German Advisory Council
on Global Change (WBGU)

Scenario for the derivation of global CO_2 reduction targets and implementation strategies

Statement on the occasion of the First Conference of the Parties to the Framework Convention on Climate Change in Berlin

March 1995

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Summary

On the occasion of the First Conference of the Parties to the Framework Convention on Climate Change, the German Advisory Council on Global Change submits the following statement on global CO_2 reduction targets and implementation strategies.

The Council derives a global CO_2 reduction target by using an "inverse scenario" based on simplified models for climate dynamics and the carbon cycle. By first analysing the maximum stress levels caused by climate change that one can assume to be ecologically and economically bearable, a "tolerance window" for the future climatic development is deduced. In a further step, the set of admissible emission profiles is determined, i.e. those global CO_2 emission functions which keep the climate system within the demarcated window. Among the so-defined family of emission options a specific strategy is finally singled out by feasibility criteria.

The Council believes that such an integrated assessment of the climate change problem in the "backwards mode" has several advantages in comparison with the straightforward approach. It has to be emphasised, however, that the analysis employs a number of assumptions and approximations and therefore has the character of a „Gedankenexperiment".

The conclusions of the scenario are as follows:

- Anthropogenic emissions must be reduced to almost zero over the very long term, i.e. within a period of several centuries. The climate system permits a considerable amount of freedom with respect to how the emission profile is actually shaped, however.
- The current emission patterns could be continued for another 25 years ("Business As Usual"), but this would then demand such drastic reduction measures within only a few years that the structures and technologies capable of producing such levels of abatement are not even remotely conceivable at present.
- The Council therefore believes that an appropriate and feasible emission profile must involve a reduction of global CO_2 emissions at a rate of roughly 1% per year over more than 150 years, following a short transitional period (of about 5 years).
- In the medium term, this would require substantial abatement efforts

> on the part of the industrialised nations. The Council proposes that the measures engendered through Germany's self-imposed commitment to reduce CO_2 emissions be implemented in a systematic manner. Internationally the countries have to come to agreements which extend beyond the year 2000.

One must assume that the reduction commitments imposed on Annex-I countries (the industrialised nations) as a result of the above will be limited in scope. In order to make the anticipated system of rigid national quotas more flexible, the Council recommends that the instrument of joint implementation be put into effect, and that the latter instrument be extended as far as possible to an international certificates system. Deploying these instruments would enable the necessary emission reductions to be achieved in a cost-effective way, and developing countries to obtain rapid access to energy-efficient technologies.

In addition to ongoing improvements in energy efficiency, the Council recommends that measures be implemented in the field of environmental education as a means of achieving the ambitious abatement target, since any "self-sufficiency revolution" is conditional on educational measures.

As the Council's work to date has clearly shown, global environmental problems cannot be viewed in isolation from each other; it is essential instead that interlinkages with other global trends be integrated to a greater extent into analyses and implementation strategies. This also applies to climate change, which can only be coped with if the principle of sustainable development is adhered to.

1. Theme of the Statement

The importance of the First Conference of the Parties to the Framework Convention on Climate Change (Climate Convention) taking place from 28.3. - 7.4.1995 in Berlin, referred to in short as the "Climate Conference", is emphasised not only by the fact that the Convention has been signed by the minimum number of states (50), but that it has already been ratified by a total of 121 states and the EU as of February 1995. This is a good basis for an effective joint effort on the part of the international community to ward off the potential impacts of the anthropogenic greenhouse effect. The fact that the natural greenhouse effect is indeed reinforced by human activities (with a 95% degree of certainty) was recently proven by German scientists at the Max Planck Institute for Meteorology in Hamburg.

In order to carry out the tasks it was established to perform, the Climate Conference must work on the assumption that the commitments of UNCED 1992 are in general inadequate for global warming to be effectively combated. The agreement signed in Rio, which was explicitly termed a *Framework* Convention, must therefore be supplemented by a protocol in which the Parties commit themselves to precisely defined reduction targets for the various greenhouse gases.

In the context of the Berlin negotiations, the Council welcomes the position taken by Germany, as expressed in the paper entitled *Elements for a Comprehensive Protocol to the Framework Convention on Climate Change* (the so-called "Elements Paper"), dated September 26, 1994. In particular, the Council supports the demand that, in order to achieve the objective defined in Article 2 of the Convention, all greenhouse gases be included (at least step by step) in a comprehensive protocol. Quantitative targets, time scales and the respective reduction commitments must be agreed upon for all greenhouse gases in order to reduce emissions or — as in many developing countries — to limit increases. As the Council has already pointed out at some length [1], care must be taken when defining these commitments to ensure that apportionment among the individual states or groups of states is equitable and "in accordance with their common but differentiated responsibilities and respective capabilities" (Article 3.1 of the Convention).

The focus of the Council's statement is a scenario. Unlike most other approaches, this scenario is not based on the causes but on the *effects* of climate change. This means that tolerable stresses for humans and nature are first specified, and that, by proceeding "backwards", the long-term global reduction target is derived which would ensure that these maximum stress levels are complied with.

Once a global reduction target has been agreed upon, it is necessary to specify the quota for each country participating in this reduction strategy. We assume that a standard percentage rate of reduction will be agreed upon for all Annex-I countries (industrialised nations and the transitional economies specified in the Convention). From the global perspective, however, such a procedure would increase the costs for emission reductions to an unnecessary degree, since the respective national costs for emission reduction vary considerably. In order to offset the disadvantages implied by "rigid" national quotas (i.e. identical percentages), it is necessary to deploy special instruments to make the system more flexible. The Council therefore emphasises its previous recommendation [1] that a system of joint implementation between Parties be established as part of the climate protection policy, that tradeable permit system be worked out and that the latter instrument be applied as soon as possible in the form of a pilot project within the European Union (EU).

In addition the Council recommends to foster environmental education as an important element of any national implementation strategy (Section 5).

Dealing with the climate problem in isolation from other spheres is inadequate. There is an urgent need, rather, to demonstrate the links that exist between climate change and other global environmental trends. Here the Council refers to the relevant section of its Global Network of Interrelations (Section 6).

2. Scenario for estimating minimum global CO_2 reduction targets

2.1. The "backwards mode" of the scenario

Until now, model calculations of the relation between greenhouse gas emissions and climate change have been carried out mostly in the *"forwards mode"* [2]. Based on various assumptions about demographic and economic development, a set of emission scenarios was *pre-defined*, and future climate changes predicted on that basis. Such studies are helpful to an extent in identifying non-acceptable ("non-sustainable") developments of global environmental change, but do not provide any direct answer regarding the conditions for *acceptable* ("sustainable") developments.

The *"backwards mode"* has to be used instead for such answers: taking account of the impacts of climate change on human beings and nature, the "window" of *tolerable* future climate change is defined. The next step is to calculate the global emission profiles which ensure conformity within that window. In this way, the minimum demands for a global reduction strategy can be derived directly.

The most recent analyses [3] already use some elements of the "inverse scenario". The Council pursues this path systematically in an attempt to arrive at political conclusions within a closed picture, as illustrated in Fig. 1.

In Step 1, a — generous — tolerance range is defined for potential stresses caused by climate change. This *normative* precondition, which of course involves specific notions about ecological and economicl values, enables the objectives defined in Article 2 of the Climate Convention to be operationalised. In a second step, an assessment is made of the climate changes that comply with the predefined tolerable stress levels. Using simplified models of climate dynamics and the carbon cycle, the admissible global emission profiles for CO_2 are determined in Steps 3 and 4 (other greenhouse gases from human sources are excluded here). It is particularly interesting to determine *upper limits* for total CO_2 emissions within a chosen stabilisation period, as well as "optimal" emission profiles that come close to this upper limit.

