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SCOPING OF THE IPCC 5TH ASSESSMENT REPORT
CROSS CUTTING ISSUES

Previous IPCC work related to Article 2 of the UNFCCC

(Submitted by the IPCC Secretariat)

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The IPCC's previous work related to UNFCCC Article 2 and Key Vulnerabilities

Introduction

The United Nations Framework Convention on Climate Change (UNFCCC)'s Article 2 states:

"The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."

The debate about what is dangerous anthropogenic interference and what is a sufficient timeframe has continued since the Convention came into force in 1994.

The Article 2 question was brought to the attention of the IPCC and has been addressed first in the Second Assessment Report (1995), then the Third Assessment Report (TAR) (2001) and more recently in the Fourth Assessment Report (AR4) (2007). While the notion of "dangerous" does involve value judgments, the IPCC has provided inputs to help policymakers consider this judgment.

1. First & Second Assessment Report

The range and scope of the policy analysis tools used by the IPCC have expanded over its four assessment reports. Each expansion has brought it closer to a relatively deeper treatment of sustainable development.

The central questions motivating the First Assessment Report (FAR) were those related to causes of climate change, whether anthropogenic interference in global climate systems requires a global response and what are the likely impacts of such interference? These have remained, and will remain, a central preoccupation of IPCC enquiries.

The first IPCC Assessment Report began raising a set of emerging questions related to potential impacts of climate change, what might be done, and the cost effectiveness of potential response measures. These questions gained more prominence as a new focus area in the Second Assessment Report (SAR). Stabilization scenarios (including very low emission stabilization scenarios) were included in the IPCC Second Assessment Report.

The SAR further broadened the IPCC policy discourse by introducing the issue of equity into the IPCC assessments. The SAR Synthesis Report specifically addressed Art. 2 of the UNFCCC.

Then in October, 1994, an IPCC Special Workshop on Article 2 of the UNFCCC was held at Fortaleza, Brazil. Amongst other issues the question of instabilities and irreversibilities of climate change, often called 'tipping points', or the concept of 'critical thresholds' (i.e. exceeding of certain levels determined on scientific grounds) were proposed at this workshop and then later addressed briefly in the TAR.

2. Third Assessment Report

By the Third Assessment Report (TAR), climate impacts as well as cost-effectiveness were both firmly established as continuing focus areas of the IPCC. Meanwhile, questions about equity, which had only begun to be raised in SAR, started to gain a little more prominence as a new focus of the assessment process. In addition, TAR contributed to the evolutionary broadening of the IPCC process by introducing discussions about alternative development pathways and global sustainability (especially through its emphasis on scenarios) into the IPCC mix.

By this time, Article 2 was specifically addressed under Question 1 of the Synthesis Report for the Third Assessment Report (TAR). The TAR SYR: “Natural, technical, and social sciences can provide essential information and evidence needed for decisions on what constitutes dangerous anthropogenic interference with the climate system” (SYR, Question 1).

In the TAR, under the theme termed “reasons for concern”, scientists created an image to represent the possible risks associated with increases in global mean temperature (GMT) and explained particular reasons for concern. The TAR explored the parameters of the impacts relating to Article 2, which it calls ‘reasons for concern’, namely:

- risk to unique and threatened systems,
- risk from extreme climate events,
- distribution of impacts, aggregate impacts,
- different development and technological pathways that might achieve stabilisation,
- and risk from future large-scale discontinuities / irreversibilities.

The TAR also explored the array of different metrics for evaluating ‘levels’ as mentioned in Article 2, such as: market impacts, human lives, biodiversity loss, distributional effects, quality of life and it provided an assessment of the potential for achieving a broad range of levels of greenhouse gas concentrations in the atmosphere through mitigation, as well as information about how adaptation can reduce vulnerability.

Irreversibilities and ‘critical thresholds’ were also addressed in Question 4 of the TAR Synthesis Report (‘the risk of abrupt/non-linear changes’). This represents another dimension of the concept of dangerous anthropogenic interference with the climate system, the subject of Article 2 of the UN Framework Convention on Climate Change (UNFCCC).

More specifically, among other things, TAR SYR Question 4 was: “What is known about the influence of the increasing atmospheric concentrations of greenhouse gases and aerosols, and the projected human-induced change in climate regionally and globally on:

- …
- The risk of abrupt/non-linear changes in, among others, the sources and sinks of greenhouse gases, ocean circulation, and the extent of polar ice and permafrost? If so, can the risk be quantified?
- The risk of abrupt or non-linear changes in ecological systems?”

For example, the TAR concluded that: “Changes in climate could increase the risk of abrupt and non-linear changes in many ecosystems, which would affect their biodiversity, productivity, and function.”

Indeed, the following major TAR conclusion contributed significantly to this issue and confirmed the appropriate role of the IPCC with regard to Article 2 of the UNFCCC: “Natural, technical, and social sciences can provide essential information and evidence needed for decisions on what constitutes "dangerous anthropogenic interference" with the climate system. At the same time, such decisions are value judgments determined through socio-political processes, taking into account considerations such as development, equity, and sustainability, as well as uncertainties and risk.”

The TAR noted also an essential lack of knowledge on what is a “dangerous anthropogenic interference with the climate system” and that this question requires comprehensive and integrated investigations (see Question 9 of the IPCC TAR SYR).

3. The Fourth Assessment Report (AR4)

The 18th Session of the IPCC (Wembley, UK, 23-29 September 2001), where the TAR SYR was adopted considered the necessity for strengthening the scientific efforts related to Article 2 and noted it as one of the priorities of its future work.

From 21-22 January 2003 an IPCC Expert Meeting on the "Levels of greenhouse gases in the atmosphere preventing dangerous anthropogenic interference with the climate system" was held in Geneva, Switzerland. This meeting concluded amongst other things, that this is a significant issue that must continue to be addressed by the IPCC in its future work programme.

The 20th Session of the IPCC (February 2003, Paris) agreed that consideration of Article 2, including key vulnerabilities, should be one of seven cross-cutting themes in AR4. It was further agreed to pay attention to the full range of scientific, technical and socio-economic issues associated with Article 2 of the UNFCCC and that the Cross Cutting Theme (CCT) should fully involve all three IPCC Working Groups.

