 %, perhaps even more. Still, they would by 2010 not yet be responsible for half of the total emissions in spite of their four-fold larger population.

- None of the IPCC scenarios for greenhouse gas emissions during the 21st century, in which no specific efforts to stabilise atmospheric greenhouse gas concentrations have been assumed, will lead to stabilisation by 2100 except possibly one. In that case, however, it has been assumed that the world population would be merely about seven billion at the end of the century, which is far below the UN projections. Obviously, stringent measures will have to be taken for commitment periods beyond 2010 in order to gradually stabilise greenhouse gas concentrations in the atmosphere.

- No restrictions on the use of fossil fuels for energy production during the 21st century implies that conventional reserves and resources of oil and natural gas will not suffice to provide the projected increase of global energy needs and will be gradually depleted, (Table 1). About 75%

Table 1. Global reserves, resources and additional occurrences of fossil fuels in terms of potential carbon dioxide emissions, in comparison with resources used so far (Gt C).

		Consumption			Reserves	Conventional resources to be discovered		Recoverable with techn.	Additional occurrence
	1860-1990	1990	2000	1860-2000	identified	Low estim.	High estim.	progress	at least
Oil									
Conventional	62	2,4	2,7	88	110	30	110		
Unconventional	-				130			170	280
Gas									
Conventional	25	1,1	1,3	37	70	140	330		150
Unconventional	-				100			300	330
Hydrates	-								12000
Coal	145	2,5	2,7	171	700			2230	4100
Total	232	6	6,7	296	1110	170	240	2700	16900

Data source: IPCC, 2001c.

of these reserves are found in the southern parts of the Russian Federation and in Middle East countries. The very large coal and unconventional oil resources will then increasingly become attractive options, but have the common property that the carbon dioxide emissions per unit energy produced is much larger compared to conventional oil and gas.

- The role of no-carbon-emitting primary energy sources has increased very slowly during the last few decades. These must, however, become more competitive or be subsidised to avoid that the global society is further locked into an energy system increasingly based on fossil fuels, because of the major investments required for their exploitation.

- The implementation of any strategy to combat climate change will require an analysis of the very different circumstances in which industrial and developing countries find themselves today. This is illustrated by the fact that the average per capita emissions of carbon dioxide from industrial countries (about 3 ton C per person) are about five times larger than the average emissions from developing countries (about 0.6 ton C per person), but the latter are increasing their emissions rapidly, since their economic development can hardly be achieved unless more energy will be available (Figure 2). Their limited financial resources imply that cheap fossil fuels will continue to be their prime resort for quite some time to come.

