FORSCHUNGSZENTRUM JÜLICH GmbH

Monographien

Agreements on Climate Protection – The Verification Problem

by

W. Fischer, H.-J. Hoffmann, W. Katscher, U. Kotte, W.-D. Lauppe, G. Stein

IKARUS

Instrumente für Klimagas-Reduktionsstrategien

Monographien des Forschungszentrums Jülich Band 25

Forschungszentrum Jülich GmbH
Programmgruppe Technologiefolgenforschung

Agreements on Climate Protection – The Verification Problem

by
Wolfgang Fischer, Hans-Jürgen Hoffmann, Werner Katscher,
Ulrich Kotte, Wolf-Dieter Lauppe, Gotthard Stein

Programmgruppe Technologiefolgenforschung
Forschungszentrum Jülich

Monographien des Forschungszentrums Jülich Band 25/1995

ISSN 0938-6505 ISBN 3-89336-175-8

Herausgeber: Forschungszentrum Jülich GmbH
Programmgruppe Technologiefolgenforschung (TFF)
Vertrieb: Forschungszentrum Jülich GmbH
ZENTRALBIBLIOTHEK
D-52425 Jülich
Telefon (02461) 61-5368 · Telefax (02461) 61-6103

Druck: Graphische Kunstanstalt Dieter Gehler, Düren-Birkesdorf

Monographien des Forschungszentrums Jülich, Band 25

ISSN 0938-6505

ISBN 3-89336-175-8

IKARUS Instrumente für Klimagas-Reduktionsstrategien

Final Report Subproject 9
"International Greenhouse Gas Verification"

Agreements on Climatic Protection – The Verification Problem

Wolfgang Fischer, Hans-Jürgen Hoffmann, Werner Katscher, Ulrich Kotte, Wolf-Dieter Lauppe, Gotthard Stein

Programmgruppe Technologiefolgenforschung
Forschungszentrum Jülich

IKARUS – A development project of the Research Centre Jülich on behalf of the Federal Ministry for Education, Science, Research and Technology (previously BMFT), Bonn

---

Management:
Program Group Technology Assessment of the Research Centre Jülich

The research activities were carried out under the number ET9188A on behalf of the BMBF (former BMFT).
The publication has the approval of the clients.
The autors take the responsibility for the content.

The study was finished in February 1995

Co-ordinator subproject 9 "International Greenhouse Gas Verification":
Dr. G. Stein

Programmgruppe Technologiefolgenforschung
Forschungszentrum Jülich

Preface by the Project Management

The sustained reduction of climate gas emissions associated with the generation, conversion and utilization of energy is clearly becoming an ever more important task in energy and environmental policy. Different strategies are conceivable in order to fulfil this mission. The aim of the IKARUS Project (Instrumente für Klimagas-Reduktionsstrategien - Instruments for Greenhouse Gas Reduction Strategies) was to provide a set of tools with which strategies can be developed and reconstructed (making conceptual use of the various technologies) and also tested with respect to their internal consistency and examined with regard to their economic impacts.

Corresponding to the great complexity of the task in hand and the technological range of energy applications, the set of instruments is very extensive. It consists of two parts: a data base with a comprehensive data collection and several computer models of various types.

The relational **data base** in ORACLE with a graphics interface has a twofold function as a supplier to the model and as an independently usable information system. It is subdivided into a technology data base, model data base and general data base. The data were collected in six data subprojects for the reference year of 1989 and estimated for the years 2005 and 2020. The **technology data base** contains technological, economic and ecological data on representative technologies ranging from primary energy extraction up to final energy use, supplemented by commentaries, graphics, structural diagrams and characteristic curve fields. The reliability of the data is represented and annotated by an assessment diagram so that a reconstructible, comprehensive basis for strategy discussions capable of finding consensus can be provided in accordance with the objective. In addition to the individual technologies, aggregated "mixed technology" data were generated as input data for the optimization model mentioned below and stored in the **model data base**. In order to keep this aggregation sufficiently flexible with respect to optimizing the energy supply and utilization system the user is provided with some aggregation tools, developed in the data subprojects, upstream of the optimization model in the interface of the data base. Finally, the **general data base** contains exogenous quantities from the models such as inquiries about energy services, application limits and inventory data for technologies, as well as background information for designing user inputs and interpreting model results.

The central feature of the developed models is a technology oriented, linear **optimization model**, which simulates the energy flow in the Federal Republic of Germany by means of about 2000 (aggregated) technologies. The "placeholder concept" of the model permits these technologies to be exchanged. The model determines optimum-cost energy technology structures for the sample years of 2005 and 2020 under predefined boundary conditions, e.g. upper and lower application limits for technologies and, above all, upper limits for emissions. The **macroeconomic information system, MIS**, serves to verify the economic compatibility of the model results and also provides general data on economic development. A simulation model permits a comparison of **energy technology chains** providing a certain predefined energy service. Sector-specific **simulation models for "space heat", "electricity and district heat", "transport"** and **"industry and small consumers"** are applied both for detailed studies in the respective sector as well as (in addition to the tools mentioned) for the production of aggregated technologies in the optimization and chain model.

The **"Verification"** project was integrated into IKARUS as a link between the national project and the international environment, enabling the examination of technologies and methods for verifying the compliance of states party to the Framework Convention on Climate Change.

The BMBF´s (Federal Ministry of Education and Research) contractor was the Research Centre Jülich (KFA), which performed two of the subprojects and undertook the project management. Subcontracts were placed for the remaining work. Nine equal partners contributed to the development of IKARUS in "subprojects" with more than 50 subcontractors. The nine subprojects, the institutions responsible and sectors of work are as follows:

Subproject 1:
Research Centre Jülich (KFA), Programme Group Systems Analysis and Technology Evaluation (STE): model development - optimization model with macroeconomic embedding, chain model, submodels for space heat, electricity and district heat, transport.

Subproject 2:
Special Information Centre (FIZ), Karlsruhe: data base - conception and programming.

Subproject 3:
German Institute for Economic Research (DIW), Berlin: primary energy - extraction of domestic fossil energy carriers, foreign trade with energy carriers, renewable energy sources.

Subproject 4:
Institute for the Energy Economy and Efficient Energy Use (IER), University of Stuttgart: energy conversion, storage, transport and distribution.

Subproject 5:
Chair of Energy Economy and Power Plant Engineering, Technical University of Munich: households and small consumers - space heat, domestic appliances, process heat.

Subproject 6:
Fraunhofer Institute for Systems Engineering and Innovation Research (ISI), Karlsruhe: industry - energy-intensive single industries, branches of industry, lines of business. Submodel industry and small consumers.

Subproject 7:
Technical Control Board (TÜV) Rhineland Safety and Environmental Protection, Cologne: passenger and goods transport by road, rail, water and air.

Subproject 8:
Research Establishment for the Energy Economy (FfE), Munich: cross-sectional technologies - intersectoral and interindustrial technologies for energy conversion.

Subproject 9:
Research Centre Jülich (KFA), Programme Group Technology Assessment (TFF): verification measures within the Framework Convention on Climate Change.

The reports drawn up as part of the project have been available from the Central Library of the Research Centre Jülich (KFA) since 1994. These reports are intended, on the one hand, to ensure the general availability of reliable data and, on the other hand, provide access to the results of the project to those who are only interested in closely defined subsectors.

After its completion, the set of instruments will be distributed on CD-ROM by the Research Centre Jülich (KFA) and the Specialist Information Centre Karlsruhe (FIZ) (data base only). Updated versions are planned, in the first instance, for 1997 and 1999. Information, training and in-depth discussion meetings on selected subjects are on offer to users of the instruments and all other interested parties.

G. Stein, IKARUS Project Management

Table of Contents

Page

1. International Verification of Agreements on Climate Protection

Two results were particularly obvious at the International Rio Conference (United Nations Conference on Environment and Development, UNCED) in 1992. On the one hand, it became apparent that the environmental aspect had quite generally become one of the major topics of national and international policy. The introduction of new national laws and international treaties reflects to an increasing extent this growing environmental awareness. On the other hand, it can be seen from the protracted negotiations on bringing the Framework Convention on Climate Change (FCCC) into being how complex this issue area is and how controversial the topics are. This complexity and controversy is also reflected in discussions on verification aspects of the International Greenhouse Gas Convention.