The First AR4 Scoping Meeting (FSM, Marrakech, Morocco, 14-16 April, 2003), following the decision of Plenary XX, further developed the scope of CCT's to be addressed in the AR4 process. The theme "Key vulnerabilities including issues related to UNFCCC Article 2" (KV&Art2) was amongst them. Prior to the FSM WGII Co-Chair Dr. Martin Parry in consultations with WGII Co-Chair Dr. Osvaldo Canziani and Vice-Chair of the IPCC Dr. Yuri Izrael prepared and distributed a note on KV&Art2. Interaction with three other CCTs was deemed to be essential as well: "integrated approach to adaptation and mitigation", " risk and uncertainty" and "climate change and sustainable development".

At the adoption of the AR4 outline at the 21st Session of the IPCC in Vienna, Austria, 3-7 November 2003, IPCC Chairman, Rajendra K. Pachauri, explained, "The Third Assessment Report very rightly stated that decisions on what constitutes dangerous anthropogenic interference 'are value judgments determined through socio-political processes, taking into account considerations such as development, equity, and sustainability, as well as uncertainties and risk'. In its most unimpeachable form a scientific assessment can, however, provide essential information that is needed for such decisions and highlight:

(1) key vulnerabilities,
(2) the specific nature and extent of impacts of climate change including damage to ecosystems, and the socio-economic implications of these impacts; and
(3) the risk of occurrence of such impacts across a wide range of possible development futures and climate scenarios (ranging from unmitigated to stabilized)."

In the context of the AR4 scoping, and following approval of the AR4 outline, concept papers for the different CCTs were prepared and co-ordinated by so called 'co-anchors'.

For KV&Art.2 a concept paper was prepared by Patwardhan, et al., 2004. It identified some of the key issues to be addressed under this cross cutting theme, such as:

- focus on assessing scientific, technical and socio-economic aspects related to the three UNFCCC criteria mentioned above;
- identification of indicators or parameters on the basis of which these criteria could be evaluated;
- consideration of various types of thresholds and of critical levels and outcomes;
- consideration of the overall consequences for human well-being (HWB), and in particular, the negative effects on the components of HWB, such as health, prosperity, social development and ecosystem services and for the WEHAB (Water, Energy, Health, Agriculture and Biodiversity) framework and its components (plus coastal regions);
- evaluation of the societal costs of climate change, including market as well as non-market goods and services, and aspects of intergenerational and distributional equity.

In addition, the cross cutting theme concept paper further developed the concept of critical thresholds, distinguishing different types of thresholds such as incremental changes that exceed tolerances, as against significant non-linear processes in physical systems that might affect major system stability (e.g. of the West Antarctic Ice Sheet).

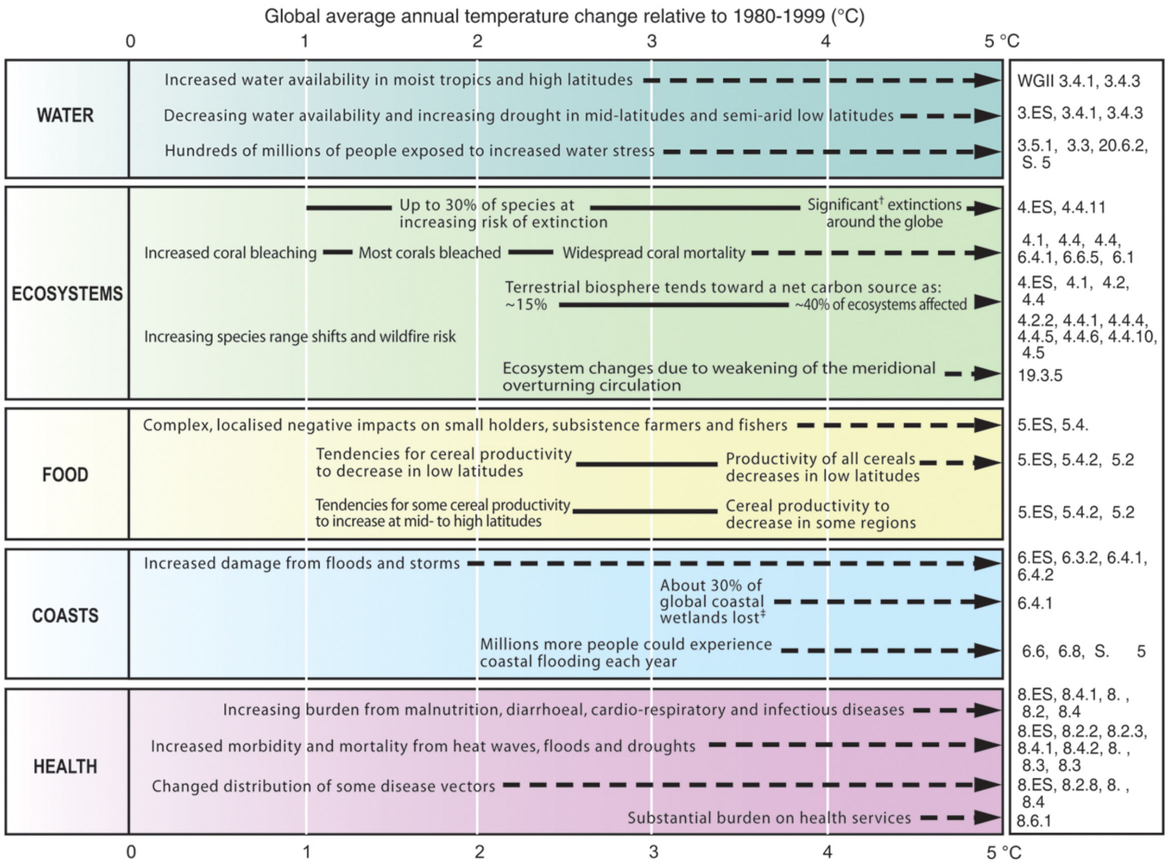
The concept paper concluded that the Fourth Assessment Report (AR4) should focus assessment predominantly on the three UNFCCC criteria, assessing their scientific, technical, and socio-economic aspects, although it could summarize various views expressed in the literature about the elements of more normative analysis. It said that in particular, it will be important to identify the basic indicators or parameters on the basis of which these criteria could be evaluated. That is, it said the IPCC assessment could evaluate the range of possible climate change outcomes and the uncertainty associated with these outcomes corresponding to different adaptation and mitigation policies, without attempting to evaluate acceptability of such outcomes. This process had already been represented by IPCC WG 2 TAR as five “reasons for concern”. It concluded that the assessment of risk (probability of the occurrence of events) is a scientific function, whereas choice of which risks are acceptable or how mitigation or adaptation should be deployed are political value judgments.