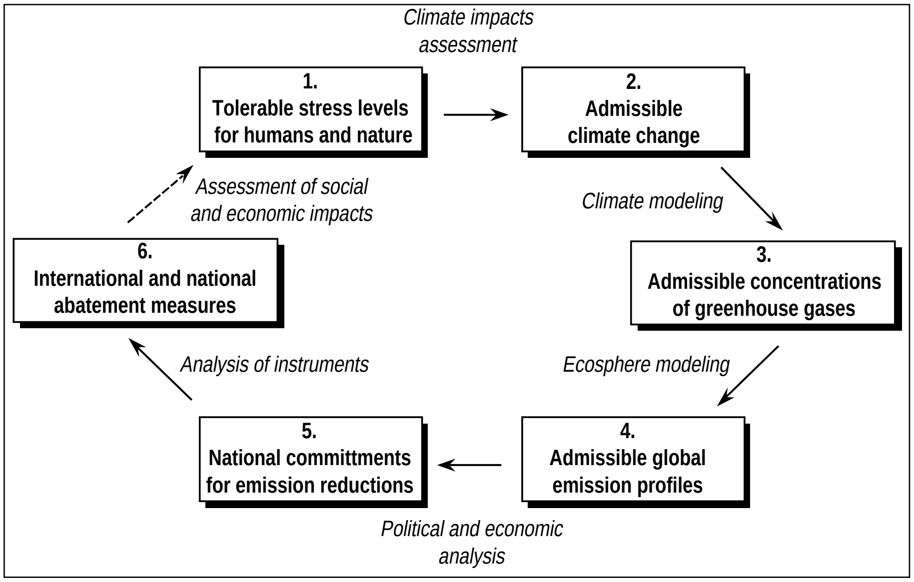

Fig. 1: The Council's "inverse scenario"

In Step 5 — subject to the criteria of international environment and development policies — reduction commitments for the individual countries or groups of countries can be derived. The sixth and final stage is to analyse which reduction instruments at what locations are able to achieve the most effective emission reductions, and which mix of instruments implies the least costs.

Studies featuring a combined focus on all relevant aspects to the climate problem are now appearing at an increasing rate. One current example is a study worked out by Bach [4] in connection with the German Parliament's Climate Enquete Commission. However, this analysis, too, is carried out in the "forwards mode" (i.e. anti-clockwise in Fig. 1).

In the following analysis, the Council restricts itself in the main to Steps 1 to 4. Furthermore, the admissible minimum reduction function for the Annex-I countries (Germany included) is determined on the basis of the most probable international quota system (Fig. 4). As far as steps 5 and 6 are concerned, the Council gives some indications (Sections 3-5); full clarification of these issues has yet to be achieved, however, and poses a major challenge for research.

The analytical procedure adopted here can be developed further, by assessing the worldwide socioeconomic impact of reduction measures, to produce an *integrated model* for climate policy (broken arrow between steps 6 and 1 in Fig. 1). Within such a model, the costs of adapting to changed climatic conditions can be compared with the costs of preventing climate change. However, the Council dispenses provisionally with this fully integrated perspective, since it still involves too many uncertainties — the direct and indirect effects of abatement efforts on humans and on nature (e.g. diminishing environmental stress due to reduced traffic levels) are extremely difficult to quantify at present. Taking only *direct* climatic impacts into account means that the severity of anthropogenic climate forcing is probably underestimated in the scenario.

2.2. The basic assumptions of the scenario

In order to arrive at an approximate but sound assessment of the possible impacts of climate change, despite the highly complex mechanisms involved, the Council applies the principles of

- preservation of Creation
- prevention of excessive costs.

The boundary conditions of the scenario are developed from these two principles.

A tolerable temperature window

The first principle, preservation of Creation in its present form, is presented within this scenario in the form of a tolerable “temperature window”. This window is derived from the range of fluctuation for the Earth’s mean temperature in the late Quarternary period. This geological epoch has shaped our present-day environment, with the lowest temperatures occurring in the last ice age (mean minimum around 10.4 °C) and the highest temperatures during the last interglacial period (mean maximum around 16.1 °C). If this temperature range is exceeded in either direction, dramatic changes in the composition and function of today’s ecosystems can be expected. *If we extend the tolerance range by a further 0.5 °C at either end, then the tolerable temperature window extends from 9.9 °C to 16.6 °C*. Today’s global mean temperature is around 15.3 °C, which means that the temperature span to the tolerable maximum is currently only 1.3 °C.

Stresses acting on society

The second principle, the prevention of excessive costs, is defined in terms of a simple economic indicator. Economists assume that severe social and economic disruptions would likely ensue if the costs of adapting to climate change, including the costs of repairing impact damages, were in the order of 3-5% of Gross Global Product (GGP). In our scenario, a mean value for the burden on global society of 5% of GGP is taken as the maximum tolerable limit (to the extent that this burden can be expressed in monetary terms). It has to be taken into account that, given the uneven spatial distribution of climate impacts, some states may be affected much more seriously than others (e.g. Bangladesh, island states).

Most estimates of the global annual costs resulting from a doubling of the CO_2 concentration by the end of the next century arrive at 1-2% of GGP. Doubling of the CO_2 concentration over that period would lead to a mean temperature increase of roughly 0.2 °C per decade in the various climate models used. However, all of these estimates fail to include either extreme events (droughts, floods, tropical storms), or possible synergies between the various forms of global environmental change. *If these events are also included, there is good reason to assume that with a temperature change of 0.2 °C per decade the upper limit for adaptation costs of 5% of GGP would be reached*.

Declining adaptability

This upper limit for the maximum admissible rate of temperature change is probably only valid for as long as the ecosphere is located in the centre of the temperature window. As the upper temperature limit of 16.6 °C is approached, however, the capacity to adapt will decline. *This means that the tolerable temperature gradient at the upper boundary goes to zero*.

With the help of these three basic assumptions, and taking into account a number of other factors (e.g. non-linear dependencies and irreversibilities), we can now define a two-dimensional climate domain $\mathfrak{D}$ that the climate system should not depart from. This domain is called the “tolerable climate window”. Further details of this analysis can be found in the Annex. One should note that all boundary conditions have been deliberately defined within broad limits to ensure that the resultant demands for climate protection policy are not assessed too pessimistically. The reduction commitments presented below are therefore to be seen as *minimum values*.

2.3. The key conclusions of the scenario

The special benefit of the inverse analytical approach is that climate is not seen as a problem of prediction, but as one of *control*: the future of the global environment depends to a significant extent on the CO_2 emission profile E(t) of the next centuries, and this profile can be *chosen*, within certain limits, by humankind.

The model calculations on which this study is based permit the identification and classification of all admissible emission profiles. From the wealth of results obtained, only the two most important profiles will be presented, each displaying very different characteristics. But note that in view of the major gaps in our knowledge and understanding of the climate system, all of these results are in effect probability statements.

General conclusions of the scenario

In order to ensure conformity within the tolerable climate domain $\mathfrak{D}$, the total volume of all future anthropogenic emissions must not exceed a certain *finite* value Σ. On the basis of the modeling parameters used here, Σ is calculated as almost 1,600 gigatons of carbon (Gt C). If somewhat different parameter sets within the existing range of scientific uncertainty are taken, this upper limit could rise to approx. 2,000 Gt C.

The conclusion, however, is the same in all cases. *Emissions of CO_2 from human sources must be reduced almost to zero over the long term, i.e. within a time scale of several centuries*. This conclusion would only need to be qualified if there are still some unknown negative (i.e. climate-protecting) feedback mechanisms — particularly those that might involve the biosphere.

The model calculations display a special feature of the ecosphere, namely that the climate system grants considerable liberties regarding the choice of the emission profile E(t): highly differing distributions of the same emission sum σ ($\leq \Sigma$) over the next centuries can ensure conformity with climate domain $\mathfrak{D}$. This contradicts somewhat the common assumption that only through immediate and full stoppage of global CO_2 emissions can climate changes be kept within tolerable limits.

To that extent there is a certain margin that permits *sociocultural, political and economic criteria* to be taken into account when defining the global emission profile. This does not imply, however, that future CO_2 emission levels can be set arbitrarily — the boundary conditions defined by $\mathfrak{D}$ are of crucial importance especially in the medium-term planning range, as is illustrated by the following Business-as-Usual example.

Maximum emission profile for initially unchecked growth

Global emissions of CO_2 are currently increasing at a rate of approx. 1.7% annually relative to the 1994 level. Hypothetical projection of this linear trend is termed "Business as Usual". The Council's model calculation shows that such emission behaviour could lead within less than 30 years to the limits of the climate window; the climate system could then be kept within the permissible range only if drastic changes were implemented, *i.e. a reduction of emissions by approx. 40% within only a few years*. Figure 2 shows the respective (smoothed) emission profile $\tilde{E}_1$ for the first 200 years.