The subject of this study can be summarized in the question of how the states' commitments laid down in an agreement on climate protection can be verified. This may involve the Framework Convention on Climate Change in its present or an amended form, or special protocols on climate protection, e.g. for individual sectors. To put it negatively, the question is what are the states' commitments worth if they are not verified.

Why has this issue been included in the IKARUS Project as a separate subproject?

Although IKARUS is a set of instruments for analysing national (German) reduction strategies, nevertheless this mission cannot be tackled without taking the international situation into consideration. Subproject 9 thus represents the link between international developments and the national IKARUS Project leading to the following interactions:

- IKARUS permits an improved understanding of the complexity of the energy system, the major source of greenhouse gases, as well as of the feasibility of reduction strategies.

- The development of the data base for IKARUS comprises a fine structure and a resolution of the energy system which is also of interest for verification.

- On the other hand, insights applicable to the IKARUS Project arise from international discussions on the standardization of greenhouse gas inventories.

- The modelling and simulation of energy aspects, particularly on the submodel level, may make a contribution towards verification.

It should be noted that over and above the energy sector, Subproject 9 also considers the sectors of forest, land use and agriculture, which are important for greenhouse gas emissions, so that approaches for the verification of (future) agreements can also be identified here.

What is verification, how does it differ from monitoring?

There are many definitions of verification [cf. Efinger 1990, p. 50ff], but they all have a common core. Verification is a political process of "confirmation" by means of which the states' party to the treaty wish to make "certain" that the contractually agreed standards, rules and goals are complied with or achieved by all the states involved. To this end, they make use of technical and other instruments, processes and methods, which - ideally - should either be applied reciprocally by the states themselves or by an international panel (an organization) appointed for this purpose.

International greenhouse gas verification can in general be assigned to the category of verification of environmental agreements. Whereas verification is a well-worn topic in international arms control and disarmament policy, it represents a relatively new issue with respect to international environmental agreements since their approaches are subjected to stronger dynamics. This can also be observed for the process of the framework convention. The 1992 Rio Conference and its results represent a first culmination in this development, initially establishing a discussion stage. However, in the discussions of the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change (INC-FCC) this topic was further developed and refined in the two subsequent years as well as in the preparations for the first Conference of the Parties in 1995. The same is true of the technical and organizational aspects of greenhouse gas verification. Nevertheless, the Rio results must continue to be regarded as an initial orientation line.

In the present study, a graduated concept is established for the verification of climate agreements, in the course of which it is assumed that in creating a climate protection regime, the FCCC provisions will be tightened up and more countries will take on reduction commitments. This may be implemented by amending the FCCC itself or - more probably - by means of protocols.

The verification of environmental conventions in general and climate agreements in particular displays differences especially in comparison to arms control and disarmament verification. An evident difference can be immediately read off from **Table 1**. This table makes it clear that in contrast to the international verification of other fields, such as the peaceful uses of nuclear energy or the prohibition of the possession and manufacture of chemical weapons, in the case of greenhouse gas verification it is not possible to establish a general quantitative record and thus, for example, a comprehensive measuring technique for verifying the greenhouse gases (GHG) released by the states. In contrast, for instance, to international fissile material safeguards, verifications of plausibility or consistency play the central role in greenhouse gas verification. However, the findings presented here also indicate that measuring techniques for recording individual elements of the data base or satellite-assisted information gathering can make a positive contribution towards implementing verification under certain restricted conditions.

The following basic issues which need to be addressed were identified for the study. They comprise questions

- of the necessity for and density of greenhouse gas verification;
- of an appropriate national declaration;
- of the feasibility and applicability of verification concepts, methods and techniques;
- of the organization required to implement these verification measures.

Sector	International treaty	Verification objects and relevant quantities	Essential verification measures
nuclear	Non-Proliferation Treaty	nuclear material $\approx 10^3$ tonnes	nuclear material balancing
chemistry	Chemical Weapons Convention	toxic and other substances $\approx 10^6$ tonnes	ad-hoc inspections
climate	Framework Convention on Climate Change	greenhouse gases $\approx 10^9$ tonnes	plausibility and consistency checks

Table 1: Essential verification measures in various treaty systems

The study is structured by these issues. In a summarizing final chapter, a graduated verification system will be outlined which can be adapted to the tightening up of climate agreements demanded by some states and many scientists.

2 The Verification Problem within the Framework of the Climate Convention and its Future Development

The development of a verification concept must be preceded by a clarification of important terms and the analysis of the general verification problem and its causes. In contrast to *monitoring*, which represents a scientific analysis of the condition and development of a problem area (identified by a treaty), *verification* aims at examining compliance on the part of states in specific issue areas regulated by treaty [Lang 1994]. In the issue area of climate protection, monitoring is, for example, concerned with measuring the global atmospheric concentration development of the GHGs. The Mauna-Loa curve of the atmospheric CO_2 concentration is an example of such monitoring, which is intended to provide information enabling a problem to be better understood (scientifically). Verification deals with the question of whether the release of GHGs declared by states (pursuant to a treaty) or the asserted implementation of climate protection measures actually conforms to reality, i.e. whether emissions have been reduced and measures implemented. In this connection, information obtained for the purposes of monitoring may be of signficance. However, as a rule this data does not fulfil the demands of verification, i.e. of providing information about the national origin over time. Compliance must also be distinguished from the *effectiveness* of an agreement. Thus, for example, a treaty strictly adhered to by all participants may not solve a problem if the provisions are not sufficiently stringent. In contrast, more stringent provisions which may not be fully complied with may be less efficient with respect to the protective goal.

Verification is influenced by the specific political and technical boundary conditions in the respective issue area. However, it is also, and quite fundamentally, an expression of a basic challenge of organizing and maintaining cooperation between states in an international system which does not recognize any central governmental authority ("governance without government" [Young 1992, p. 253]). This need for cooperation is above all the outcome of international interdependences and of increasing pressure with at the same time a reduced ability to cope unilaterally with this challenge on the part of those actors who continue to play a central role in the international system, namely the states. There are, moreover, growing capacities for action in order to deal with these problems. It is apparent that particularly in the issue area of climate protection international cooperation is necessary, at least between the 20 largest emitters responsible for more than 80 % of emissions. The task of verification is to determine whether and how reliably states are engaged in these contractually regulated cooperative efforts and with what results.

2.1 Factors determining verification

Verification problems are not new and occur in international politics on numerous occasions and in many issue areas [Lang 1994], frequently under other guises. This is true, for example, of economic agreements in which compliance with customs regulations or subsidy practice is verified, of human rights conventions, where verification is analysed by state agencies in the form of international fact-finding commissions, occasionally also of environmental treaties if national reports on contractual implementation are discussed at international conferences, and above all of arms control and disarmament treaties which, from the historical point of view, represent the starting point and, relative to the frequency and intensity of verification, are still at the heart of all international verification efforts. Verification problems are encountered wherever the state actors are not prepared to rely on mutual assurances of compliance (mainly contractual) with agreed standards, rules and targets [Efinger 1990]. This verification need is expressed in a desire for information in order to measure the actual behaviour of a state against its commitments. Verification is therefore intended to provide certainty about whether and to what extent agreements are complied with by all participating states, or whether they are being violated. Certainty is achieved when the need for verification and verification capability can be harmonized, i.e. when states actually receive the information which they would like in order to satisfy their thirst for knowledge (cf. **Fig. 1**).

This need for knowledge may have different levels, i.e. states may demand more or less information and require more or less verification. This verification demand is a function of three factors:

(I) The political relevance of a problem, i.e. the significance of an issue area for the "national interest" from the perspective of the decisive actors. The same hierarchy can be observed in all political systems: The issue area of security (disarmament, arms control) has a high rank and the need for verification is very high as a rule since the actors perceive that a great deal is at stake. The need for verification is considerably lower in the issue area of the environment since environmental problems do not (perhaps as yet) occupy the same level as security problems [Ausubel/Victor 1992].

(II) The standards on which verification is based, i.e. the politically defined demands made by decision makers on the intensity of verification. They express the degree of mistrust in the "opposing" parties and their interests, and define, implicitly or explicitly, the reasons why a state violates agreements - i.e. whether the violations are intentional and specific or the consequence of a lack of ability to comply with the treaty.

(III) The degree of openness of the political system and the autonomy of society is concomitant with different information requirements; open societies generally demand more information and verification than closed societies.