Following those initial steps, in Buenos Aires, Argentina (18-20 May 2004) an Expert Meeting on the Science to Address UNFCCC Article 2 including Key Vulnerabilities reviewed existing knowledge that related to the issue of Article 2 and key vulnerabilities. The Expert Meeting considered how best this can be incorporated in AR4, particularly for a more integrated treatment of the subject across the three Working Groups. The full report of this meeting can be found on the IPCC website, while the concept paper prepared by Patwardhan, et al., 2004 (Annex C) relating to the 4th cross cutting theme for the AR4 is attached to this document for further reference.

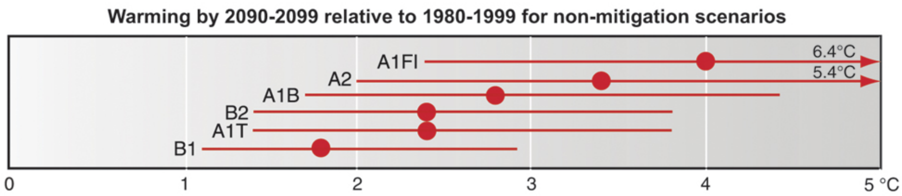
These steps led to an enhanced coverage of relevant issues in the AR4.

First of all, the AR4 reported that studies since the TAR have enabled a more systematic understanding of the timing and magnitude of impacts related to differing amounts and rates of climate change.

Examples of this new information for systems and sectors are presented in Figure 3.6 of the AR4 Synthesis Report (see below). The upper panel shows impacts increasing with increasing temperature change. Their estimated magnitude and timing is also affected by development pathways (lower panel). *{WGII SPM}*



† Significant is defined here as more than 40%. ‡ Based on average rate of sea level rise of 4.2mm/year from 2000 to 2080.



Reasons for concern

Second, the Synthesis Report for the AR4 under Topic 5 of the Technical Summary, section 5.2 “Key vulnerabilities, impacts and risks – long term perspective” reviewed the ‘reasons for concern’ identified in the TAR. The AR4 notes that these 5 ‘reasons for concern’ remain a viable framework to consider key vulnerabilities.[1]

Therefore, the following ‘reasons for concern’ in the TAR were updated in the AR4:

- Risks to unique and threatened systems
- Risks of extreme weather events
- Distribution of impacts and vulnerabilities
- Aggregate impacts
- Risks of large-scale singularities (unique phenomena)

Section 5.2 of the Technical Summary states: “The five ‘reasons for concern’ identified in the TAR are now assessed to be stronger, with many risks identified with higher confidence. Some risks were projected to be larger or to occur at lower increases in temperature.” For example, as for

[1] The SPM of the AR4 in section 5 “The long-term perspective” states: “Determining what constitutes “dangerous anthropogenic interference with the climate system” in relation to Article 2 of the UNFCCC involves value judgements. Science can support informed decisions on this issue, including by providing criteria for judging which vulnerabilities might be labelled ‘key’.”

aggregate impacts, it said “It is likely that there will be higher damages for larger magnitudes of global temperature increase than estimated in the TAR, and the net costs of impacts of increasing warming are projected to increase over time.”

Understanding about the relationship between impacts (the basis for ‘reasons for concern’) and vulnerability (that includes the ability to adapt to impacts) has improved since the TAR. This is because of more precise identification of the circumstances that make systems, sectors and regions especially vulnerable and the growing evidence of the risks of very large impacts on multiple-century time scales.

Assessment of various emission trajectories for stabilisation

The AR4 SPM concludes, “Delayed emission reductions significantly constrain the opportunities to achieve lower stabilisation levels and increase the risk of more severe climate change impacts”.

Related to this point, Section 5.4 of the AR4 Synthesis Report Technical Summary ‘Emission trajectories for stabilisation’ states:

- “Mitigation efforts over the next two to three decades will have a large impact on opportunities to achieve lower stabilisation levels.”

The AR4 explored the feasibility of achieving various stabilisation levels. Section 5.5 of the AR4 Synthesis Report Technical Summary ‘Technology flows and development’, states:

- “There is high agreement and much evidence that all stabilisation levels assessed can be achieved by deployment of a portfolio of technologies that are either currently available or expected to be commercialized in coming decades, assuming appropriate and effective incentives are in place for their development, acquisition, deployment and diffusion and addressing related barriers.”

The AR4 reviewed the costs of stabilisation. Under section 5.6 of the Technical Summary ‘Costs of mitigation and long-term stabilisation targets’, the following was stated:

- “There is high agreement and medium evidence that in 2050, global average macro-economic costs for mitigation towards stabilisation between 710 and 445ppm CO2-eq are between 1% gain and 5.5% decrease of global GDP. This corresponds to slowing average annual global GDP growth by less than 0.12 percentage points.”

Finally, the AR4, among other things, reviewed the costs of climate impacts at global and regional levels. The AR4 SPM concluded that:

- “Responding to climate change involves an iterative risk management process that includes both adaptation and mitigation and takes into account climate change damages, co-benefits, sustainability, equity and attitudes to risk.”

Annex C: Cross cutting theme paper 4: Assessing the science to address UNFCCC Article 2

A concept paper relating to cross cutting theme number four

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Introduction and Background

Article 2 of the UN Framework Convention on Climate Change (UNFCCC) states that: “The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system”. The Framework Convention on Climate Change further suggests that “Such a level should be achieved within a time frame sufficient

- to allow ecosystems to adapt naturally to climate change,
- to ensure that food production is not threatened and
- to enable economic development to proceed in a sustainable manner.”