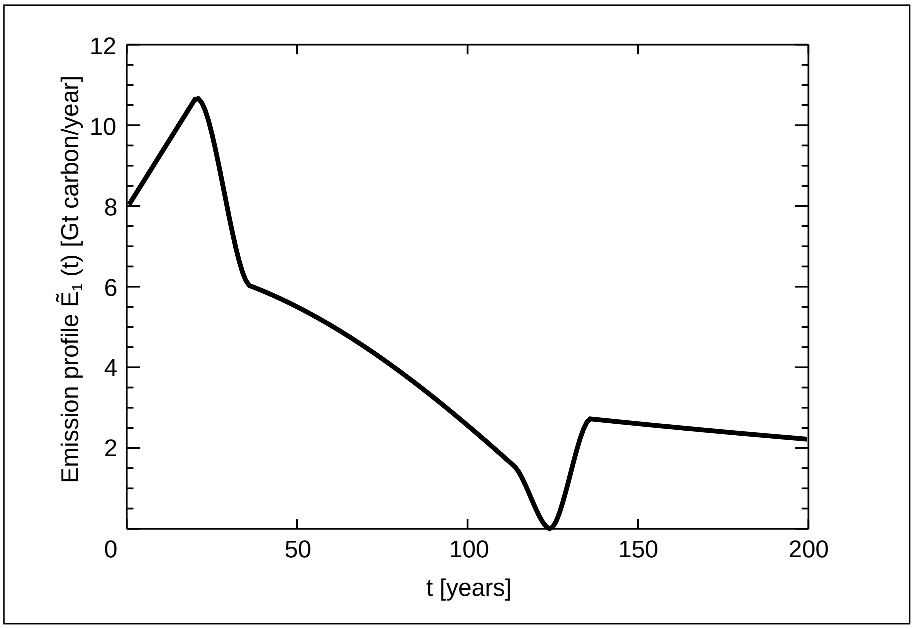

Fig. 2: Global CO_2 emission profile $\tilde{E}_1$ for initial Business as Usual

The profile shown is "optimised" in the sense that the cumulated CO_2 emission level at any point in time is approximately the maximum amount acceptable for the climate. This results in an annual mean emission of 4.2 Gt C. As a comparison, the emissions of the industrialised nations are currently about 6.1 Gt C, those of the developing countries around 1.5 Gt C.

Current global emissions therefore amount to approx. 7.6 Gt C annually.

The Council believes that emission profile $\tilde{E}_1$ is neither feasible nor desirable. In particular, the extreme reduction requirements that arise after approx. 30 years would then exceed the elasticity of the world economic system.

Maximum emission profile for constant percentage reduction

Fig. 3 shows the global emission profile $\tilde{E}_2$, which is ecologically and economically the most favourable alternative.

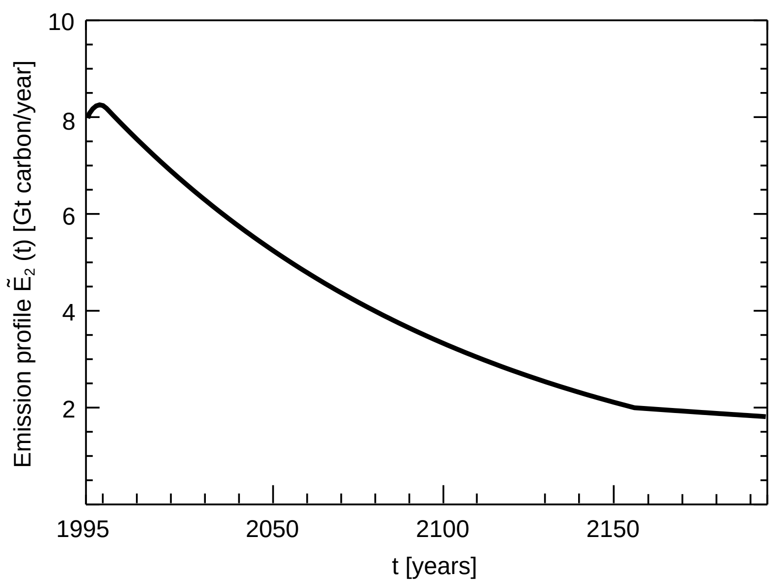

Fig. 3: Global CO_2 emission profile $\tilde{E}_2$ for reduction at constant percentage

This climate protection strategy would involve, after a 5-year transitional period (initial “bending” of the Business-as-Usual trend), an annual reduction in CO_2 emissions of roughly 1% until the year 2155, followed by annual reductions of approx. 0.25%. $\tilde{E}_2$ behaves as a compound exponential function and represents, of all curves of this type, the admissible *limit function*. All higher emission profiles in this class would cause the climate system to depart from $\mathfrak{D}$. The level of total emissions associated with $\tilde{E}_2$ over the next 200 years is 802 Gt C; $\tilde{E}_1$ (Fig. 2) permits 820 Gt C over the same period, which is only 2% more. Because profile $\tilde{E}_2$ is not only much easier to implement than $\tilde{E}_1$, but also offers *long-term security of planning* through the agreement of a *constant* annual rate of reduction, this climate protection strategy is clearly to be preferred!

Percentage reduction profile for Annex-I countries

In a sense, emission profiles $\tilde{E}_1$ und $\tilde{E}_2$ define *global pollution quotas* as a function of time. These global quantities can be transformed into *national reduction commitments* if, for example, a politically negotiated allocation formula is laid down in a CO_2 protocol in order to implement the Climate Convention. Consensus could be reached more easily on such a formula if it allocates reduction commitments exclusively to Annex-I states at first, and envisages that all these countries reduce their respective emissions by the same percentage. The developing countries would then have to accept the fixed current quota of approx. 1.5 Gt C per year.

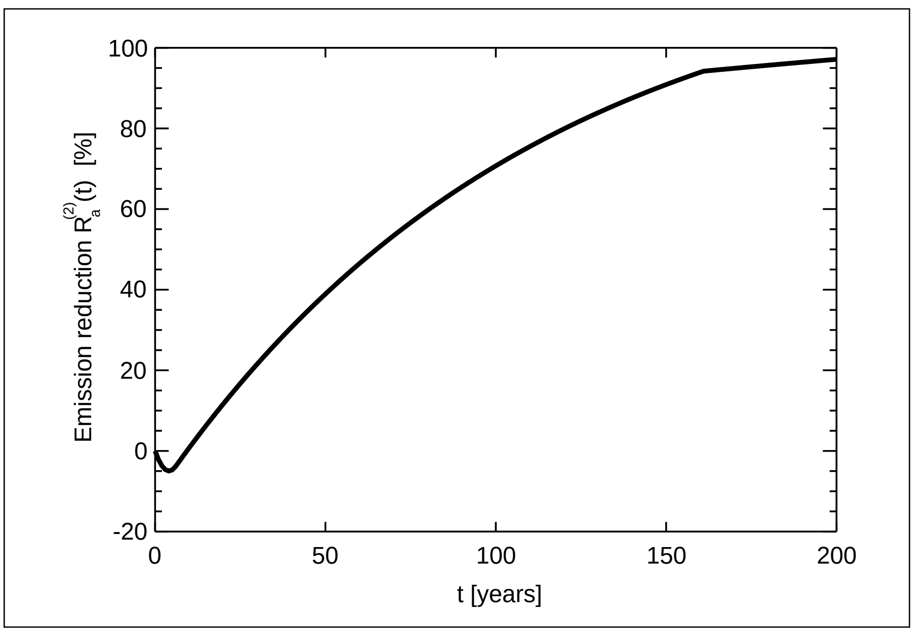

Fig. 4: Percentage reduction profile for Annex-I states according to $\tilde{E}_2$

Fig. 4 shows the corresponding minimum-reduction profile $R_a^{(2)}$ associated with the emission profile $\tilde{E}_2$ for the Annex-I states including Germany (the conversion method is explained in the Annex). This profile shows that enormous abatement efforts will have to be made in the medium term by the industrialised nations, who are historically and currently responsible for the largest share of greenhouse gas emissions.

It has to be emphasised that the allocation formula for the emissions on which the above abatement scenario is based presumes a freezing for the developing countries at the current 1.5 Gt C/year. Taking into account that these countries should have some margin for additional emissions over the next decades and considering further that other greenhouse gases such as methane, nitrous oxide or CFCs have been excluded in the scenario the reduction requirements in Fig. 4 clearly represent the lower limit.

The Council welcomes Germany's commitment to reduce its CO_2 emissions by at least 25% relative to 1987 levels by the year 2005. The measures necessary to achieve this must be implemented in a systematic manner. Internationally the countries have to come to agreements which extend well beyond the year 2000.

3. Standard national quotas and their importance for international instruments

The debate over national reduction quotas appears to be heading at present towards the same percentage reduction commitment being imposed on all Annex-I states, possibly differentiated according to transitional economies and the other industrialised nations. The extent to which this will produce a cost-effective solution can only be assessed by analysing regional differences in reduction potential.

3.1. Regional differences in technical reduction potentials

The conclusions of the scenario show the urgent need for rapid and clear-cut reduction of global CO_2 emissions. If implementation of ecologically indisputable measures is to be economically efficient, preference must be given to procedures that take effect in those areas (and sectors) that contain the greatest present and future potentials for emission reductions. So far, however, there has been no comprehensive analysis of the technical potentials for

CO_2 reduction that exist or are thought to exist worldwide; this should therefore be carried out as a matter of urgency. Available information already allows a rough picture to be drawn, however, in which a distinction can be made between regions that:

— emit or will emit quanitatively significant amounts of CO_2 in the present and/or the future,

— are still lagging far behind countries that possess advanced technologies (i.e. Japan and the states of Western Europe especially) in terms of energy efficiency,

— are most likely to have the highest rates of economic growth.