In order to satisfy the need for verification, i.e. to achieve "certainty", a corresponding verification capability is necessary arising from the following factors:

(I) The verification suitability of the "objects" to be verified, which are more or less suitable for registration and verification. Thus as a rule, large immobile objects which only exercise one function can be more easily verified than small mobile objects with intermittent multifunctions. Processes are also more difficult to verify than objects, which only need to be discriminated and are often only "counted".

CERTAINTY	
Verification capability	Verification demand
Verification suitability of the "objects"	Relevance of the issue area
Verification instruments and methods	Verification standards
Political and social willingness to accept these instruments and methods	Political system and society

Fig. 1: Factors determining verification
After: [Efinger 1990, p. 82]

(II) The availability of appropriate instruments and methods for verifying compliancy. Two aspects must be considered, firstly, whether the necessary instruments and methods are technically or systematically available and not prohibitively expensive. Secondly, which of them are suitable for what tasks, in which connection the required verification density and the features of the verification "objects" are also of significance making them more or less suitable for the application of certain verification techniques and methods. Verification suitability cannot therefore be determined completely independently of the verification instruments and methods.

(III) Finally, the willingness of the state and society to grant other countries or international organizations insights into their actions also influences the prospects of success for verification. It can generally be said that the opportunities for information gathering and verification increase with the degree of openness.

If there is a great demand for verification and if this meets with a corresponding verification capability and if the agreement between contractual commitment and action (compliance) is verified meticulously then this is defined as high verification density. Low density characterizes a verification system that only permits superficial insights into the states' behaviour. Density cannot only be judged by the number and type of instruments etc. used for verification. A quite central aspect of density is the intervention in the sovereignty of a country associated with the application of such instruments. This is termed intrusiveness.

However, the need for verification and verification capability are not constants but rather the results of their constitutive factors. These latter can once again be influenced to a varying extent. Although the verification suitability of an object is also influenced by the availability and selection of verification techniques and methods, nevertheless there are "inherently" more or less suitable objects, whose features are often predefined and which can only be altered to a limited extent or not all. In contrast, there is scope for action with respect to the need for verification and the development of those verification instruments and methods which are dependent politico-technical variables. The verification need is quite essentially dependent on the degree of international mistrust and the political relevance of the contractually regulated issue area. It is possible to "learn" through cooperation and confidence building.

Certainty is not an absolute but rather a relative concept. The relation between the demand for verification and verification capability determines the extent of certainty that countries may achieve about the behaviour of others. If the verification demand is high and the capability low there is a lack of certainty; if the demand is low but the capability high then absolute certainty is obtained. There are different degrees of certainty between these two extremes [Efinger 1990]. A low-density verification system can therefore also create "certainty". The degree of certainty which appears adequate is associated with basic assumptions about the latent (non)compliance of states as well as the reasons for this, and is influenced by a political perception process in which the risks must be weighed up. On the one hand, there is the possibility that states may violate the treaty provisions without being detected and thus obtain advantages. If states regard the advantages associated with an undetected violation as the greatest danger to their interests, then it may be assumed that they would not wish to conclude a treaty. On the other hand, states must consider and weigh up for themselves the negative consequences of a lack of contractual regulation for the problem in question.

Verification thus has the task of creating "certainty" that the participating states fulfil their commitments or of ensuring that treaty violations are detected (*detection function*).

What is meant by "certainty" is a socio-political arrangement, a perception which is determined in concrete terms by the actors in the issue area. However, verification also has further functions. Successful cooperation in verification can contribute to *confidence building*, the realization that knowledge about the functioning of the system is also in one´s own interest since weak points in one´s own system of information gathering and evaluation may be detected (*knowledge, information and learning function*). Furthermore, it can also contribute towards creating and extending the participating actors´ capacities to control processes (*capacity formation*) [cf. Victor 1994]. Although verification usually focuses on the detection function, nevertheless the sequence and significance of the above-mentioned functions is not the same in all issue areas nor is it predefined in the historical course of creating a verification system. "Evolutionary" verification systems may by all means be designed in such a manner that the knowledge and information function, as well as capacity formation, is the primary factor and that the detection function only becomes relevant at a later point, possibly together with the tightening up of the material regulations (provisions) of an agreement. This is to be expected with the FCCC, where verification in order to demonstrate compliance will probably only attain prominence with the introduction of joint implementation projects.

2.2 Compliance by states

As the discussion on Fig. 1 showed, the actors´ assessment of general compliance by states has a great influence on the demand for verification. If compliance is regarded as fairly high then there will be less demand for verification (and vice versa). In the following section, the question will therefore be posed of the findings available about compliance by states from the perspective of the two most important schools of thought on international relations, namely neorealism and institutionalism.

Whereas in the issue area of arms control, compliance has been regarded as relevant by politicians right from the beginning and has thus been a topic for the political sciences [Efinger 1990], it has only been systematically analysed in the issue area of environmental protection since the early nineties [Ausubel 1992; Fischer 1991; EPA 1990], without politicians having devoted comparable attention to the subject. The verification of environmental treaties has become relevant for research (and will probably soon receive more interest from politicians) since the number and significance of environmental protection agreements has increased (**Table 2**).

Three reasons are given for this increased attention to verification [Sands 1993, p. 368]: problem pressure, i.e. a growing consumption of resources has resulted in increasing emissions and environmental pollution to which politicians must react; pressure of costs, i.e. environmental protection agreements exert pressure to make high investments so that bypassing the treaties would lead to competitive advantages (at least on occasion and in certain sectors), verification should therefore also contribute towards preventing "eco-dumping"; effectiveness, i.e. the nature and scope of the commitments increasingly influence core areas of economic activity. Politicians, who are gradually becoming aware of these problems, are reluctantly beginning to devote more attention to the verification problem in environmental agreements.

Even if the extent of compliance by states in general and in the environmental sector in particular has only been roughly estimated as yet [Chayes 1993; Ausubel/Victor 1992], nevertheless the results are in agreement with the theory that the majority of states fulfil most of their commitments more or less reliably. Whereas all schools of thought basically agree on this point, attention is (correctly) also drawn to the fact that in central issue areas some serious treaty violations (nonproliferation of nuclear weapons) and generally a lax attitude to commitment can be perceived in the environmental field. Nevertheless, on the average compliance is certainly the rule although the reasons for it are open to dispute. (Neo)realism and institutionalism are opposed to each other in this point and argue about whether compliant behaviour is influenced at all by treaties and the norms etc. laid down in them ("whether treaty-induced compliance ever occurs", [Mitchell 1992, p. 26]). The background to this is a basic lack of agreement between institutionalism and realism concerning the nature and functioning of politico-social systems and the behaviour of actors.

Treaty	1950s	1960s	1970s	1980s	Total
Oceans	4	4	14	8	30
Atmosphere	0	0	1	4	5
Nature conservation*	1	1	3	2	7
Nuclear	0	4	1	2	7
Antarctic	1	0	1	2	4
Others**	0	2	6	2	11
Global, overall	5	9	12	7	33
Regional, overall	1	2	14	14	31
Total	*6*	*11*	*26*	*21*	*64*

Table 2: **Multilateral environmental agreements of the last 40 years**

* incl. agreements on the protection of wild animals;
** waste, space etc. [Brenton 1994, p. 90]

The theory of realism transfers the assumption of economic theories - that all actors are egoistical and wish to maximize their benefits - to the international system: policies and their results, for example treaties, are a reflection of the international distribution of interests and power, which crystallizes in relations between states. Accordingly, states only comply with treaties as long as it is in their interest to do so or a "hegemonic" state forces the other nations to comply. If in reality there is a high level of compliance then according to this school of thought this only shows how accurately the treaties reflect the international constellations of power and interests, or else how successful the "hegemonist" is: treaties are dependent variables, their existence and the norms laid down in them do not influence compliance.