Thus, the term “dangerous anthropogenic interference” may be defined or characterized in terms of the consequences (or impacts) of climate change outcomes, which can be related to the levels and rates of change of climate parameters. These parameters will, in turn, be determined by the evolution of emissions and consequent atmospheric greenhouse gas concentrations. Evaluating the consequences of climate change outcomes to determine those that may be considered “dangerous” is a complex undertaking, involving substantial uncertainties as well as value judgments. In this context, the IPCC’s role should be to assess the literature with a view to providing information that is policy-relevant, without being prescriptive.

While the notion of “dangerous” does involve value judgments, the IPCC could certainly provide inputs to help policymakers consider this judgment. The three criteria mentioned in Article 2 may be evaluated as purely scientific questions to varying degrees. At the same time, it is important to recognize that these three criteria are normative in nature, that is, they may considered as objectives of policy, and not only as indicators or markers, per se. . For example, while evaluating the questions of whether ecosystems can adapt naturally, and whether food production is threatened it will be necessary to examine not only the range of climate outcomes, but also the adaptive capacity of the systems at risk, which is, in turn, determined by human perception, evaluation and response. The criterion of sustainable economic development is even more complex, , inasmuch as there are various definitions of sustainability, and it is not entirely independent from the first two criteria. There has long been debate about whether “things”—e.g., specific species or resources—are what is to be sustained, or rather productivity capacity, given optimistic expectations for substitutability . We will defer to the CCT “Climate change and sustainable development”for guidance on definitions.

The Fourth Assessment Report (AR4) should thus focus assessment predominantly on these three UNFCCC criteria, assessing their scientific, technical, and socio-economic aspects, although it could summarize various views expressed in the literature about the elements of more normative analysis. In particular, it will be important to identify the basic indicators or parameters on the basis of which these criteria could be evaluated. That is, the IPCC assessment could evaluate the range of possible climate change outcomes and the uncertainty associated with these outcomes corresponding to different adaptation and mitigation policies, without attempting to evaluate acceptability of such outcomes. This process has already been represented by IPCC WG 2 TAR as five “reasons for concern”: see Figure 1. Assessment of risk--probability of the occurrence of events—is a scientific function, whereas choice of which risks are acceptable or how mitigation or adaptation should be deployed are political value judgments.

The necessity for strengthening the scientific efforts related to Article 2 has been noted by the IPCC XVIII Session (Wembley, UK, 24-29 September, 2001). The IPCC Synthesis Report, adopted by the session, had noted essential lack of knowledge on what is a “dangerous anthropogenic interference with the climate system”, and that this question requires comprehensive and integrated investigations (see Question 9 of the IPCC Synthesis Report - SYR). Plenary XVIII considered this question as one of the priorities of its future work (see Document IPCC-XVIII/INF. 6 of the IPCC XVIII Session). As was stated in the SYR, “Natural, technical, and social sciences can provide essential information and evidence needed for decisions on what constitutes dangerous anthropogenic interference with the climate system” (SYR, Question 1). However, it should be re-emphasized that developing and taking such value-laden decisions are not within the IPCC mandate and in practice will happen through socio-political processes that go beyond the IPCC. At the same time, it is likely that better understanding of the socio-political and institutional processes that underlie responses and policies at different scales will itself lead to an improvement in the response to climate change.

The IPCC XX Session (Paris, France, 19-21 February, 2003) has decided to treat this issue as a crosscutting theme (CCT). The plenary requested, following the recommendations of the IPCC expert meeting on “Levels of greenhouse gases in the atmosphere preventing dangerous anthropogenic interference with climate system” (Geneva, Switzerland, 21 – 22 January, 2003), that this theme should include attention to the scientific, technical and socio-economic issues associated with Article 2 of the UNFCCC (*see above*).

The First Scoping Meeting (FSM, Marrakech, Morocco, 14-16 April, 2003) following the decision of Plenary XX developed a list of the CCT’s to be addressed in the AR4 process. The current theme “Key vulnerabilities including issues related to UNFCCC Article 2” (KV&Art2) is amongst them. Although its co-ordination is housed in Working Group II (WGII) of the IPCC at present, we believe that to really address the issues in this theme close co-operation and interaction between all the three Working Groups will be essential. Interaction with three other CCTs will be essential as well: “integrated approach to adaptation and mitigation”, " risk and uncertainty" and “climate change and sustainable development”.

Prior to the FSM WGII Co-Chair Dr. Martin Parry in consultations with WGII Co-Chair Dr. Osvaldo Canziani and Vice-Chair of the IPCC Dr. Yuri Izrael prepared and distributed a note on KV&Art2. This note stated: “It is likely that the theme (i.e. KV&Art2) will give attention to exposure fields additional to food, ecosystems and development and include, for example, health, water and settlement; and it may address relevant sensitivities and vulnerabilities in subject areas across all three Working Groups. Local, regional and global scales will need to be considered, as well as the multiple stresses due to climate and non-climate factors”. Subsequently, the FSM requested a Concept Paper (CP) on KV&Art2 outlining how these issues should be incorporated and reflected in the AR4 outputs of the IPCC Working groups.

Scientific understanding of the issue to date

The term “dangerous” is used in UNFCCC Article 2 with regard to “anthropogenic interference with the climate system”. Thus, this term is related on the one hand to the consequences or impacts of climate change, and on the other, to the levels of greenhouse gas concentrations that are responsible for the climate change. The evaluation of dangerous anthropogenic interference requires therefore an understanding of the consequences of climate change together with an assessment of their undesirability, as well as the sustainability implications of both climate impacts and climate stabilization levels and their timing (see three UNFCCC criteria above).

Different attributes of climate parameters closely related to these consequences could be employed in characterizing climate change. Such attributes might include mean values, variances, and trends (rates of change) , and the concentrations of greenhouse gases and rates of their changes that are likely to be associated with these attributes.