The first criterion — absolute level of emissions — is important when defining the geographical areas that are responsible for the greatest quantities. Where high magnitudes of CO_2 emissions are combined at the regional level with highly efficient power stations or the achievement of a low level of specific energy consumption (second criterion), this is an indication that there is little scope for significant emission reductions *in the short term*. Experience shows that additional reduction measures and/or increases in energy productivity imply very high costs and could exceed the adaptability of the economic system (cf. second marginal condition of the scenario). Negative growth rates in the highly developed nations would reduce emissions, as experience in the new federal states in Germany has shown, but would at the same time exacerbate the unemployment problem in many industrialised countries, affecting the entire global economy and thus the developing countries as well. A “self-sufficiency revolution” is only possible, on the other hand, if there is a high level of environmental awareness. This can be achieved only *in the long term* and would therefore have to be developed through appropriate educational programmes (see Section 5 below). Significant short-term successes in the CO_2 reduction will only be achieved as a rule where there is both a high level of energy consumption and technical scope for improving energy productivity. This potential can be exploited all the more easily the higher the anticipated or targeted growth rates are (third criterion), since new plants and technologies are the most effective means for attaining higher degrees of efficiency and/or lower specific energy consumption.

The following countries are particularly important in any rough assessment of existing CO_2 reduction potentials and/or regional prioritisation:

— the USA and Canada (within the OECD),

— the People's Republic of China and most CIS states and Eastern European states (among the non-OECD nations).

In 1990, these regions accounted for about two thirds of global CO_2 emissions [5], [6], [1], as well as the highest annual per capita CO_2 emissions (Table 1).

The People's Republic of China is the third largest energy consumer in the world, after the USA and Russia, due primarily to the high industrial demand for energy, predominantly met with coal (just under 72% of industrial energy demand in 1991). According to calculations carried out by the International Energy Agency, the People's Republic of China will be emitting almost 5 billion tons of CO_2 (= 1.4 Gt C) in the year 2010, equivalent to about 18% of global CO_2 emissions today, if current trends continue and/or its growth targets are attained. Fuel consumption per unit of GDP among the countries and regions listed below was far above that of other major CO_2 emittors in 1990 (Table 1).

Table 1: Annual per capita CO_2 emissions and fuel consumption per unit of GDP[a] in selected countries and regions

Region	Annual per capita CO_2 emissions [tons]	Fuel consumption per unit of GDP [gigajoule/1,000 $ GDP]
North America	20.2	11.9
CIS states	13.6	no figures available
Germany[b]	13.0	11.3
Eastern Europe	10.6	28.8
Western Europe	8.1	7.1
Japan	8.1	3.9
Asia (incl. China)	1.5	34.9
India	0.7	13.7

a) GDP = Gross Domestic Product; b) incl. new states in eastern Germany

Sources: [5], [6], [1]

3.2. Conclusions regarding the determination of reduction commitments

In order to allocate reduction commitments to individual states, a number of additional criteria must be applied, such as responsibility for the greenhouse effect according to the polluter pays principle, for example, and aspects of international equity such as the economic capacity of states to implement abatement measures on a large scale. One method would be to take account of these different components in an allocation formula, whereby the allocation formula and hence the allocation of commitments would have to vary, depending on the time scale in question. However, the Parties to the Climate Convention are more likely to agree on percentage reduction rates applying to the absolute emissions of all Annex-I states.

Assuming this it is all the more important, given the enormous variations in regional reduction potentials, that international strategies permitting greater flexibility in the application of rigid national quotas be implemented alongside purely national instruments for climate protection. Greater flexibility can take account of the very different CO_2 reduction potentials that already exist between the Annex-I countries and even within the Annex-II states (the sub-group of industrialised states, excluding the transitional countries), as shown above. Were such a system in place, individual states could achieve their CO_2 emission quotas at much lower cost. In view of the difficult adaptation process that implementing the reduction commitments implies for each country, the Council strongly advocates that this opportunity be availed of. Rendering a rigid system of percentages more flexible could be the key to binding commitments in the field of international climate protection policy, and hence to real progress in combating the greenhouse effect. One important element in the flexibilisation of national quotas, and hence the reduction of adaptation and prevention costs for all states participating in such a system, is the joint implementation of mitigation or reduction measures, another being a global system of tradeable permits.

4. Flexibility under a system of standard national quotas: Joint implementation and the tradeable permit system

4.1. Joint implementation

The Council supports the option provided for in the Climate Convention, namely that part of a country's national reduction commitment be met by financing mitigation measures in other countries. The Climate Conference should therefore agree on appropriate criteria for joint implementation and the requisite institutional arrangements [1].

In addition to the benefit of reduced avoidance costs, joint implementation provides a framework for promoting the transfer of private capital, technology and know-how from the industrialised to the developing countries, and at the same time for promoting the capacity building that is indispensable for development progress. Mindful of the lack of public funds in developing countries the Council considers it imperative not to underestimate this aspect.

Should the first Conference of the Parties in Berlin fail to agree on binding criteria for joint implementation, then it should at least decide that a *pilot phase* be started with relatively open conditions. This would merely entail all projects having to be communicated to the Secretariat of the Framework Convention on Climate Change — or some other institution — for registration and evaluation. This institution should be granted a *mandate* to further develop internationally acceptable conditions for joint implementation. Through voluntary application of the instrument during the pilot phase, suitable criteria can be developed which could then be defined later as binding criteria for the international recognition of joint implementation projects.

With regard to the *crediting* of emission reductions achieved through joint implementation projects against the reduction commitments of the Parties listed in Annex-I, the Council wishes to point out that if no form of crediting is introduced, an important driving force for joint implementation projects would be lost. Even if crediting must be dispensed with during the trial period in order to achieve some form of international consensus on joint implementation, the concept cannot be put into operation on any comprehensive scale unless reductions can be credited against national reduction targets and incentives exist for private sector involvement. The objections raised by some countries and environmental groups against the crediting of emission reductions could be met by committing the Annex-I states to realising the major proportion of their reduction obligations — say 70-80% — within that group of states (i.e. including countries undergoing the transition to a market economy). If measures for reducing emissions outside the territory of a specific state are implemented, then the reduction commitment should be raised by a certain specified amount — in other words, emission reductions achieved elsewhere should not be credited in full against national targets.

In the long term, protection of the environment will only obtain the desired acceptance and importance at international level — as at national level — when the right environmental measures are accompanied by implementation of the right economic policies. On the whole, the Council welcomes the efforts of the Parties to the Climate Convention to integrate economic aspects, in the form of joint implementation, as part of the climate protection strategy. This can build confidence in the functional effectiveness of this untested instrument, and thus enhance its acceptance. At the same time, as developments in the USA have shown, this type of compensation model can lead to valuable experience being acquired for later and more comprehensive deployment of economic instruments. One of the most important such instruments, especially as a means for making the application of rigid national quotas more flexible, is that of internationally tradeable permits.

4.2. An international tradeable permit system

The Council expressly advocates the protocol proposed by AOSIS *(Alliance of Small Island States)*, and the German government's proposals that economic instruments be deployed to a greater extent than hitherto as a means of reducing emissions of greenhouse gases in order to make climate protection measures as cost-effective as possible. At the global level, the introduction of a tradeable permit system would contribute to greater flexibility with respect to national quotas. In such a system, the Parties would be permitted to sell their allocated emissions to other states for given periods in the form of negotiable emission permits. The latter states could then use the emission permits to cover their own emissions until they have fully developed their own emission avoidance technologies, for example. A developing country could also act as a seller of permits if it is unable to make full use of the emission volume allocated to it, but would first like to obtain income by “renting out” these rights. When the economy has developed further, partly with the income from renting out emission permits, the allocated emission rights could then be made use of.

Such a system would enable targets to be achieved much more cost-effectively, or greater CO_2 reductions being achieved with the same budget, regardless of the allocation system (national quotas) initially selected [1], [7]. In principle, therefore, such an international tradeable permit system would mean that the Parties can operate a trade in emission permits. What precise measures the individual states deploy in order to comply with their emission ceilings would be a matter of national sovereignty.