In contrast, institutionalism proceeds from the possibility that actors recognize and pursue the public interest or common good and that this orientation is supported by international provisions and treaties. Treaties do not only reflect power and interests but they also alter the behaviour of states and their relationships, and encourage them to act in accordance with the agreed norms. Accordingly, treaties are independent variables whereas the states' behaviour represents a dependent variable to a certain degree [Mitchell 1992]. Representatives of institutionalism [Chayes 1993] specify further reasons for the states' disposition towards compliance:

- It is efficient to follow agreed norms. Since decisions always consume resources, administrations cannot regularly analyse for all agreements whether a contractual violation would be worthwhile. Organization theory reaches the same result when it emphasizes that bureaucratic systems discharge their duties in an established routine, which also includes the implementation of treaties. Deviations from this bureaucratic efficiency can only be achieved with great political effort. Admittedly, it is apparent here that politics and society do play a role. At least as far as the decision-making processes are concerned, centralistic dictatorships are more easily able to break out of the routine than federal, democratic constitutional states.

- The interests of the states involved are precisely defined for the long term in a common learning process, also involving international actors, before concluding a treaty so that compliance reflects a compromise supported by all parties. If compliance is slight then this expresses an unfair balance of interests. Attention is therefore drawn to the negotiating processes for material regulations.

- "Pacta sunt servanda", treaties which have been concluded must be complied with. This basic norm of international law is in the interest of all states since only in this way can vital stability and predictability be maintained in the international system. Furthermore, international interest groups emerge who have an interest in compliance by their respective nation for economic or other reasons and who urge compliance on the national authorities.

A critical assessment of the present state of the art in international relations [Rittberger 1990] comes to the conclusion that neither of the two theories can claim to give plausibly and empirically reliable reasons for (non)compliance. It is difficult for realism to explain why states still comply with treaties even if the interest and power positions (structure) of those involved have changed, whereas institutionalism has problems in explaining the by no means unique contractual violations in general and the "accumulations" of infringements with respect to location and subject. (Some states seem to violate treaties more often and breach of commitment is more frequent in some issue areas than others.) The question remains open of whether this is related to the intensity of verification, the probability of detecting the violation and thus to the possibility of sanctions. Corresponding evidence that reliable safeguards and credible threats of sanctions lead to increased compliance would support the explanatory power of the realistic theory.

This clash of theories, which still remains to be settled, is not an academic exercise and has serious implications for the conception of verification systems since the realists expect an opportunistic defiance of treaties so that the participants in the issue areas regarded as relevant would have to remain vigilant to obtain the highest possible degree of certainty about the behaviour of all parties. The need for verification is very high and verification would therefore have to be very dense and intrusive. Institutionalism, which bases its arguments on consistent, predictable compliance with agreements on the part of states, would in contrast be satisfied with a small degree of certainty and a low verification density and would cut back the demands made on the organization of the verification system on the international level.

2.3 Reasons for treaty violations

A uniform understanding of treaty violations has been assumed so far. However, institutionalism mentions further causes of treaty violations which are given less weight in the theory of realism [Chayes 1993]. The need for verification changes depending on which of the reasons for noncompliance is regarded as decisive:

1. In principle, the possibility of *international treaty violations* is acknowledged by all schools of thought. They may serve directly to achieve advantages or avert the disadvantages which may arise if commitments are fulfilled. A violation of commitments is an intentional act of considered government policy. In the political discussion and in the theory of realism, treaty violations are generally regarded as the expression of such a specific policy directed towards the states' own advantage. Intrusive verification is justified and has its field of activity here. It is intended to detect unambiguous signs of deviant behaviour at the earliest possible stage and insist on the correction of this behaviour, if necesssary by means of negative incentives (international enforcement, dispute settlement, cf. [Sands 1993]). The percentage of all violations represented by this type of treaty violation is not clear.

2. *Capacity shortage* in implementing treaties. In arms control, the commitments agreed in the treaty are addressed directly to the states. They have to reduce weapons systems, dispense with weapons tests or subject themselves to other restrictions. As a rule, only the state itself has armed forces, it alone is responsible for implementing the provisions and also has direct access to the objects to be controlled, which are government organs. In the majority of cases, the state is in a position to fulfil its commitments if so inclined, i.e. it has the capacities to implement the treaties or can make these capacities available relatively rapidly. Capacity problems are the exception, but they do indeed occur. There are, for example, technical problems in destroying chemical weapons or in making nuclear weapons material unusable. The problems are often rooted in the specific politico-economic inadequacies of the respective state. In many other agreements, however, not least in the case of environmental protection, although the states are the contracting parties nevertheless the provisions are directed towards influencing the behaviour of social entities, e.g. industry or individuals, whose activities are responsible, for instance, for greenhouse gas emissions. (Emissions of GHGs directly attributable to government action are estimated to be in the range of a few percent and largely arise in the military sector (including the production and maintenance of the military hardware and infrastructure)). In order to alter its behaviour in such a way that it corresponds to the overall result of the treaty goal, each state must undertake intermediate steps in order to reach the "lower" level of

social actors: legislation, administrative regulations, implementation and safeguards (national enforcement, cf. Sands 1993). There are no comparable problems of various levels in arms control. Thus, for example, in implementing environmental agreements many deficits in regulative governmental capacities may be revealed, there may be a lack of scientific and technical competence to develop implementation strategies and instruments, and deficiencies in the bureaucratic implementation and safeguarding capabilities or inadequate financial, technical and staff resources may become apparent.[1] Such problems are by no means rare and the contracting parties often make efforts to take remedial action. For instance, financial, technical and administrative support for "developing countries" in fulfilling their commitments is incorporated in the Montreal Protocol on Substances that Deplete the Ozone Layer and its amendments, as well as in the Framework Convention on Climate Change, which only refer to the determination of greenhouse gas emissions and the drafting of programmes to combat the anthropogenic greenhouse gas effect. A special problem arises in "transition economies", the former stated-controlled economies, whose politico-administrative systems are in part still inadequate so that it is difficult to estimate the actual implementation of environmental agreements [Kotov 1994].

3. A *time delay* in the implementation of agreements can be observed for many environmental treaties. This is closely connected with the problems discussed in the previous paragraph and may be expected at an earlier point if more time and resources are required for the implementation of commitments. In this case, there may be "latecomers" whose compliance may be regarded as low at an early point after the treaty comes into force. This might simply involve difficulties during a transition period and should not be regarded as a violation of the treaty. A decision on effective compliance can therefore not simply depend on a single event but rather on a longitudinal analysis taking into consideration the dynamics of compliance.

[1] See [Jänicke 1993] for the debate on the possibilities and limitations of government action, particularly in the environmental sector.

4. An attitude of government policy lying between intentional treaty violations and those due to lack of capacity may be termed *unwillingness* to implement, or a lack of readiness. This does not involve falsification or the lack of ability to implement the treaty, but rather passive refusal (without this becoming too apparent) to implement the necessary steps or to perform them with the diligence required - a type of behaviour which may be very difficult for the other parties to detect.

5. Finally, "normative inexactitudes ("*ambiguity*") in the sense of a vagueness or or broad interpretation of commitments" [Lang 1994, p. 822] may lead to violations, i.e. the parties´ commitments are not defined clearly enough in the contractual agreements. This involves a subtype of unintentional violations.

Treaty violations may therefore also be the result of a well-meaning but incompetent policy so that it should not be assumed that the state is unwilling to comply with the treaty. If the capacity-related or the "time lag" violations are dominant, and not intentional treaty violations due to lack of willingness or intentional violations, then on the basis of confidence in the readiness of the state to comply with its commitments, verification could be designed to be less intrusively exposing and instead more implementation-oriented and corrective. Admittedly, this would necessarily assume that all states had a basic interest in solving the problem and regarded the treaty provisions as a fair compromise. This refers back to the two schools of thought and their explanatory power for the origin of international treaties.

It must be remembered that although those schools of thought regarding international relations recognize a general need for verification of international agreements, also in the issue area of the environment and particularly for climate protection, nevertheless they represent different positions in the central quesiton of how dense this verification should be and the emphasis to be given to various modèls of treaty violation.

2.4 Verification within the framework of a climate convention and its protocols

On the basis of the recognition of the basic need for verification concerning a climate convention, a specific analysis should determine the required verification density in a pragmatic manner.

International cooperation in protecting a global common is particularly difficult since all relevant participants must contribute towards the protective goal and at the same time there is an incentive to take on the position of a free-rider and personally contribute nothing towards protecting the global common but to profit from other countries´ successful protective measures. Climate is a global common of this type [cf. Utsch 1993]. Furthermore, countries are affected to a different extent by measures for climate protection and some countries - according to much less precisely informed speculations - could even profit from climate change and its consequences [cf. Fischer 1992; Oberthür 1993].