While examining the consequences of climate change, and whether they may be considered as “dangerous”, it is useful to look at the overall consequences for human well-being (HWB), and in particular, the negative effects on the components of HWB, such as health, prosperity, social development and ecosystem services. Such an approach is absolutely consistent with the basic UNFCCC criteria concerning GHGs levels and rates of their change, namely,

- to allow ecosystems to adapt naturally to climate change,
- to ensure that food production is not threatened and
- to enable economic development to proceed in a sustainable manner.”

The umbrella term “human well-being” is now well-recognized, and is being used in assessments of global change, including, for example, the Millennium Ecosystem Assessment (REF). It is important to note that this umbrella term encompasses a range of trade-offs not only within the different components of HWB, but also including intergenerational and distributional issues.

The consequences of climate change for HWB are not amenable to high confidence quantification for all important sectors or regions. Moreover, the socio-natural system is a coupled set of interacting processes, so examinations of impacts on sectors one at a time—while a classical scientific approach—will not in the end describe the systemic nature of the coupled components that determine overall impacts. However, certain “reasons for concern” have been already identified (Figure 1) in the TAR, namely: risk to unique and threatened systems, risk from extreme climate events, distribution of impacts, aggregate impacts, and risk from future large-scale discontinuities (IPCC 2001; IPCC2001b, Chapter 19; van Ypersele and Schneider, 2003). IPCC scientists have considered some aspects of KV&Art2 problem in previous assessment reports, other publications or in working and discussant papers (see Section "Literature" below). Some ideas presented in these publications have been incorporated into this Concept paper. One of the important practical examples in this regard is the “tolerable windows” approach developed by Schellnhuber and Held (2002) and Toth et al (2002) others at Potsdam, and used to identify emission pathways that would be consistent with constraints imposed to avoid “dangerous” levels of climate change.

“Dangerous” climate change and the WEHAB framework

While HWB is appealing as an umbrella concept, in practice it may be useful to focus on some well-defined, important and more easily measurable aspects that also have policy significance. One such subset is the components that went into the WEHAB framework introduced during the 2002 World Summit on Sustainable Development (WSSD). The WEHAB framework identified a number of areas that would be considered as essential for human well-being and development: Water, Energy, Health, Agriculture and Biodiversity, which map well into the umbrella HWB concept. Thus it may be useful to focus on the WEHAB framework and its components, due to the widespread recognition of these components as being key for short- and long-term development goals. In addition to the five WEHAB components, Working Group II has added coastal regions, The WEHAB (plus coastal regions) framework also encompasses the original three criteria identified in Article 2 of the UNFCCC (see page 1 of this paper), and can also serve as a point of interface with a CCT on “Climate change and sustainable development”. For this reason, this concept paper uses the WEHAB framework as the operational representation of human well-being.

The climate system (*that is climate itself plus all biogeochemical and physical processes responsible for the Earth’s climate)* may play different roles with regard to the WEHAB – in some cases determining the availability, quality and variability of respective resources (water, food, hydro-energy, etc.), and in other cases influencing our ability to use these resources.. Examples of climate system elements might include the oceans, terrestrial permafrost, forests, fluxes of heat and moisture, global cycle of water, thermohaline circulation, ENSO, Asian summer monsoon, etc. Having identified the climate system elements and the linkages with WEHAB components, it might be possible to determine key elements of the climate system changes of which may significantly affect the WEHAB components.

Parameters (quantitative or qualitative characteristics) of such key elements of the climate system have different attributes characterizing climatic impacts on the WEHAB components. These attributes might include the levels of climate parameters, for example, surface temperature or percentage of ice cover or sea level, extent of mountain glaciers or amount of total monsoon precipitation. At the same time, these attributes might include the rates of change of the climate parameters. Long-term levels of the climate parameters, when approaching certain limits, could lead to critical impacts on the WEHAB components. The same is correct also with regard to the rates, since in some cases impacts may be critical because the rate of change of the climate parameter is too high for effective adaptation. Such limits of the climate parameters associated with critical impacts on the WEHAB components are labeled as critical limits of climate (CL-Climate).

The concept of critical impacts on the WEHAB components may be examined using notions of thresholds (or boundaries). For example, at the simplest case one could think of two types of thresholds. Thresholds of type I are simply target values of linear or other "smooth" changes that after some point would lead to damages that might be considered “unacceptable” by particular policy-makers. It is likely that such thresholds would be determined as the outcome of a socio-political process that weighs the relative risks to different sectors and regions. For example, a certain amount of sea level rise might be considered “unacceptable” for particular small island states, although the same amount of sea level rise falls within a coping range for another country. For this discussion, the help of decision analysis framework specialists will be needed, and the existing experiences involving multi-stakeholder dialogues and multi-criteria decision-making will need to be assessed. At the same time, it will be important to assess the potential and scope for adaptation strategies, together with the limits to adaptation (may be a link with CCT on integrated analysis of mitigation and adaptation).

Thresholds of type II might be those that are linked directly to the key intrinsic processes of the climate system itself (often non-linear) and might be related to maintaining stability of those processes or some of the elements of the climate system discussed earlier. Some thresholds that all would consider dangerous have no support in the literature as having a non-negligible chance of occurring. For instance, a “runaway greenhouse effect”—analogous to Venus--appears to have virtually no chance of being induced by anthropogenic activities. So our focus will be on those events that the literature suggests have a non-negligible chance of being induced by anthropogenic activities. For example, stability of thermohaline circulation or the West Antarctic Ice Sheet (WAIS) or the Greenland ice sheet, the mobilization of biospheric CO_2 stocks, changes in the Asian summer monsoons, loss of mountain glaciers, coral reefs and ENSO all appear to be of global or regional significance, respectively, and thus these are some of the natural bounds, which if exceeded, would lead to major potentially irreversible impacts. It is very likely that the irreversibility and scale of such changes would be considered “unacceptable” by virtually all policy-makers and would thus qualify as “dangerous” change. It would be important for the IPCC to perform a comprehensive identification of such potential thresholds or irreversibilities at various spatial and temporal scales, which would help in setting the boundaries for high-impact change in the climate system. More examples of different key elements of the climate system and critical thresholds can be found in (Dessai et al., 2003; Mimura, 2003).