The Council advocates that the Conference of the Parties issue the Secretariat of the Climate Change Convention with a mandate to have the conditions for establishing an international tradeable permit system investigated and identified. This will involve a whole series of definitions and stipulations. The Council assumes that the question of initial allocation of national emission quotas is relatively easy to resolve; after all, the national quotas that the Conference of the Parties will in any event have to lay down will provide a basis for calculating the emission levels that individual countries are implicitly “allowed” to produce. The Council also draws attention to the fact that the initial allocation of emission targets will also involve determining the financial burdens to be borne by the individual Parties.

Independently of the further development of a global permit system, the Member States of the European Union should take immediate action to establish such a system within its own group of nations as soon as possible. In the view of the Council, conditions in the EU are particularly conducive to the success of such a system.

5. Environmental education as a key element of implementation stategies

The Framework Convention on Climate Change acknowledges that the development of public awareness, including a change in environmental "consciousness" and action at the national and international level, is essential for the prevention of and adaptation to climate change. Education and training play an important role in this context (Article 4, paragraph 1; Article 6).

Opportunities to learn and acquire environmentally sound behaviour that has a positive impact on climate protection must be created even at pre-school level, and certainly at all levels of the formal education system, up to and including the training of lecturers and researchers at the tertiary level. Education programmes offered by many non-governmental organisations also have an important role to play. Environmental issues should not be confined to a particular school subject or a limited number of scientific disciplines; it is essential instead that an environmental dimension be integrated into all subjects and disciplines in order to show that complex environmental problems can only be solved on an interdisciplinary basis.

Assuming that environmentally damaging behaviour is learned from an early age onwards, environmental education measures must always be aimed at modifying environmentally damaging behaviour into environmentally more benign behaviour [7].

Raising awareness is not sufficient to actually change behaviour — this has been demonstrated often enough in the past. Environmentally relevant behaviour is shaped by a whole series of different factors; measures relating to education and the upbringing of children must take a wide variety of forms and be variable in their application if they are to have any real impact on behaviour.

With the example of energy-related behaviour, which is clearly of crucial importance for the reduction of CO_2 levels, it can be shown how different control measures as part of educational programmes can change behaviour.

- One very important requirement is to demonstrate *cause-effect relationships* between one's own behaviour (e.g. heat consumption, mobility behaviour) and possible climate changes, and to make these understandable and easy to grasp (e.g. by converting specific types of behaviour into CO_2 or tropical forest equivalents). Interrelations between climate changes and their impacts can be rendered transparent in a similar way. The mass media can enhance the “visibility” of such relationships perceptible for the individual — e.g. by describing and simulating different scenarios for the future — and therefore have an important role to play, particularly since anticipated climate changes are almost impossible to perceive directly.

- Another conditional complex is the *provision of instructions and incentives* for environmentally benign behaviour. Information about ways of saving energy is just as important here as incentives (which can be non-monetary) for private investments in climate protection or for changing mobility behaviour.
- Environmental education and “environmental learning” are all the more effective the more the persons concerned play an active role in defining the objectives of learning and the criteria for evaluating success. This demands active involvement at a level that individuals themselves are familiar with (“think globally, act locally”). The prerequisite is that people participate as directly as possible in decisions relating to CO_2 reduction. Such involvement can be encouraged through various forms of participation (e.g. as part of the “Climate Union of European Cities”), but also through ideas competitions in local communities, schools, etc. For such participation to materialise, however, it is necessary to provide simplified public access to information relating to CO_2 emissions, not only through reports in the media, but also through the creation of “climate services” or similar bodies.

The Council recommends to the Federal Government that the subject of environmental education be discussed at the Second Conference of the Parties to the Climate Convention.

6. The interrelation between climate problems and Global Change: the need for coordination between international conventions

The Climate Conference in Berlin focusses on environmental problems which are manifested over large parts of the Earth's atmosphere, in particular the anthropogenic greenhouse effect. This focus enables the Conference to concentrate on concrete objectives and effective measures in this area of Global Change, but at the same time harbours the risk that little or no attention be devoted to the interlinkages that exist to other problems that come under the general heading of Global Change [7].

The Council has developed a methodology which enables the interactions between global environmental trends and their links with socioeconomic factors to be visibly portrayed [1], [7]. To illustrate the interlinkages that exist between climate problems and other compartments of the global environment, the method is applied in the following to the trend labelled "Enhanced greenhouse effect". Only the most important direct influences and impacts are taken into consideration so as not to over-complicate the diagram (Fig. 5, see backcover).

It can be seen that substantial conflicts over objectives can develop within international environmental policymaking, and that different measures could act against each other in some cases. One example would be the different interactions of atmospheric trends. Efforts are being directed at decreasing the level of aerosols in the troposphere due to their direct and harmful effects on human beings and nature, although high aerosol concentrations produce substantial reductions in the greenhouse effect. In other cases, for example the reduction of summer smog, objectives run parallel — reducing poisonous tropospheric ozone mitigates the greenhouse effect. Independently of this, however, there are further processes that cannot be influenced by international policymaking. Changes in solar activity may have an impact on the Earth's climate, for example. The greenhouse effect cannot be viewed upon in isolation, therefore — an integrated approach is necessary.

This is particularly the case when different fields of global environmental policy are involved. Conflicts between climate protection measures and the Biodiversity Convention can arise, for example when major afforestation measures use monocultures genetically optimised to store carbon. Compensation mechanisms between the different objectives would be easier to establish where the respective global trends are already the subject of international environmental policies, such as the trend to the "conversion of virtually natural ecosystems" (such as forests) and the Forest Declaration of Rio de Janeiro, the Biodiversity Convention and AGENDA 21. Integrating other areas which are not yet the subject of international treaties, or only to a certain extent, such as global soil degradation [1], is much more difficult.

In the view of the Council, there is a particular need for action specifically geared to the prevention of conflicts between the objectives of international environmental conventions and measures in the socioeconomic sphere. For example, despite the fact that the global trend labelled "growing traffic volume" is linked to greater emissions of greenhouse gases, multilateral development banks continue to provide large amounts of funding to projects which are aimed at creating and expanding transport infrastructure, which induce higher CO_2 emission levels.

The Council therefore draws attention to the urgent need for coordination between the various policymaking fields, a recommendation that is not directed solely at the First Conference of the Parties to the Climate Convention, but indeed to all actors in the various fields referred to.

The conventions currently in place are only beginning to unfold their mutually interactive links. This process is hampered by the fact that the respective Conferences of the Parties to the Conventions are independent institutions that neither report to nor issue directives to international institutions capable of discharging such a coordination function (e.g. the United Nations Environment Programme, UNEP or the Commission on Sustainable Development, CSD). The different degrees of scope accorded by the conventions are restricted to the respective signatories, the number and composition of whom are different for each specific convention.

Given this lack of coordination, the Council considers it essential that the issue of an integrated strategy for managing global environmental problems be put on the international agenda as a matter of urgency. The actual network of interrelations between the various trends of relevance for the environment should be mirrored in the structures and institutions of the international political process. Special attention must be devoted to ensure that all efforts are guided by the basic principle of sustainable development agreed upon at the Rio Conference. The CSD already plays a role today as the guardian of AGENDA 21, but has no legislative provisions or powers to match the demands. Adaptation and further development of the international institutions remains an important task and challenge for the future.

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Annex I: Notes on the Inverse Scenario in Section 2

A1.1. Tolerable stress for nature and society

The potential consequences of marked climate change — to the extent they can already be identified and evaluated in the first place — take a multitude of different forms: the spectrum extends from the threat to human life through floods or heat waves to the loss of aesthetic values through extinction of species. If the different qualities of stress were properly taken into account, then the possible climate change impacts would have to be presented within a high-dimensional action space. Due to the gaps in available knowledge, however, such a presentation could only pretend to have scientific precision.

In contrast to such an approach, approximate but sound conclusions can be obtained from "first principles". These principles express fundamental values and boundary conditions defined by our society. The Council constructs its "inverse scenario" or "Gedankenexperiment" solely on the basis of the following maxims:

- preservation of Creation
- prevention of excessive costs.

The first principle can be specified in relation to the climate problem as follows: human-induced disturbances of the atmosphere are considered no longer tolerable if they cause the mean global temperature T to leave the Quarternary range of fluctuation. This would mean that global climatic conditions would be deviating markedly from those that have shaped the coevolution of humanity and ecosphere and which have thus produced the environment as we know it today.

From this principle we derive the explicit requirement for temperature T (°C):

$$T_{min} \leq T \leq T_{max} \quad ,$$

where

$$T_{min} = T_{min}\,(\text{glacial}) - 0.5 = 9.9 \quad ,$$

$$T_{max} = T_{max}\,(\text{interglacial}) + 0.5 = 16.6 \quad .$$

T_{min} (glacial) = 10.4 °C is the (smoothed) minimum temperature during the last glacial period (Wuerm), while T_{max} (interglacial) = 16.1 °C is the respective maximum temperature during the preceding interglacial period (Eem).