These special features also characterize the determination of the necessary verification density, which is the result of several factors:

1. The extent of the mutual uncertainty on the part of states concerning compliance with a convention. In the case of a climate convention, uncertainty about compliance is relatively high in comparison to other environmental treaties [Efinger/Breitmeier 1991]. The reasons for this are: a) If almost all countries are members of the climate convention, then the sheer numbers increase the chance that violations of the provisions will remain undetected. b) The states have different scales of preferences tending towards either climate protection or economic growth. This arouses uncertainty concerning compliance if the two goals come into conflict. c) A large number of governmental and non-governmental actors are contracting parties or are affected by the national implementation of a convention; a large number of measures must be implemented and their success controlled. d) Supplier countries wish to obtain evidence from recipient countries that the funds transferred for climate protection have been used appropriately. e) Results of (conceivable) programmes on the joint implementation of climate protection measures must also be verified as well as the envisaged ????-based compensation models for the optimum distribution of funds among countries where the greatest reduction in GHG emissions can be achieved. f) The states have different agrees of ability to control the implementation of agreed policies; there is a lack of methods. g) There may be countries which regard themselves as "winners" with respect to climate change or as "losers" of a protective strategy and which have been forced into the climate convention without any intention of complying with the provisions.

2. The dominant conflict type [Efinger/Breitmeier 1991]. Typologies concerning the subject of a conflict assume that the way in which countries act is determined by the nature of the subject: The climate (convention) issue area is one of the type of conflicts concerning means or interests with respect to absolutely valued goods and is therefore less competitive and comparatively open to cooperation. (In the case of conflicts about means, the aims are not in dispute but rather "only" the means of achieving the goal. Conflicts of interest about absolutely valued goods, such as sufficient food, clean water, pure air, offer good chances of being solved since these goods - within limits - can be increased and have their own value for each actor, quite irrespective of how much the other parties possess.) Consequently, distrust concerning the behaviour of other states and thus the need for verification is lower than in the issue area of (international) security and arms control where questions of power represent an important aspect, i.e. relative goods. Zero-sum games are frequently encountered here. Nevertheless, the drastic reduction in greenhouse gas emissions of 60 to 80 % required by many scientists (for the highly industrialized countries) could result in such serious impacts on the economy and patterns of trade that conflicts about relative goods (shifts in power) may arise. Within the framework of such a strict (still very hypothetic) convention, which would be a medium for modifying international power structures, there would be a great incentive to deviate from commitments. Consequently the verification density would increase together with the regulation density of the convention.

3. The significance of the issue area. After the first oil shock, the concept of (international) security was supplemented by an economic dimension (economic security). Today the "ecological dimension of security" is emphasized, not least with a view to the consequences of the climate problem for politics and science [Sands 1993; critical attitude: Daase 1992]. In the case of security-relevant problems, there is a desire for more, and more precise, information about the actual behaviour of the other states. Only in this way can it be ensured that some contracting parties are not clandestinely evading the costs and burdens of a climate convention. This is closely related to the problem of free-riders.

4. The consequences of a convention violation. Relative to the individual event, these consequences would be of less objective relevance than a violation in the case of arms control treaties. "Clandestine" emissions of several million tonnes of carbon (C) would be of marginal significance in view of global anthropogenic

releases in the order of six billion tonnes of C. A verification system for a climate convention therefore need not display the density regarded as necessary for arms control where every atomic warhead and every carrier system counts. From the perspective of climate policy, however, the individual violation is not a problem but rather the signalling effect of such an event or indeed even the suspicion that there might be substantial undetected violations. The entire climate regime might collapse (domino effect). The detection of less serious, persistent violations must therefore be ensured.

As a result, it may be established that the need for verification in the issue area of climate protection is initially low and mainly concentrated on violations resulting from capacity shortages or implementation delays (time lag). One reason for this is the low regulation depth of the Framework Convention on Climate Change, which only contains a few, fuzzily formulated material commitments [Oberthür 1993; Fischer 1992] providing hardly any starting points for verification. The verification system for the Framework Convention on Climate Change therefore displays a low verification density and concentrates on verifying the completeness, transparency and reconstructibility of national emission declarations or on compliance with certain criteria in drawing up the declarations (e.g. consideration of emission factors). There is no independent verification of the correctness of the declared data. If a dynamic climate protection regime should develop and protocols with extensive, precisely timed and burdensome commitments for the reduction of greenhouse gases should be agreed then there will probably be a moderate verification need which would also pay increasing attention to the elements of international treaty violation. Verification density will increase and will also have to consider the correctness of national data on emissions etc. Verification density would then probably be somewhere between the intrusive safeguarding of disarmament agreements and the low verification density which has characterized most environmental protection treaties to date.

The following discussion assumes a need for verification above the present level and implicitly assumes more stringent regulations with a firmer timetable and incorporating more countries and more emission sectors for the limitation and reduction of GHG emissions than the present (slight) regulation density. Based on this assumption, the question arises of the instruments and methods which can be used to verify such a strengthened climate convention and whether some of them may already be able to contribute towards verifying the present meagre commitments.

3 Elements of Verification in a Climate Convention and its Protocols

Declaration and verification are directly related to each other so that any discussion of verification problems also requires a consideration of the declaration on which they are based. The declaration records what the states have done and what they intend to do. It is a (in part quantified) activity and planning report which is the starting point for and subject of international verification. What the states have to declare is generally described in the treaty. Verification refers to these declarations. It is facilitated if not only subject matter but also forms and methods are predefined serving as a guide for the states in compiling their reports. This is also the case within the framework of the FCCC and if the commitments are to be expanded, the demands made on such terms of reference will also increase. For this reason, before undertaking a detailed analysis of methods and techniques of verification, attention will be directed to the national reports and important terms of reference with respect to their structure.

3.1 National declaration

3.1.1 Declaration commitments

In the FCCC, commitments with respect to communicating information on the implementation of the treaty (national report) are laid down in Article 4(1) and Article 12. They are considerably more extensive for highly developed industrial states than for other countries and, to the extent that they directly refer to the countries' own emission problems,[2] comprise the following information:

- a national register of anthropogenic GHG emissions (apart from substances covered by the Montreal Protocol) from sources, taking into consideration their degradation by sinks; for this purpose comparable methods are to be applied;
- a precise description of policies and measures resolved for the fulfilment of commitments;
- an estimate of the impacts of these policies and measures on anthropogenic GHG emissions and the development of sinks, i.e. forecasts or scenarios of the effect of measures and policies;

[2] Article 4(3,4,5) also contains a commitment to provide information on the special provision of assistance and aid to "developing countries" in connection with the Convention.

- further information which may be useful.

A summary of these commitments can be found in **Table 3**.

	Main Elements of Information Contained in National Communications
(1)	**Inventories**
·	Emission estimates (by gas, by main source/sink activities) *)
·	Emission factors (by gas, by main source/sink activities)
·	Activity data *)
·	Method description
·	Discussion of data quality/uncertainty
(2)	**Policies and Measures Description**
·	Identification of individual measures, type, objective and their status.
·	Benchmarks and how effects are to be monitored over time.
·	How the measure is functioning.
(3)	**Projections and Effects of Measures for the Year 2000**
·	Gas by gas for CO_2, CH_4, N_2O emissions and CO_2 removals (separate) - projection - total effects - individual effects
·	Model descriptions and quality discussion
·	Key assumptions (1990 and 2000) *)
*)	Data points that can be checked against independently published estimates.