In the process of determining criteria or defining critical thresholds (both target values–Type I--and intrinsic thresholds—Type II), uncertainty is an important factor to be considered. Scientific knowledge is always limited, and capability of policymakers to adequately assimilate scientific information for making decisions is also limited. Therefore, selection of key elements and establishing critical thresholds implies differing levels of confidence (see the concept paper on Risk and Uncertainties CCT).

It should be emphasized, that decisions on what level of WEHAB-related impacts is “acceptable” and which key elements of the climate system should remain stable are to be made by policymakers with use of scientific information provided by the IPCC. Acceptability is negotiated through socio-political processes at country, regional or global level, “taking into account development, equity and sustainability considerations, as well as uncertainties and risk” (IPCC 2001, 2001, Question 1, p. 2]

What metrics are involved in describing impacts on WEHAB?

In describing the impacts and consequences for the WEHAB elements, it is important to construct appropriate metrics or “numeraires” of damage / change, which go beyond a simple, binary market and non-market characterization (see Table 1). A good example of a diverse set of numeraires is provided by Schneider, Kuntz-Duriseti and Azar (2000), who summarize the effects of climate change in terms of the “Five Numeraires”: Monetary loss; loss of human life; degraded quality of life (including coercion to migrate, conflict over resources, cultural diversity, loss of cultural heritage sites, etc.); species or biodiversity loss, and mal-distribution/equity (e.g., the common scenario in the literature in which the cooler rich countries in the political “North” get improved crop yields while hotter, poorer countries in the political “South” get reduced crop yields with warming).

The WEHAB elements include market as well as non-market dimensions. While economic theory provides a number of approaches for valuing changes in market goods and services, there is little agreement on how to value and monetize changes in the non-market goods and services that form a part of HWB. It is clear that any comprehensive attempt to evaluate the societal value of climate change should include market as well as non-market goods and services, as well as aspects of intergenerational and distributional equity. Some of the end-points could include, for example, loss of species diversity, loss of coastline from increasing sea level, environmentally-induced displacement of persons, change in income distributions and regional differences in agricultural losses. It is well recognized that the environment has a variety of sources of value, including, existence value (a priority is placed on preserving the environment, even if one doesn’t intend to personally experience it), or option value.

The relevance of this discussion for KV & AR 2 is that it is essential for analysis of costs of climate change impacts or mitigation or adaptation strategies to consider explicitly alternative numeraires and to be as clear as possible which are being used and what is omitted. Moreover, before any aggregation is attempted — e.g., cost-benefit optimization strategies — authors should first disaggregate costs and benefits into several numeraires and then provide a "traceable account" (see Moss and Schneider, 2000) of how they were re-aggregated. Such transparency is essential given the normative nature of the valuation of various consequences characterized by the different metrics, and the fact that different decision makers at different levels are likely to perceive (see Dessai, 2003) “dangerous anthropogenic interference” very differently and thus the socio-political process requires assessments that make the scientific dimensions of the risk-management tradeoffs as transparent as possible.

Critical limits of climate parameters (CL-Climate): deterministic and stochastic approaches

Main sequential steps in analysis of "dangerous" climate change are a) to identify key elements of the climate system, b) map linkages between these elements and numeraires for HWB, c) establish, where feasible, critical outcomes affecting HWB, and d) calculate for such outcomes associated critical limits of parameters of the climate system (temperature, percentage ice-cover, sea level rise, water balance etc.) and/or rates of their changes. Since some degree of uncertainty will always remain in our knowledge, data, calculations and judgments, instead of assessing precise critical limits, ranges and probabilities are all that can be produced in most cases. Moreover, in many cases these will be subjective probabilistic (i.e., Bayesian) estimations. Of course, such limits/range(s) will be regionally specific in the many cases, in particular, depending on other non-climatic factors.

<u>*Three categories of outcomes*</u>. While steps a), b) and d), as well as uncertainty analysis are scientific assessments, value judgments often play essential roles in establishing critical thresholds for the consequences for HWB (step c). The following categorization of outcomes encompasses the earlier classification of thresholds (type I and type II), with type I mapping into Categories 2 and 3 and type II mapping into Category I.

Category 1. In the first instance, assessors can look at those climate outcomes that would lead to widespread negative consequences for each of the WEHAB categories. That is, in these types of outcomes, in socio-economic sectors there are no “winners”, only “losers”-- viewed at virtually any scale of decision-making – temporally or spatially. These would include, for instance, WAIS or thermohaline collapse, or perhaps large-scale or rapid changes in the monsoon. For ecosystems these outcomes could include loss or near total loss of an ecosystem and a large fraction of its endemic species.

Category 2. These limits are associated with consequences that are unambiguously negative for specific regions, sectors, populations or ecosystems (e.g., Parry et al. 2001), and with high degree of confidence. In this category, “dangerous” interference could be evaluated in light of rights-based or other ethical or cultural considerations. Here a “reverse Pareto” criterion could apply – at least some sector or region will be substantially worse-off, and others are not likely to be benefited by that outcome. For ecosystems this would imply that there are substantial negative effects on specific ecosystems and substantial increase in vulnerability or risk of extinction over reasonable time frames for some taxa.

Category 3. These kinds of outcomes are those where gains and losses are widely distributed . The determination of “unacceptability” may be partly informed by examining costs and benefits. Scientific assessment can help delineate components that would aid in making such judgments.

We recommend that the IPCC consider a systematic approach of synthesizing the appropriate literature for each of these species of thresholds, and identify from the literature particular measures and indicators that could be tracked.