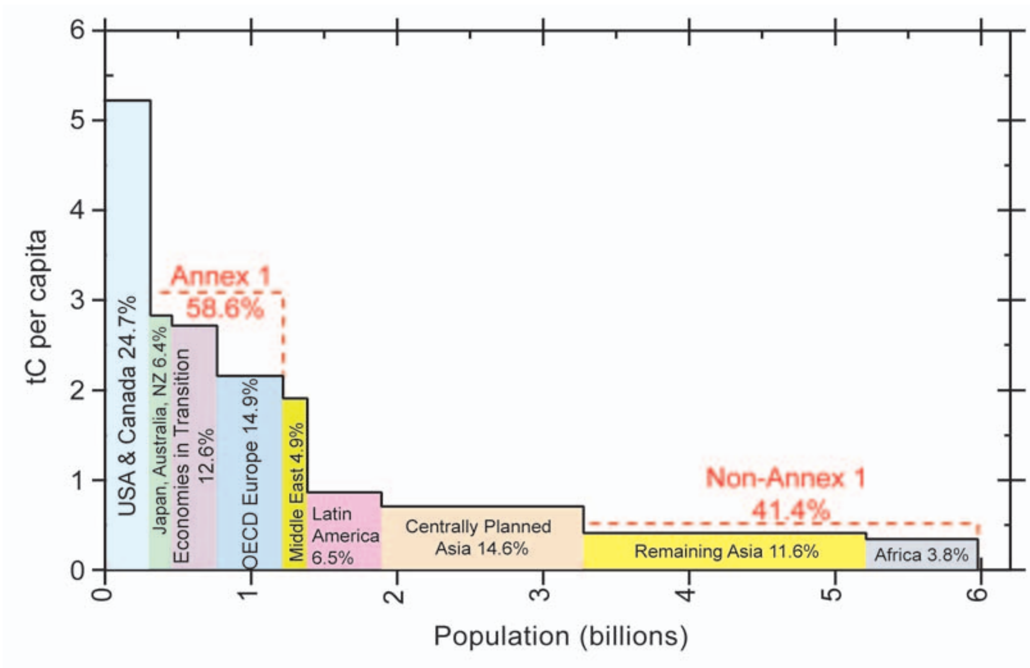

Figure 2. *Per capita fossil fuel emissions 1999 averaged for nine geographical regions and grouped in Annex-1 and non-Annex 1 countries. Height of bars gives the average per-capita emissions of each region. Width of bars gives the population. Area of the bars is proportional to the 1999* CO_2 *emissions from fossil fuels and cement production. The percentages indicate the fraction of the 1999 total global emissions attributed to each region (cf Bolin and Kheshgi, 2001)*

- Even if industrial countries would have decreased their carbon dioxide emissions by 50% by the middle of the century, developing countries would never be able to emit on average more than about 1.3 ton C per capita, if a stabilisation level for carbon dioxide twice the pre-industrial concentration should be achieved (Figure 3). This limit is merely about 40% of the present average per capita missions in industrial countries, about a quarter of those emitted presently by USA and less than 50% of its 2050 emissions. This would still be far from equity between the countries of the world.

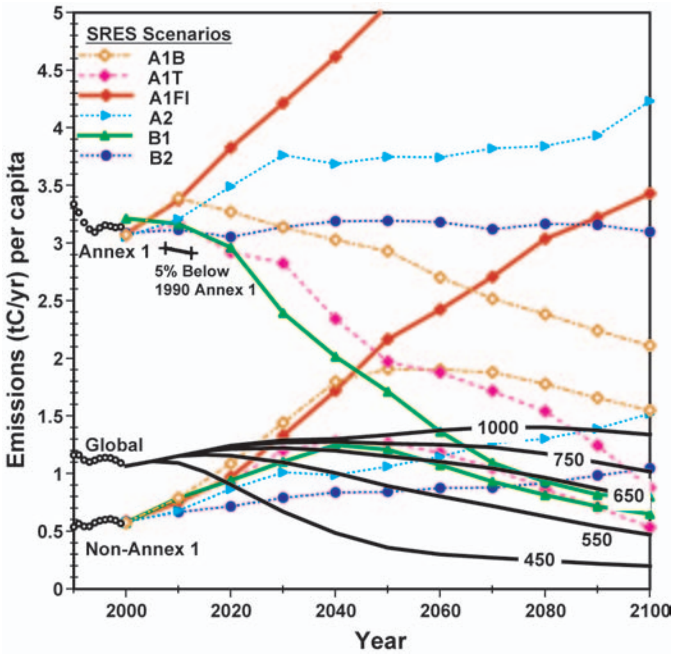

Figure 3. *Per capita fossil fuel emissions of CO_2. The blck circles show emissions per capita from 1990 to 1999. A line segment shows emissions 5% below the 1990 Annex 1 rate during the period 2008-2012 as aimed for in the Kyoto Protocol. Deduced global fossil emissions leading to the specified CO_2 pathways towards stabilisation of atmospheric concentrations from 450 to 1000 ppmv are shown as black solid curves. Per-capita fossil emissions for Annex 1 and non-Annex 1 regions, according to six key IPCC scenarios are shown by the curves and the symbols as given (cf. Bolin and Kheshgi, 2001; IPCC, 2000). —— To reach stabilisation, the emissions pathways for Annex 1 countries (at present well above any of the stabilisation curves), and those of non-Annex 1 countries (at present consistently below) must assymptotically and simultaneously approach the particular stabilisation curve being aimed for (cf. Bolin and Khesgi, 2001).*

- It is doubtful if it would be possible to stabilise the atmospheric carbon dioxide concentration much below 550 ppm and since it is not easy to reduce the enhanced concentrations of the other greenhouse gases below present levels, we might expect that the equivalent carbon dioxide concentration in any case might reach 600 ppm by the end of the century causing a considerable change of the global climate.

- The development of new technology might, however, well be a profitable undertaking in the long run, but only provided the prevention of climate change would become a globally agreed guiding principle for the future. The longer it will take until the Kyoto Protocol has entered into force the more demanding and costly will later measures become with the aim of stabilising greenhouse gas concentration at some agreed level. Its ratification by Russia and the USA is therefore urgently awaited. Undoubtedly, we are at a critical point for the development of a long-term global climate policy.