Table 3

If one takes a look at the national reports compiled in 1994 then it is immediately striking that a dominant role is played by statements on (future) measures and policies, and their (conceivable or probable) results. Based on experience with verification in general and with reporting commitments in other environmental agreements, this concentration on qualitative aspects is unusual. It can only be explained by the present status of regulations within the framework of the FCCC which does not lay down any targets *or* timetables with respect to emission goals even for developed industrial countries. Apart from a compilation of present emissions, quantitative aspects are hardly required. Emphasis is still placed on policies and measures which at some time or another should lead to a reduction in GHG emissions. If, as assumed here, the FCCC should develop into a real climate protection regime and if emission reductions should be specified in terms of time and quantity, then the quantitative declaration will also take on central significance and greater weight in the national reports. However, on the basis of the present commitment catalogue this will also be the case at least in the medium term. Implemented policies and measures must after all at some time lead to a limitation or reduction of GHG emissions, they must at some time become quantifiable. As far as the reduction of GHGs is concerned, they are proof of the success or failure of policies and measures. The qualitative sections of the national report will undoubtedly retain their significance but will gradually recede into the background in favour of quantitative emission declarations. This actually all comes out against making the compilation of GHG inventories the centre of activities by international organizations at present. If, however, as will be shown, they receive the greatest attention then one reason for this is that the compiling of a base line for the respective national GHG emissions on the basis of comparable measures is accorded a central role. For only if they are more or less reliable, comparable and capable of achieving an international consensus can reduction steps be reconstructible. At the same time, their compilation according to the most uniform possible method, while still remaining reconstructible, is a prerequisite for verification, which is to be part of a more highly developed climate regime. If the methods and procedures for determining emissions are inpenetrable, inadequate or not comparable, then verification will fail since in this case only the inpenetrableness, inadequacy or non-comparability can be established in the verification process.

All these reasons plead the case for paying close attention to this central aspect of declaration.

3.1.2 Greenhouse gas inventories

The regular compilation of reliable (national) emission inventories comprising all essential sources (and sinks) is of central significance for the global restriction of anthropogenic greenhouse gas emissions which is the aim of the climate convention. These inventories are the basis for assessing the effectiveness of national measures for reducing greenhouse gas releases. Transparency and reconstructibility of the data and methods on which compilation of the inventories is based are essential for international comparability and verification. Even if commitments for limiting GHG emissions were tightened up and extended to more countries, compiling the inventories would receive central significance thus justifying more detailed consideration of these inventories.

In the following, the present status of international efforts towards developing uniform methods of compiling inventories is examined. Furthermore, studies of the data base in Germany will be discussed in order to provide an instance of the data quality currently to be expected in national communications with the example of the situation in a highly developed industrialized country.

3.1.2.1 *IPCC/OECD method development*

Probably the most important impetus for international method development emanates from the Intergovernmental Panel on Climate Change (IPCC), which was set up in 1988 by the two United Nations organizations WMO (World Meteorological Organization) and UNEP (United Nations Environmental Programme). The tasks first undertaken by the IPCC in three working groups composed of experts cooperating worldwide are

- assessment of the scientific knowledge available on climate change,
- estimate of the socio-economic and other environmental impacts of climate change and
- formulation of avoidance strategies.

The first comprehensive scientific report by IPCC was published in 1990 [IPCC 1990], a supplement dates from February 1992 [IPCC 1992]. The second comprehensive report is to be presented in advance at the 11th IPCC Plenary Session in Rome in autumn 1995. A Special Report by the IPCC, containing amongst other aspects the global warming potentials and the "Guidelines for National Greenhouse Gas Inventories", will be published at the Conference of the Parties in March 1995.

In developing methods and establishing guidelines for compiling national greenhouse gas inventories, IPCC is supported by the Organization for Economic Cooperation and Development (OECD), which presented its first comprehensive report in August 1991 [OECD 1991]. This is to be regarded as the first milestone along the path towards developing an internationally agreed methodology, so-called Guidelines, which initially comprise the gases CO_2, CH_4, NMVOC (non-methane volatile organic compounds), CO, N_2O and NO_x. All known essential greenhouse gas sources influenced by man will be covered, ranging from energy and industrial technology to the waste economy and the sectors of food industry, forestry, utilization of biomass and the consequences of modified farming methods. In February 1994, dispatch was started of the three-volume "IPCC Draft Guidelines for National Greenhouse Gas Inventories" [IPCC 1994a]. This revised version will be available for the Conference of the Parties in 1995.

The methods developed by IPCC/OECD and internationally approved are to be regarded as a proposal to the states; they will not be bound to apply these methods. According to the current treaty position, the states can also make use of their own methods although they must ensure the transparency and comparability of the methods, and thus of the inventories. With respect to verification, which is now also an IPCC topic, this means that it must be adapted to the respective national method of data collection, which naturally increases the effort involved. An agency entrusted with the task of verification will have to collect a vast quantity of information in order to assess the various national communications. Such information should comprise energy statistics, demographic and economic data, as well as details of structures and trends in the industrial, transport or agricultural sector, i.e. as much data as possible which may be used as indicators of the correctness and completeness of the declared inventories.

3.1.2.2 Method development within the framework of UNO activities

An important development in connection with IPCC/OECD method development, and also related to it, may be the envisaged compilation of an "Emission Inventory Guidebook" as outlined in the form of a proposal at the UN-ECE (United Nations Economic Cooperation in Europe) Task Force Meeting on Emission Inventories in Delft, The Netherlands, on 7 June 1993 [ECE 1993]. The aim of the Guidebook is to provide a comprehensive summary of methods for determining the inventory of each gas to be inventorized and all sources to be identified. This has also been undertaken with the awareness that fulfilment of commitment to compile inventories undertaken within the framework of various environmental agreements must not be made more difficult by divergent methods.

Accordingly, the Guidebook should be designed in such a way that it covers the inventory requirements of at least the most important international activities such as those of the Convention on Long-Range Transboundary Air Pollution, the Fifth Environment Action Programme of the European Community, or IPCC/OECD activities. The following gases will be included: SO_2, NO_x, NMVOC, CH_4, CO, CO_2, N_2O, NH_3 and to a certain extent heavy metal and POP (persistent organics) releases. One chapter will deal with verification. A first incomplete draft of the Guidebook was presented at a UNECE/EMEP Task Force Meeting at Regensburg in June 1994 [ECE 1994]. The second draft will be adopted at the next Task Force Meeting in Oslo in June 1995.

The Guidebook is based on the source-oriented approach of the CORINAIR emission inventory of the EU. However, close OECD/IPCC cooperation should ensure that the approach will not only be applicable for one programme so that finally harmonization can be achieved. As an initial step, software was developed to convert CORINAIR data into IPCC inventories. It is hoped that the methods will be largely harmonized by 1996.

3.1.2.3 *Data base for greenhouse gas emissions in Germany*

The first national report by the Federal Republic of Germany [BMU 1994a] was published in September 1994 thus fulfilling its obligation to compile a report after ratifying the FCCC of Rio de Janeiro. In its Chapter 3 "Inventories on Anthropogenic Emissions and Determination in Stores and Sinks" it contains a summary of the quantities of the gases CO_2, CH_4, N_2O, CO and NMVOC released in 1990 as well as individual data on the very long-lived (up to 50,000 a for CF_4) gases CF_4, C_2F_6 and SF_6.

An overview of the German 1990 inventories compiled according to sectors as well as the assessment of the reliability of the data for the most important greenhouse gases CO_2, CH_4 and N_2O - both taken from [BMU 1994] - is given in **Tables 4** and **5**.

Sources and sinks of greenhouse gases	CO_2 Mt/a		CH_4 kt/a		N_2O kt/a		NO_x as NO_2 kt/a		CO kt/a		NMVOC not including CFCs/CCs kt/a	
Total emissions	1 012		6 218		223		2 944		10 768		2 978	
	709	303	5 015	1 203	183	40	2 377	566	7 131	3 637	2 234	744
1. Energy-related	983		1 767		33		2 923		10 104		1 679	
	687	296	1 574	193	24	9	2 361	561	6 526	3 578	1 093	586
2. Industrial processes	29		11		100		21		664		129	
	22	7	9	2	95	5	16	5	605	59	111	18
3. Use of solvents and products					6						1170	
					5	1					1030	140
4. Agriculture			2 043		80		n.a.		n.a.		n.a.	
			1 497	546	55	25	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
5. Land use changes and forestry"	(-20)											
	(-14)	(-6)										
6. Waste management	n.a.		2 397		4		n.a.		n.a.		n.a.	
	n.a.	n.a.	1 935	462	4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a
High-seas bunkerings"	8		0		n.a.		155		37		16	
	7	1	0	0	n.a.	n.a.	128	27	31	7	13	3
International air transport"	11		0		n.a.		50		58		9	
	11	1	0	0	n.a.	n.a.	49	2	54	4	9	1

n.a. Not available
" Not included in total emissions
Source: Federal Environment Agency

Germany	
Former West Germany	Area of the former GDR

Tab. 4: Greenhouse Gas Emissions 1990 in Germany

Table 4 clearly shows the dominance of energy-related emissions for CO_2 accounting for 97 % of total emissions. In contrast, only 28 % of the emissions are energy-related for CH_4, whereas the waste economy dominates with 39 %. In the case of NO_2, the energy-related fractions with 15 % in comparison to agriculture (36 %) and industrial processes (45 %) are of minor significance. Industrial N_2O releases will also drop significantly in future due to process modification at the two nylon producers.