It should be emphasized that the problem of uncertainty requires very serious attention in calculating CL-Climate. The following can illustrate this with an example. Assume that one estimated a value ΔT_0 that is an upper limit for increase of long-term mean temperature for a region. Maintenance of actual rise in long-term mean temperature below this limit implies a high confidence in the stability of some key element of the climate system, for instance, the Greenland ice sheet. In this case ΔT_0 equals approximately to 3ºC according to the TAR (IPCC 2001, 2001a, p. 17). A "stair" curve in figure 2 illustrates a deterministic case with no uncertainty. In this case, if a long-term increase in mean temperature is more than ΔT_0, the chosen key element looses stability with probability 1 (see figure 2). However, any models employed in such assessments cannot be absolutely precise. This inevitably results in uncertainty in magnitude of ΔT_0. Therefore, the "stair" curve on figure 2 is replaced with a "smooth" curve quantifying probability *P* of the event: - if a long-term increase of mean temperature exceeds ΔT, the chosen key element implies losing stability with a probability more than *P*(ΔT) (stochastic case). If one decided to adopt a level of confidence, for instance, 90%, two different critical limits would emerge, for instance, $\Delta T_1 \approx 1$ºC and $\Delta T_2 \approx 5$ºC (see figure 2). If $\Delta T < \Delta T_1$, the critical threshold would not be exceeded with probability > 90%. If $\Delta T > \Delta T_2$, the critical threshold would be exceeded with probability > 90%. In this example, the range from 1 to 5 ºC is a zone of uncertainty. A size of any zone of uncertainty can be reduced through obtaining new knowledge, data and modeling results. This requires more assessment, research, monitoring and modeling activity.

Thus, in reality we usually must formulate a probabilistic distribution, and thus define a certain level of risk for quantifying any critical limits. Moreover, there will be uncertainty in the very probability distribution assessed. Thus, which value to use - lower or upper - is still problematic. This example of estimating a range or distribution of critical limits is one-dimensional just for simplicity. In reality the task will be multidimensional, and will involve a number of different trade-offs.

In practice, the determination of "acceptable" levels of risk is a complex mixture of positive and normative processes. Particularly in situations where there is an enormous diversity in the set of stakeholders and actors, reaching consensus for such quantities might be extremely difficult (e.g., Functowitz and Ravetz, 1993). In such situations, the IPCC role could be to assess the literature to derive estimates of the probability (WGs 1, 2, and 3) and consequences of outcomes (WGs 2 & 3).

Critical levels for GHG concentrations (CL-GHG)

The UNFCCC, Article 2, does not refer directly to dangerous climate, but to stabilization of GHG concentrations at a level that would prevent "dangerous" interference with the climate system. Therefore, the next scientific task is to determine the constraints on the evolution and stabilization of GHG concentrations, to maintain climate parameters and rates of their changes within some set of defined critical limits. This task could be subdivided into two subtasks: A) to calculate critical levels for GHG concentrations and rates of their changes (CL-GHG) associated with defined critical limits for climate parameters (CL-Climate), and B) to fashion pathways and scenarios for global emissions of greenhouse gases likely not to exceed CL-GHG.

The concept of critical levels has been successfully used in applied environmental science, where they have been employed in setting of ceilings for environmental pollution (Radunsky, 2003). They have also been applied in the health sector, and some lessons could be drawn from the WHO methodology (WHO, 1999). At this stage once again a problem of uncertainty and associated risks has emerged, since "GHG concentrations – climate" models (even very advanced) cannot be precise. Therefore, uncertainty in CL-Climate plus inaccuracy of models will inevitably lead to a range and/or distribution of CL-GHG rather than to particular values.

Risk is classically defined as probability times consequence, and that framework needs to be considered in all calculations of critical levels for GHG concentrations in the atmosphere from critical limits for climatic parameters. This has not been done in the case of Figure 1, although many aspects of the TAR in WG 1 and WG 2 did assess confidence levels or likelihood with respect to a quantitative scale of subjective probability (see Moss and Schneider, 2000). Since Figure 1 suggests that larger warming is more likely to imply more damage (and not necessarily linearly—suggesting the possibility of threshold phenomena), the question of what is the probability of a given level of greenhouse gas concentration (and thus eventual warming) must be addressed. IPCC WG 1 TAR did combine 6 SRES scenarios with several climate models of differing climate sensitivities (the climate sensitivity is typically defined as by how much the atmosphere at the Earth's surface warms in equilibrium for a doubling of CO_2 from pre-industrial levels). In the TAR, the models used had climate sensitivities in the range of typically 1.5 to about 4 ^{o}C warming for a doubling of CO_2. However, probabilities were neither assigned to the 6 SRES scenarios nor the climate model sensitivities, thus the joint probability of warming in 2100—the left hand side of figure 1) is not given; only a range is shown—the gray shaded part.

Upon estimating critical levels for GHGs concentrations in the atmosphere, further questions logically emerge:

- How far contemporary concentrations are from the critical levels?
- At which rate they are approaching those limits?
- Have we any realistic opportunities to reduce the levels and rates?
- How to fashion pathways and scenarios for global emissions of greenhouse gases likely not to exceed CL-GHG.

How should the KV&Art2 CCT be reflected in the WGs contributions to AR4?
Some findings on the KV&Art2 problem are presented in previous IPCC assessment reports as well as in other IPCC publications (see section "Literature"). As the issue will likely be one of the major *foci* of the AR4, even more results are expected in the next 4 years on the basis of assessing recent scientific literature. According to their traditional scope, the following KV&Art2 related issues could potentially be considered by the IPCC WGs:

WG2
- key elements of the climate system at different scale (local/country, regional, global) determining availability and quality of WEHAB-related resources;
- critical outcomes in terms of consequences for HWB;
- critical limits of climate parameters associated with these outcomes (CL-Climate);
- timing aspects, including temporary exceedance of the critical limits and effects of various rates of change.
- adaptation options;
- adaptation costs.
-benefits of various mitigation pathways
-distribution of costs and benefits

WG1
- critical levels for stabilization of GHG concentrations in the atmosphere associated with the critical limits for climate parameters (the latter jointly assessed by WG1 and WG2); these scenarios should include the full range of GHGs and aerosols (and land use change, as new literature is emerging on this potential forcing factor—e.g., Pielke, et al, 2002);
- current and future GHG content in the atmosphere;
- stabilization scenarios (considered jointly by WGI and WGIII, based on "SRES-like" coherence with socio-economic driving forces);
- timing aspects, including temporary exceedance of the critical levels of climate parameters, and effects of various rates of change;
- effects of uncertainty in the climate sensitivity for the determination of critical levels of GHGs and the timepath by which they are achieved.