The tolerable temperature window is obtained by extending the natural range between these extremities by 0.5 °C at either end, i.e. the range of acceptable temperature is demarcated rather generously. For comparison, the mean global temperature T_0 today is 15.3 °C.

The second principle should make immediate sense; the problem here is how to express in monetary terms the effects that result from climate change (see also section A2.2), and how to interpret the word “excessive”. The decline S in percent of Gross Global Product (GGP) caused by climate change shall serve as a one-dimensional cost indicator in a first approximation. It is not our intention to discuss here the advantages and disadvantages of GGP as an economic indicator.

Economists assume that resultant costs of climate change in the order of 3-5% of annual GGP over a period of several decades would cause severe disruption of social conditions with far-reaching political consequences. (By way of illustration, one should note that the current annual volume of transfer payments from West to East Germany is about 5% of GNP). Furthermore, one should realise that a moderate value for S would also involve temporary but extreme stresses for many regions in the world on account of the considerable geographic inhomogeneity of climate impacts. The second limiting condition is therefore

$$S \leq S_{max} \quad ,$$

where $S_{max} = 5$.

The resultant range of acceptance $\mathcal{A}$ in the 2-dimensional stress-temperature space is shown in Fig. A1.

$\mathcal{A}$ is not over-confined in any sense: coping with the stress potential involved implies an enormous challenge for a growing and largely underdeveloped global population. The definition of a fundamental tolerance window is an operationalisation of the objective in Article 2 of the Convention on Climate Change and forms the starting point for all further analytical steps.

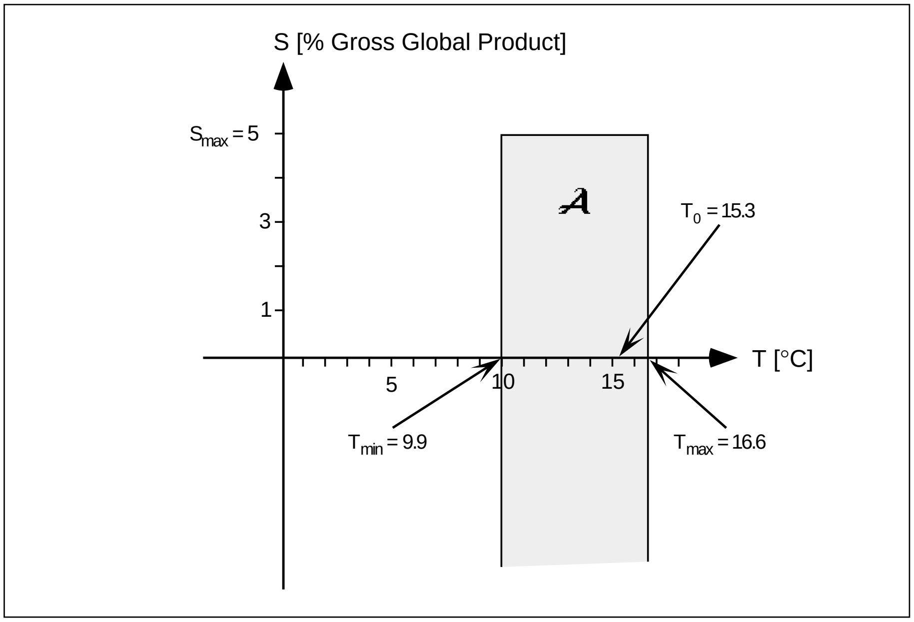

Fig. A1: Range of acceptance according to first principles. T_0 is the present global mean temperature

A1.2. Admissible climate change

Since even the best available coupled ocean-atmosphere general circulation models (GCMs) can still not provide any reliable predictions on the critical regional scale of future precipitation patterns, wind fields, etc., climate dynamics is characterised here purely as changes in global mean temperature T(t), where t is the time variable.

We also make the (plausible) assumption that the "climate cost function" S depends solely on the global mean temperature T and its temporal derivative

$\dot{T} = \frac{d}{dt} T(t)$, i.e. that

$$S = S(T, \dot{T}).$$

This reflects the idea that the speed of a given climate change is a major determinant of the adaptation costs.

T and $\dot{T}$ span the so-called phase space of climate dynamics. The set of all climate developments T(t) that conform to the range of acceptance $\mathcal{A}$ fills a sub-area $\mathfrak{D}$ of the phase space; this domain $\mathfrak{D}$ must be determined in the next step.

The following definitions are made in order to simplify the task:

Time t = 0 corresponds to the year 1995. New variables are introduced according to

$$X = T - 0.5\,(T_{max} + T_{min}) = T - 13.25 \quad ,$$
$$Y = \dot{T} = \dot{X} \quad .$$

It follows from this that:

$$X_{max} = T_{max} - 13.25 = 3.35 \quad ,$$
$$X_{min} = T_{min} - 13.25 = -3.35 \quad ,$$
$$X_0 = T_0 - 13.25 = 2.05 \quad .$$

The unit for Y was chosen as °C per decade. The current value Y_0 lies between 0.05 and 0.10; for definiteness, a „best-guess value“ of 0.07 is picked. The present state of climate dynamics is thus represented by the point $P_0 = (X_0, Y_0) = (2.05, 0.07)$ in the X-Y plane.

Due to the transformation of variables carried out above, we must consider S (X, Y) rather than S (T, $\dot{T}$) in the following analysis. For $Y \geq 0$, the cost function is chosen as follows:

$$S(X,Y) = \begin{cases} S_{max}\left(\dfrac{Y}{Y_{max}}\right)^2 (X - X_{min}) & , \quad X_{min} \leq X \leq X_{min} + 1 \\ S_{max}\left(\dfrac{Y}{Y_{max}}\right)^2 & , \quad X_{min} + 1 \leq X \leq X_{max} - 1 \\ S_{max}\left(\dfrac{Y}{Y_{max}}\right)^2 (X_{max} - X)^{-1} & , \quad X_{max} - 1 \leq X \leq X_{max} \end{cases}$$

and

S (X, Y) = ∞, if X is outside the range $[X_{min}, X_{max}]$.

Interpretation of the ansatz for the cost function

Within the permissible temperature interval $[X_{min}, X_{max}]$, S is supposed to reflect only the costs of adaptation to climate change. These costs are most likely to depend non-linearly on the speed of change Y; the simplest assumption is quadratic growth.

In the centre of the temperature window, i.e. in the range $[X_{min}+1, X_{max}-1]$, the adaptability for a given value of Y should show little or no variation. The situation changes, however, as we approach the boundaries of the window: a temperature increase would probably be more and more difficult to adapt to as the right-hand ("hot") boundary is approached, but progressively easier as the left-hand ("cold") boundary is approached. To simplify the model, these relationships are expressed by multiplication factors that are directly or inversely proportional to the distance from the temperature threshold values. The damage to the human organism caused by rising body temperature would be described in a similar way for states of undercooling or high fever.

If these simplest possible yet non-trivial assumptions are applied, the shape of S (X, Y) is fully determined but for a "calibration constant" Y_{max}. The latter is obtained as follows:

- Most integrated assessments of the annual and global direct costs of CO_2 doubling by the end of the next century are of the order of 1-2% of GGP (see, for example, [8] and references therein). This rise in CO_2 over such a period corresponds in the climate models employed to a mean temperature increase of somewhat less than 0.2 °C per decade.
- The annual costs incurred through general environmental degradation in Germany is considered by experts to be 2-3% of GNP.
- Estimations to date of the resultant costs of climate change do not take systematic account of either extreme events (droughts, floods, tropical storms, fluctuations in ocean currents, etc.) or possible synergies between the various trends of Global Change (e.g. interaction between anthropogenic greenhouse effect and soil degradation).

If all these factors are included in the analysis, then a figure of

$$Y_{max} = 0.2$$

is not over-pessimistic: inside the permissible temperature window, a temperature gradient of 0.2 °C per decade might well cause adaptation costs of up to 5% of GGP annually.

Since adaptation to global cooling should lead to problems similar in severity to adaptation to global warming in a first approximation, S(X, Y) can be extended to the range $Y < 0$ using the symmetry requirement

$$S(X, -Y) = S(-X, Y) \quad .$$

We are therefore looking for the domain $\mathfrak{D}$ in the X-Y space of climate dynamics that does not lead to any departure from the range of acceptance $\mathcal{A}$

in the T-S stress zone. $\mathfrak{D}$ is referred to as the admissible "climate window". On the basis of the assumptions being made, the boundary

$$Y = \Gamma(X)$$

of $\mathfrak{D}$ results directly from the equation

$$S(X, \Gamma(X)) = S_{max} \quad .$$

For the foreseeable future of the climate, the first quadrant (X, Y ≥ 0) of the climate phase space is of particular importance. In that area,

$$\Gamma(X) \quad = \begin{cases} Y_{max} & , \quad 0 \leq X \leq X_{max} - 1 \\ Y_{max}(X_{max} - X)^{0,5}, & \quad X_{max} - 1 \leq X \leq X_{max}. \end{cases}$$

The admissible domain for climate dynamics is depicted by the shaded area in Fig. A2.