With the exception of methane and N_2O, the data quality is only classified as E (excellent) by the Federal Environmental Agency (UBA) for the energy-related emissions. According to the UBA, this category is defined as having deviations of less than ± 10 %. In contrast the ranges F (fair) and P (poor) are not quantifiable.

Insights into the data situation are provided by two studies commissioned within the framework of IKARUS Subproject 9 from the Öko-Institut in Darmstadt. The aim of the first study [Fritsche 1992] was to evaluate the data bases in Germany for *energy-related* climatically relevant *emissions*.

Four data sources were available for the analysis, namely the Federal Environmental Agency (UBA), the Programme Group Systems Analysis and Technology Evaluation of the Research Centre Jülich (KFA-STE), the Öko-Institut e.V. and the Institute of Energy and Environmental Research (IFEU) in cooperation with the Technical Control Board (TÜV) Rhineland. Of these, only the data bases of the UBA and the Öko-Institut provided information about the majority of greenhouse gas emissions from different sectors, whereas KFA-STE only considered CO_2 from the combustion of fossil energy carriers and IFEU/TÜV only the transport sector. Furthermore, according to these findings, the data available for Eastern Germany are often unreliable or incompatible with the data for Western Germany.

The analysis of the features and content of the four data bases showed that in general no primary information was available but rather secondary data supplied by "intermediate collectors" (e.g. from energy associations, the Association for Energy Balances (AGEB), federal and state ministries and authorities) or originate from the literature.

Sources and sinks of greenhouse gases	CO_2	CH_4	N_2O
1. Energy-related emissions	E	F	F
A Combustion-related	E	F	F
1 Energy generation and transformation	E	E	F
2 Industry	E	F	F
3 Traffic and transport	E	F	F
4 Small consumers	E	F	F
5 Households	E	F	F
6 Agriculture and forestry	E	F	F
7 Other	E	F	P
8 Burning of biomass	-	P	P
B Non-combustion-related	E	P	F
1 Extraction and distribution of oil and gas	E	F	F
2 Coal mining	-	P	-
2. Industrial processes	F	F	F
A Iron and steel industry	-	F	-
B Non-ferrous metal production	F	-	-
C Chemical industry (inorganic)	F	F	F
D Chemical industry (organic)	-	-	E
E Nonmetallic minerals	F	-	-
F Other	-	F	-
3. Use of solvents and products	-	-	F
A Painting	-	-	-
B Degreasing and dry cleaning	-	-	-
C Production and use of chemical products	-	-	-
D Other	-	-	F
4. Agriculture	-	F	P
A Fermentation	-	F	-
B Animal waste	-	P	P
D Agricultural soils	-	-	P
E Burning of agricultural waste	-	-	-
5. Land-use changes and forestry	F	-	-
A Conversion of forest land to arable or pasture land	-	-	-
B Conversion of grassland to arable land	-	-	-
C Set-aside of agricultural land	-	-	-
D Managed forests	F	-	-
6. Waste management	-	P	P
A Dumpsites	-	P	-
B Wastewater treatment	-	P	P
C Other	-	-	-

*) Qualitative evaluation of data accuracy
E Excellent
F Fair
P Poor

Source: Federal Environment Agency

Tab. 5: Assessment of the Data Reliability for the Most Important German 1990 Greenhouse Gas Inventories

The situation with the methods used for assessing the greenhouse gas emissions often proved to be unfavourable. Frequently, only subjective estimates were available on the basis of scattered information. This is generally true of CH_4 emissions from non-energetic sources. The situation with respect to N_2O emissions was even more unfavourable. With a view to verification, this means that the lack of clear standards may lead to difficulties in assessing the reliability of declared values.

Due to these methodological inadequacies, the Öko-Institut placed major emphasis on determining emission factors and also on methods of estimating the energy-related emissions of CO_2 from the combustion of fossil energy carriers. To this end, the characteristics of the fuels in question were described and evaluated. It became apparent here that although in many cases values from different sources were not in agreement thus leading to variations in emission factors (i.e. of the greenhouse gases emitted in the mass per unit of converted energy), nevertheless, in comparison with other greenhouse gases the quality of energy-related CO_2 emission data can be regarded as good. In determining the completeness of the combustion process it was assumed for the majority of emission processes considered that oxidation was complete. This assumption is correct for plants with typical burn-up rates of 99 % and more, and is also in accordance with the current IPCC approach of complete carbon conversion. Only in Eastern Germany burn-up factors of as little as 80 % due to unfavourable combustion conditions when using domestic lignite have been found - a problem which, however, is becoming increasingly less significant with the current restructuring and technological modernization taking place there.

The most important data source for calculating CO_2 emissions from the energy sector has proved to be the Association for Energy Balances (AGEB). The AGEB provides consistent energy balances for Western Germany, which have also been extended to the new federal states in Eastern Germany for the years after 1991. The Öko-Institut study shows that the present AGEB methodology is capable of improvement, particularly with respect to the completeness of data and allocation of calorific values to certain fuels. If the improvements are made then a restriction of uncertainty for energy-related CO_2 emissions in Germany in the order of less than $\pm 5\%$ is to be expected.

The Öko-Institut furthermore expects that the uncertainties in the overall emissions may be reduced to values of about $\pm 1\%$ by solving the delimitation problems of transboundary traffic and also definition questions involved in CO_2-relevant non-energetic consumption.

As noted above, the data uncertainties for other energy-related greenhouse gas emissions are considerably greater, above all in the transport sector, but also in the other final energy sectors. Improvements may result here from the IKARUS data.

Whereas the IKARUS project concentrates on energy-related greenhouse gas releases, the topic of "verification within the framework of an international greenhouse gas convention" cannot be restricted to this alone but must also include the other emissions caused by man. In order to obtain an overall view of the data situation in Germany in this respect as well, the Öko-Institut was commissioned with a further study on the data bases of non-energy-related greenhouse gas emissions [Buchert 1993].

The study is concerned with the trace gases CO_2, CH_4, N_2O, NO_x, NMVOC, SO_2 and CO, as well as CFCs and CHCs, directly or indirectly influencing the climate, from the sectors of industry, agriculture and forestry as well as waste management. Furthermore, it points to other greenhouse gases, to which little attention has been paid as yet, but which are becoming increasingly important due to their long atmospheric life (see above) such as sulphur hexafluoride or tetra- and hexafluoromethane emissions originating from aluminium production.

The UBA data base was the only German data base to be identified by the Öko-Institut as comprehensive. Only publications on subsectors of greenhouse gas emission were found from other institutions such as the Federal Ministries of the Environment or Agriculture and Forestry, environmental agencies of the federal states, industrial associations and research establishments.

On the whole, the Öko-Institut established that uncertainties in the data base are to be estimated at about ± 50% in the most favourable case, and that variation ranges - about an unknown average - often exceed a factor of 2.

It is considered possible that the data position for specific releases of SO_2, NO_x and CO can be improved for strong emitters in the next few years by means of continuous measurements, whereas the Öko-Institut does not expect any significant improvement for NMVOC, CH_4, N_2O and CO_2. There are still methodological problems with CFCs and CHCs in converting consumption data to emission data (consideration of the banking effect, e.g. by the confinement of CFCs in foams), in considering and assigning stored transboundary quantities as well as in disposal.

A considerable need for research to improve the data situation has been identified in the sectors of agriculture, forestry and waste management. Here greenhouse gas inventories are based practically exclusively on estimates with a mainly small, often foreign data basis.

The data problems are exacerbated, particularly in agriculture and forestry and for the GHGs of CO_2 and CH_4, by the comprehensive approach laid down in the FCCC. It envisages compiling a net emission balance for GHGs, offsetting emissions and sinks against each other. Precisely the quantitative recording of sink capacities is difficult and involves great uncertainties; in some sectors no data at all are available yet (see Table 5). A verification of such data can only confirm the great uncertainty of the estimates so that the comprehensive approach considerably complicates verification.