WG3
- evaluation of stabilization scenarios including the significance of climate sensitivity uncertainty (considered jointly by WGI and WGIII);
- timing aspects (pathways of emissions);
- mitigation options;
- costs of various mitigation pathways;
-distribution of costs and benefits
-decisionmaking frameworks

<u>*Special sections for CCTs*</u>. Since IPCC WGs have a very broad scope, their assessments on the issues listed above will be inevitably spread throughout their contributions to AR4. Therefore, to facilitate the use of the assessments relevant to KV&AR2, especially for policymakers who would find it difficult to dig these issues out of hundreds of pages, it is expedient to place a summary on KV&Art2 issues—including a guide to sections of the WG reports where these topics are discussed in detail - somewhere in each of the IPCC AR4 publications. We suggest the following two options be considered by WG Co-Chairs and discussed by interested IPCC scientists at the Second Scoping Meeting (SSM):

a) Each WG has a special chapter or section (i.e. sub-chapter) devoting to KV&Art2 CCT, and a list of sections of the WG report where key related issues are discussed.
b) Major findings on CCTs, in particular, on KV&Art2 will be reflected in the AR4 Synthesis Report.

A Workshop is needed

An IPCC workshop would be extremely useful to discuss ideas and approaches to the critical limits/levels setting presented in the world scientific literature. This could be a good starting point and form of guidance for the authors that will work on respective chapters of the WGs contributions to the AR4. It is expedient to take into account the results of the IPCC Special Workshop organized in Fortaleza in 1994 (IPCC, 1994).

Of particular importance is a frank and open discussion of the subjective probabilities that might be attached both to SRES storylines and the climate sensitivity results of models and semi-empirical studies that have emerged in the past few years—many since the TAR. Moreover, illumination of the joint probability of scenarios and sensitivities needs to be explicitly considered, again in the light of recent debates in the literature.

Broad representation of experts involved with the relevant aspects of all three working groups need to be in attendance, as well as some experts with special skills appropriate for this CCT (e.g., decision analysis).

This workshop should take place at the end of 2003/beginning of 2004.

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TABLES AND FIGURES

Table 1. The Five Numeraires. Multiple metrics for the valuation of climatic impacts are suggested (from Schneider, Kuntz-Duriseti and Azar, 2000). Typically in economic cost-benefit calculations, only the first numeraire—market sector elements—is included. Different individuals, cultures and governments might have very different weights on these five—or other—numeraires, and thus it is suggested that analysis of climatic impacts be first disaggregated into such dimensions and that any re-aggregation provide a traceable account of the aggregation process so that decision makers can apply their own valuations to various methods of analysis.

The Five Numeraires*

{Vulnerabilities to Climate Changes}

• Market Impacts	{$ per ton C}
• Human Lives Lost	{persons per ton C}
• Biodiversity Loss	{species per ton C}
• Distributional Impacts	{Income redistribution per ton C}
• Quality of Life	{loss of heritage sites; forced migration; disturbed cultural amenities; etc. per ton C}

*Disaggregate by value differences—provide traceable account of re-aggregations to make value differences transparent

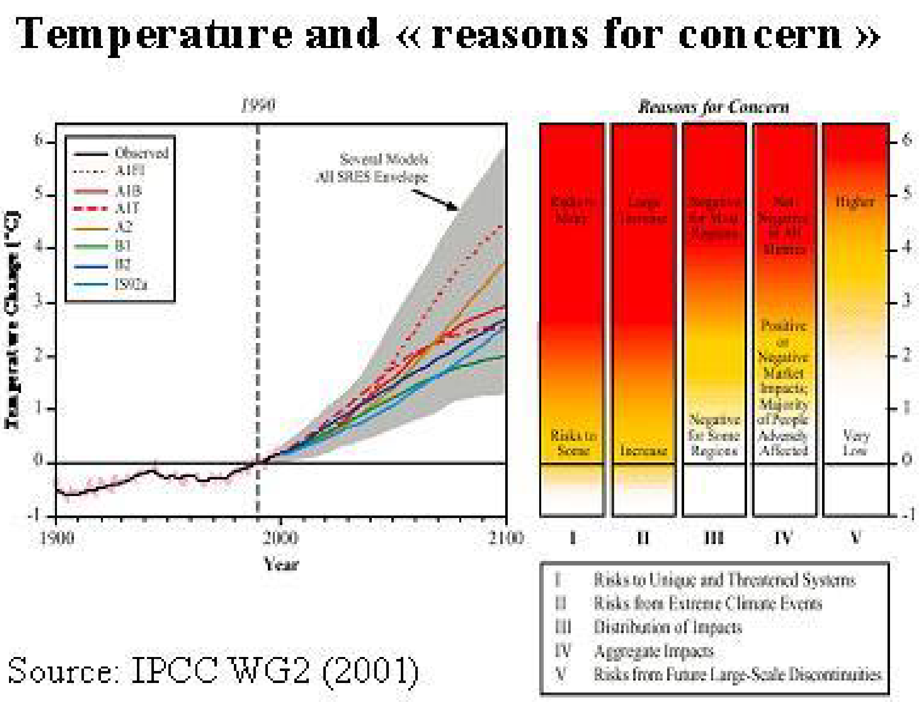

Figure 1. Reasons for concern if temperatures are to continue to rise as projected by applying various SRES scenarios linked to several climate models (left hand side of the figure—from IPCC WG 1 TAR). Note that the darker shades of red—implying intensified impacts more likely to be defined as "dangerous" than lesser impacts represented by the lighter shading—occur for the most part above "a few degrees" warming, as noted in IPCC WG 2 TAR. These are mapped onto the five reasons for concern. Note that for some unique and valuable systems significant damages that some might label as "dangerous" are already occurring or are about to occur, whereas for other dimensions—e.g., risks of large scale discontinuities—warming of several more degrees is suggested before large and thus potentially "dangerous" changes become highly probable. The AR4 could further explore such a representation, stressing the many specific examples of significant impacts and spelling out explicitly as possible the subjective confidences in assessments of such impacts in the literature and among lead authors for each example. Such scientific assessments can help to put socio-political judgments as to what is "dangerous" on a firmer scientific foundation.

Fig. 2. Probability of damage vs. temperature increase: deterministic (stair) and stochastic (smooth curve) cases