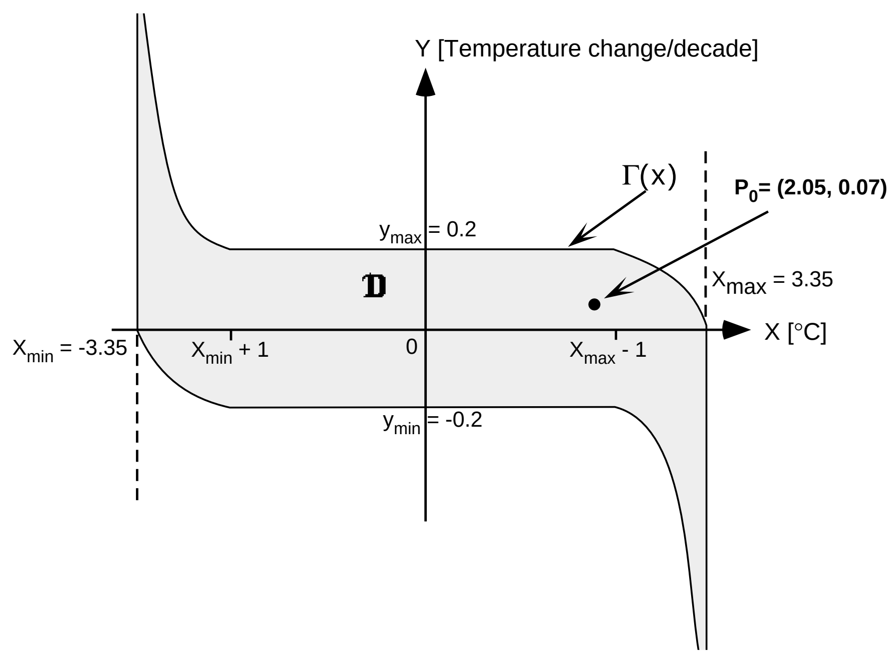

Fig. A2: Tolerable climate domain $\mathfrak{D}$. P_0 is the present climate status

It is emphasised here that various assumptions about the climate damage function S(X, Y) are mere *educated guesses*. This is particularly the case with the quantitative relation between Y_{max} und S_{max}. The definition of the tolerable climate domain $\mathfrak{D}$ still makes sense, however, even when macro-economic factors are left out of the reckoning. The demarcation of the acceptable temperature range $[X_{min}, X_{max}]$ reflects to a certain extent long-term preservation objectives, while the limitation of Y relates to medium-term preservation aspects: Ecosystems would probably have major difficulties adapting to temperature gradients of more than 0.1 °C per decade [9]. If the elasticity of natural systems in the centre of the window is taken to be double the value normally assumed, and if the special conditions near the temperature boundaries are taken into consideration, then one directly obtains the tolerable climate domain $\mathfrak{D}$. This domain would certainly be narrowed by including the economic impacts of climate change, which means that defining $\mathfrak{D}$ in the manner above is more likely to produce an *underestimation* of the risks to humanity and nature than vice versa.

A1.3. Admissible increases in CO_2 concentration and corresponding global emission profiles

With the help of a simplified coupled climate-carbon cycle model devised by the Max Planck Institute for Meterorology in Hamburg [10], the tolerable climate development domain $\mathfrak{D}$ can be “reverse-translated” to obtain the set of the admissible global emission profiles E(t). The dynamics of the total atmosphere-ocean-biosphere system and the radiative forcing on climate by CO_2 is taken account of by parameterisations. The increased concentration of CO_2 over the period under investigation is calculated by considering the atmospheric lifetime of the gas and the proportion of emissions that are not directly absorbed by the oceans and other ecosystems.

The emission profiles which come into question are not wholly arbitrary functions, however. It would make sense to apply the following boundary conditions, for example:

$$E(0) = E_0 \quad ,$$

$$\dot{E}(0) = E_1 \quad ,$$

$$\dot{E}(\hat{t}) = 0 \text{ and } E(t) = E(\hat{t}) = \text{const. für } t > \hat{t}\ .$$

Here E_0 equals the current annual amount of CO_2 emissions, while E_1 is the mean increase in emissions over the last few years and $\hat{t}$ is the planning horizon (e.g. 300 years) for the final stabilisation or cessation of emissions. The boundary conditions could be defined differently, in principle; it is found, however, that these conditions do not have a major influence on the key results.

Let $\mathfrak{E}$ be the set of all emission profiles E(t) that are compatible with $\mathfrak{D}$ (and hence with $\mathcal{A}$) and which also fulfil the specific boundary conditions imposed. This set is obviously high-dimensional and cannot therefore be presented in the form of a simple graph.

Before carrying out a full analysis of $\mathfrak{E}$ later, one should attach greater priority in the meantime to fundamental issues that have direct relevance for environmental policymaking. Of special interest in this context, for example, is the marginal emission profile $E_*(t)$ that realises the maximum admissible amount of global CO_2 emissions within a given (or indeed any) planning horizon.

E_* can be selected from the total set $\mathfrak{E}$ with the help of optimisation procedures. Optimal solutions to such a problem frequently display relatively bizarre forms, however, and do not usually match the available options for external control. Precisely in the case of global emission profiles, one must make the realistic assumption that successful reduction agreements will be based on elementary principles such as continuity and security of planning. In a complementary study one should therefore discuss in detail restrictions of $\mathfrak{E}$ which reflect the technical and socioeconomic boundary conditions for the regulation of emissions.

In any case, however, E_* defines an upper limit for the total sum of CO_2 emissions.

One can also calculate the benefit that a policy of rapid emission reductions would produce compared to a more reticent approach. To do this, one may consider the set of emission profiles $\bar{E}(t)$ with Business as Usual or horizontal initial segments, for example. With reference to the remaining segment of the function, one then searches for the optimum admissible profile, i.e. the curve $\bar{E}_*(t)$ that enables the maximum amount of CO_2 emissions within the restricted set of profiles. Comparing the different solutions enables conclusions to be drawn about the positive impacts of environmental policies geared to prevention rather than cure.

A1.4. National reduction commitments

Let us assume an optimal global emission profile $\tilde{E}(t)$, i.e. the curve representing the first choice within the climatic and other boundary conditions. $\tilde{E}$ can but does not need be equal to E_*. $\tilde{E}(t)$ has to be fractionated into dynamic national "pollution rights", $\in(L;\, t)$, according to politically defined allocation formulae. Here the index L numbers the various countries in the world, hence

$$\sum_L \in(L;\; t) = \tilde{E}(t) \ .$$

The dynamically adjusted national reduction commitments r (L; t) are then derived from the national pollution rights according to the formula

$$r\,(L;\, t) = 100\ [1 - \frac{\in(L;\; t)}{\in_0(L)}] \quad ,$$

where $\in_0(L) = \in(L;\, 0)$ represents the current annual CO_2 emissions of country L, and the respective reduction commitment is expressed as a percentage of $\in_0(L)$. Note that $r(L;\, 0) = 0$ for all L, i.e. that national reduction commitments start to grow from zero.

What allocation principle should be used to determine the emission quotas $\in(L;t)$ of the individual states? Let P(t), B(t) be the global population and GGP expressed as a function of time, and p(L; t), b(L; t) the respective national values. The following factors in particular would play a role in determining the quotas of the individual states:

$$f(L) \quad = \quad \frac{\in_0(L)}{E_0} \quad \text{: current share of global emissions}$$

$$g(L;\, t) = \quad \frac{p(L;\; t)}{P(t)} \quad \text{: dynamic proportion of the world's population}$$

$$h(L;t) \ = \quad \frac{b(L;\; t)}{B(t)} \quad \text{: dynamic share in GGP.}$$

This means that

$$\in(L;\, t) =$$

$$= F\,(f(L_1), f(L_2)\ ...;\ g\,(L_1;\, t), g\,(L_2;\, t)\ ...;\ h\,(L_1;\, t), h\,(L_2;\, t)\ ...),$$

where the allocation function F is the result of international negotiations.