Storage of Dioxide

The possibility to store carbon dioxide in terrestrial systems, the oceans or geological formations to reduce the rate of increase of carbon dioxide in the atmosphere is of course an alternative or supplementary approach in the efforts to mitigate climate change. This has recently come under close scrutiny. The following should be noted:

- Terrestrial systems may temporarily serve as a sink for carbon dioxide. The total storage capacity is, however, limited and the long-term stability of such a storage may be questioned not the least because of the expected change of climate. Even though the rate of photosynthesis and the uptake of carbon by the vegetation increase with temperature, provided water is available in sufficient amounts, the rate of decomposition of organic material and the return of carbon dioxide to the atmosphere are also enhanced and likely to be dominating in the case of a major climate change.

- Enhanced ocean storage is technically difficult and costly to achieve, and may also be illusive. Its efficiency depends on ocean circulation that may change as a result of climate change. Warmer surface waters will increase the vertical stability of the oceans and thereby possibly decrease the rate of carbon dioxide transfer to deeper strata.

- Geological storage in deserted oil and gas fields as well as aquifers below 800-1000 metres has interesting prospects, but has not yet been considered carefully with regard to stability and possible environmental implications. They indeed deserve careful consideration. The magnitude of such storage opportunities should be assessed, but they are probably large and possibly quite stable. Their geographical location has to be mapped to permit a more accurate assessment of the amounts that might be stored in such a manner. It is also of interest that this possibility might be technically attractive for the energy industry, since the exploitation of deep storage fits well into its traditional structure and technology. Rough estimates of the costs for such a technological development indicate about a doubling of the costs for providing primary energy in exploiting this storage possibility.

Concluding Remarks

This analysis is primarily based on the IPCC assessments, and on the conviction that the threat of a global climate change is an environmental issue that needs serious and more urgent attention than it has been given so far.

There are still some controversies about the seriousness of the climate change issue, but a reasonably robust picture has emerged. There are uncertainties, but primarily in the details, and this fact must not paralyse the climate change policy debate. In view of the clear risk for a substantial impact of a climate change on human life and institutions **more concerted actions are required now to limit the ongoing change and to keep the ultimate costs for stabilisation of climate within reasonable bounds**.

In the short perspective we can speculate about winners and losers and countries will of course try to reach most favourable conditions when negotiating future agreements for actions. However, poor people will be more at risk than inhabitants of rich countries and need support in their struggle for development and a forthcoming protection against climate change. This issue will not be resolved unless a basic solidarity between countries is established. To address the climate change issue effectively must be viewed as an essential part of our efforts to achieve a future sustainable development in the world. Rich countries, partly so because of their greater access to valuable natural resources, must take on a particular responsibility. Otherwise a major irreversible climate change will certainly hit us all. Also, a more equitable world will be to the advantage of everybody, rich and poor, in the north and in the south and might pave the way for effective measures in order to limit human-induced climate change.

To prevent a major change of the global climate is a basic challenge for the countries of the world in their attempts to find a sustainable future for all of us.

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The Stockholm Environment Institute (SEI)

SEI is an independent, international research institute specializing in sustainable development and environment issues. It works at local, national, regional and global policy levels. The SEI research programmes aim to clarify the requirements, strategies and policies for a transition to sustainability. These goals are linked to the principles advocated in Agenda 21 and the Conventions such as Climate Change, Ozone Layer Protection and Biological Diversity. SEI along with its predecessor, the Beijer Institute, has been engaged in major environment and development issues for a quarter of a century.

Mission

SEI's mission is to support decision-making and induce change towards sustainable development around the world by providing integrative knowledge that bridges science and policy in the field of environment and development.

The SEI mission developed from the insights gained at the 1972 UN Conference on the Human Environment in Stockholm (after which the Institute derives its name), the work of the (Brundtland) World Commission for Environment and Development and the 1992 UN Conference on Environment and Development. The Institute was established in 1989 following an initiative by the Swedish Government to develop an international environment/development research organisation.

Climate and Energy Programme

For over two decades, SEI has worked with collaborators throughout Africa, Asia, Europe, and Latin America to support climate and energy strategies consistent with the goals of social equity, environmental sustainability, and efficient economic development. The geographical scope ranges from local village-scale activities, to regional initiatives, to national analyses, to global negotiations. The Energy and Climate Programme conducts research, develops tools, and implements energy projects. Through capacity building and outreach, the programme has broadened the participation of stakeholders and civil society in energy and climate issues. The programme focuses on sustainable energy planning, with a special interest in biomass energy, and promotes sound environmental assessment and management practices that fully account for the externalities of energy production and use. The programme analyses and advocates policies and measures to reduce the climate change threat, including the crafting of an effective and equitable global climate regime.

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