The mere projection to the future of the relative levels of pollution "owned" by the Parties would mean allocation according to the following formulae:

$$\in (L; t) = f(L)\tilde{E}(t)$$

and

$$r(L; t) = 100 \, [1 - \frac{\tilde{E}(t)}{E_0}] \quad .$$

In this case, therefore, all states in the world would always have to reduce their CO_2 emissions simultaneously.

Any form of allocation that releases the developing countries from any reduction commitment would necessitate greater cuts on the part of the industrialised countries.

Let

$$S = \sum_{\text{Non-Annex-I States}} \in_0 (L)$$

be the current annual total emissions of the non-industrialised states. If this quota remains unaltered, then the Annex-I countries would have total emission rights amounting to

$$\tilde{E}(t) - S \quad .$$

If equal obligations are imposed on all these states, their dynamically adjusted reduction obligation $R_a(t)$ would be:

$$R_a(t) = 100 \, [1 - \left(\frac{\tilde{E}(t) - S}{E_0 - S}\right)] \quad .$$

Given the political preconditions discussed above, this reduction profile would also apply to Germany.

The industrialised countries would face a much greater challenge if the allocation formula were determined by the elementary humanitarian principle of “equal emission rights for all”. In such a case,

$$\in (L;t) = g(L;t) \, \tilde{E}(t)$$

and

$$r(L;t) = 100 \, [1 - g(L;t) \, \frac{\tilde{E}(t)}{\in_0 (L)}] \quad .$$

However, one must note in this calculation that factors g(L; t) are not yet known precisely and can only be estimated at best with the help of demographic projections. Inserting the current figures, however, gives an idea of how allocation by share of population leads to a shift in weightings.

If $g_o(D) = g(D; 0)$ is the current share of the world's population in Germany, the reduction commitment $R_b(t)$ for Germany under the static and egalitarian scenario would be as follows:

$$R_b(t) = 100 \left[1 - g_o(D) \frac{\tilde{E}(t)}{\in_0 (D)}\right] .$$

The "worst case" for the OECD countries would be an allocation of emission rights that goes beyond demographic weighting and which also takes account of the need for sustainable development in Third World countries. In this case, the formula would have to be

$$\in (L; t) \sim g(L; t)/h(L; t)$$

$$= \left[\frac{p(L;\ t)}{b(L;\ t)}\right] / \left[\frac{P(t)}{B(t)}\right]$$

and the scope for emissions on the part of the industrialised nations would tend towards zero! Since the chance of implementing such an allocation formula is similarly close to zero, this scenario is not given any further consideration here.

Annex II: The Advisory Council — members and tasks

Members of the German Advisory Council on Global Change as of February 1995:

Prof. Dr. Friedrich O. Beese

Agronomist: Director of the Institute for Soil Science and Forest Nutrition at the University of Göttingen

Prof. Dr. Gotthilf Hempel

Fisheries biologist: Director of the Centre for Tropical Marine Ecology at the University of Bremen

Prof. Dr. Paul Klemmer

Economist: President of the Rhenish-Westphalian Institute for Economic Research in Essen

Prof. Dr. Lenelis Kruse-Graumann

Psychologist: “Environmental Psychology” Department at the Open University of Hagen

Prof. Dr. Karin Labitzke

Meteorologist: Institute for Meteorology at the Free University of Berlin

Prof. Dr. Heidrun Mühle

Agronomist: Head of the Department “Rural Landscapes” at the Environmental Research Centre Leipzig-Halle

Prof. Dr. Hans-Joachim Schellnhuber (Deputy Chairman)

Physicist: Director of the Potsdam Institute for Climate Impact Research

Prof. Dr. Udo Ernst Simonis

Economist: Technology - Work - Environment Research Unit at the Science Centre Berlin

Prof. Dr. Hans-Willi Thoenes

Technologist: Rhenish-Westphalian Technical Control Board in Essen

Prof. Dr. Paul Velsinger

Economist: Head of the Department of Regional Economics at the University of Dortmund

Prof. Dr. Horst Zimmermann (Chairman)

Economist: Department of Public Finance at the University of Marburg

The German Advisory Council on Global Change (Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen, WBGU) was established by the German Government on April 8, 1992 in the run-up to the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro.

The Advisory Council is responsible for preparing an Annual Report to the Federal Government on the current status of global environmental change and its impacts, containing recommendations for further research and for the implementation of research results in the field of environmental policy-making.

The following tasks ensue from these terms of reference:

1. Summarising and continuous reporting on current and acute problems in the field of global environmental change and its consequences, e.g. with regard to climate change, ozone depletion, tropical rainforests and fragile terrestrial ecosystems, aquatic ecosystems and the cryosphere, biological diversity and the socioeconomic impacts of global environmental change;

   Natural and anthropogenic causes (industrialisation, agriculture, overpopulation, urbanisation, etc.) should be considered, and special attention should be given to possible feedback effects (in order to avoid undesired reactions to measures taken).

2. Observation and evaluation of national and international research activities in the field of global environmental change (with special reference to monitoring programmes, the use and management of data, etc.).

3. Identification of deficiencies in research and areas where greater coordination is required.

4. Suggestions on how to avoid and correct maldevelopments.

The administration of the Advisory Council is shared alternately by the Federal Ministry for Education, Science, Research and Technology and the Federal Ministry for Environment, Nature Conservation and Nuclear Safety. The Federal Government also forms an Inter-ministry Working Group (IMA) in which 10 ministries are kept informed about the work of the Council.

A secretariat was established at the Alfred Wegener Institute for Polar and Marine Research in Bremerhaven.

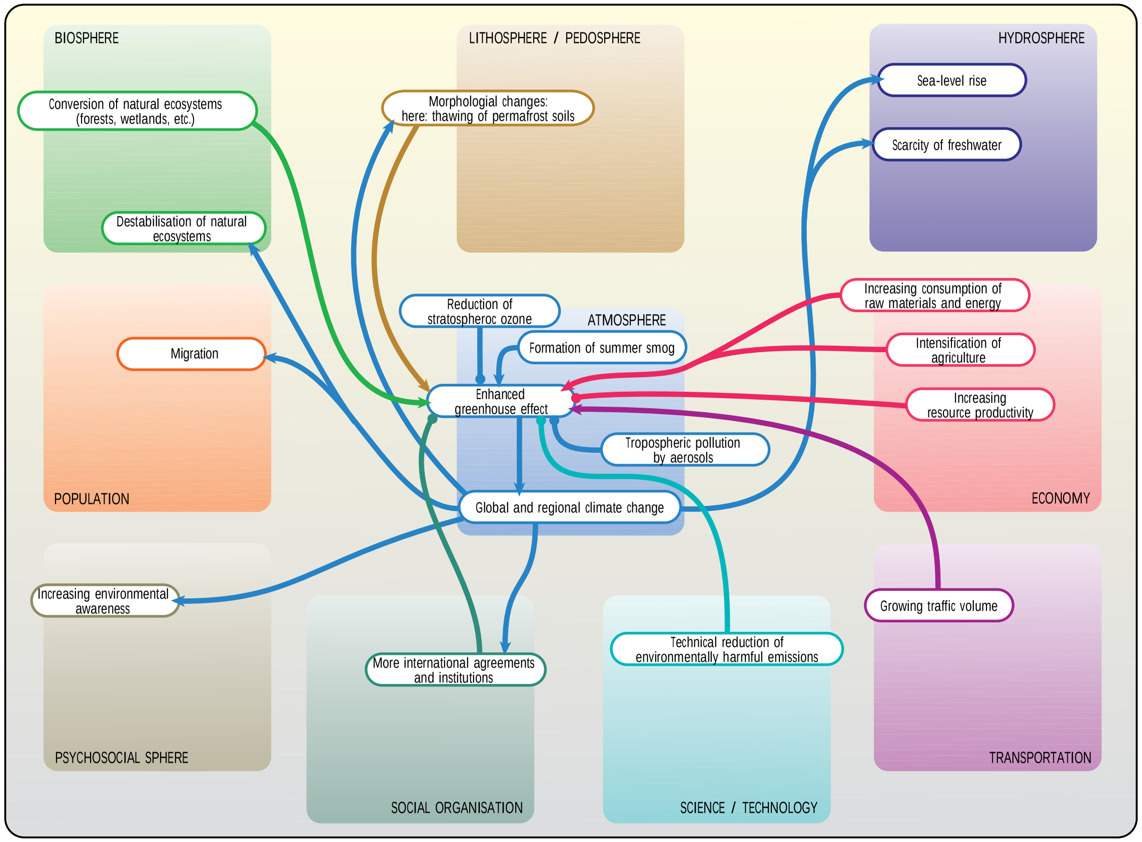

Figure 5: The enhanced greenhouse effect in the Global Network of Interrelations. Enhancing trend: ⟶ *; abating trend:* —● *.*