3.1.3 Global warming potentials

The quantities of greenhouse gases released do not themselves give any indication of their significance for the climate; this requires a weighting with respect to their radiative forcing.

The Global Warming Potential (GWP) was developed to obtain a manageable value for political decisions and has now become accepted on an international level [IPCC 1990, 1992, 1994b] and, in spite of all its weaknesses, will continue in future to serve to assess the radiative forcing of the various gases.

As a simple multiplier, GWP designates the radiative forcing of the released quantity of the gas under consideration as a multiple of that of CO_2; i.e. it provides direct CO_2 equivalents and thus a direct yardstick for assessing the overall radiative forcing in the optimization calculations of the technical measures determined. However, due to their mutual influence, current GWPs are strictly speaking only valid for the atmosphere in its present composition.

Publications by the IPCC [IPCC 1990 and 1992] contain a detailed description of the concept of the global warming potential. The available current numerical values have been compiled in a recently published "Summary for Policy Makers" [IPCC 1994b]; a comprehensive report is expected in autumn 1995. The following discussion is based on the above-mentioned IPCC reports.

The GWP describes the integrated contribution to radiative forcing over a period of t years (= induced radiation energy flux change at the tropopause) of the gas i for the spontaneous release of a unit of quantity (1 kg) in comparison to that for the release of 1 kg of CO_2. It follows that:

$$GWP_i = \frac{\int_0^t a_i c_i dt}{\int_0^t a_{CO_2} c_{CO_2} dt}$$

a = greenhouse effect from the released unit quantity
c = concentration of trace gas at time t after release.

Attention should be drawn to the fact that as indicated by the term "global warming potential", the GWP is an indicator of possible impacts on climatic events worldwide. It can thus only refer to gases whose lifetime or residence time (generally defined as the period until degradation to the 1/e-fold) permits a global mixing in the atmosphere, i.e. is counted in at least years. However, attempts are being made to apply the GWP concept to short-lived species such as NO_x, non-methane volatile organic compounds (NMVOC) or aerosols, although these methods are still under development.

In determining the GWP, a differentiation is made between direct and indirect global warming potential. Direct GWPs refer to the direct greenhouse effect of long-lived trace gases. [IPCC 1994b] includes CO_2 (residence time 125 ± 75 a), CH_4 (14.5 ± 2.5 a), N_2O (132 a), various halogenated hydrocarbons with residence times of up to more than 1500 a as well as some extremely long-lived compounds, mainly fluorocarbon compounds with residence times of up to 50,000 a (CF_4). Indirect GWPs, which must be added to the direct GWPs, result from the formation of radiative forcing daughter products during the chemical degradation of trace gases. If the "mother" trace gases are themselves long-lived, i.e. if they are capable of global mixing in the atmosphere, then the GWP approach is also appropriate for short-lived daughter products such as ozone (days) or (tropospheric) water vapour (8 days), as for example from methane degradation. The same is true of the formation of long-lived daughter products from the degradation of short-lived mothers, thus for example CO_2 formation during the oxidation of CO (months) or non-methane hydrocarbons (days to months). Whereas in the 1990

IPCC report quantitative data were still given on the indirect GWPs, due to great uncertainties they were only included in the 1992 report by indicating their plus or minus sign. In the 1994 report only the GWP of methane - except for its conversion into CO_2 - contains its indirect fraction as well.

The most recent GWPs from [IPCC 1994b] are compiled in **Table 6** for the most important long-lived trace gases, which cover approx. 85 % of the anthropogenic greenhouse contribution. In comparison to the 1992 methane data the GWPs have approximately doubled and have increased by up to approx. 20 % for other gases. The typical uncertainty margin for GWPs is in the region of ± 35 %.

Gas	Contribution to additional greenhouse effect [%]*	Lifetime [a]	GWP for integration times 20 a	100 a	500 a	Positive or negative sign of the indirect GWP [IPCC 1992]
CO_2	50	125 ± 75	1	1	1	-
CH_4	13	14.5 ± 2.5	62	24.5	7.5	positive
N_2O	5	132	290	320	180	unknown
CFC 11	5	50 ± 5	5000	4000	1400	negative
CFC 12	12	102	7900	8500	4200	negative

* From [Bundestag 1990]. The remaining 15 % is distributed between ozone (7) and others (this distribution can only give an idea of the relative weighting; corrections are to be expected on the basis of new findings). Indirect effects from the formation of tropospheric ozone and stratospheric water vapour are included in the GWP of CH_4, but not from the formation of CO_2. The remaining GWPs only include direct fractions.

Table 6: Global warming potentials (GWPs) for the most important long-lived trace gases relative to the mass (kg) of the input gas
Source: [IPCC 1994b]

The following remarks should be made on Table 6:

a) Due to the different lifetimes of the trace gases, the integration time (see formula on page 30) plays an essential role in evaluating their relative radiative forcing. The time horizon to be applied depends largely on the goal of the respective analysis. 100 a is usual. As far as the residence time of CO_2 as a reference value is concerned, it is specified in [IPCC 1994b] with a bandwidth of 50 to 200 a. It is to be assumed that an average CO_2 residence time of 125 a was used in calculating the GWPs; a value which is 5 a above that from [IPCC 1992].

b) Although the indirect GWPs are only qualitatively mentioned in .Tab. 6, nevertheless they may possibly have a weight similar to the direct GWPs.

To date, the following major effective factors are known for the individual gases:

- CO_2 behaves inertly in the atmosphere. However, due to its influence on temperature distribution it could influence the chemical reactions of other trace gases.
- 90 % of methane is decomposed to CO_2 and water vapour in the troposphere by reactions with OH radicals, in the course of which ozone simultaneously results. The latter and the water vapour arising during methane decomposition in the stratosphere provide the major contribution to the indirect GWP.

- N_2O is decomposed by photolysis. No indirect effect is indicated.
- The indirect greenhouse effect of the CFCs is largely based on the ozone depletion they cause in the stratosphere. This effect is negative and may largely compensate for the direct effect of the CFCs, although the geographical distribution of ozone degradation is unequal.
- The remaining gases mentioned above which are covered in the IKARUS project (NMVOCs, NO_X, CO and SO_2) have relatively short lifetimes: NMVOCs days to months; NO_X days; CO months and SO_2 weeks. Qualitative data on direct radiative forcing are only found in [IPCC 1990] for NO_X, CO and SO_2, where a low effectiveness is specified for the last two. There are no data on NMVOCs.

The last-mentioned gases - with the exception of NO_X, which contributes towards additional OH radical formation - react with OH radicals; they thus influence the lifetime of trace gases, which also undergo a degradation reaction with OH radicals, such as CH_4. NMVOCs and CO have CO_2 as their long-lived degradation product with a correspondingly positive indirect GWP contribution.

The above-mentioned trace gases influence the formation of the greenhouse gas ozone - largely in the troposphere - NO_X being particularly dominant. The indirect contribution of SO_2 is especially found in aerosol formation and thus also influences cloud formation. According to [WMO 1991], the sulphate aerosols in the atmosphere cause a negative greenhouse effect, which is confirmed by recent model calculations [IPCC 1994b]. In any case, in the same way as their precursors, they have a short atmospheric lifetime so that changes in emission are effective within a matter of weeks. It does not seem possible at present to quantify the radiative forcing of SO_2.

Whereas the indirect effects for NO_X, NMVOCs and CO were still quantified positively in [IPCC 1990] in the ratio 150/31/7 (integration time 20 a), [IPCC 1992] only contains qualitative statements about the positive or negative sign: positive for NMVOCs and CO, and indeterminate for NO_x. [IPCC 1994b] does not contain any quantitative values.

In view of their nature, GWPs will defy verification within the framework of an international climate convention. However, they will have a decisive influence on quality demands in drawing up inventories of the various greenhouse gas emissions and their verification. Particular attention should therefore be paid to their development.

3.2 International verification

As a verification of states' compliance, verification is directed in the first instance and above all towards the national reports in which the states provide information about their compliance. As already outlined, these reports, and this will probably not change in future, have a quantitative and a qualitative side. The quantitative aspect provides information about GHG inventories and reduction or stabilization targets. On a qualitative level, measures and policies for climate protection are laid down. Both aspects require verification. A first step is the verification of the completeness and consistency of the GHG inventories. In a further step, it can be verified whether the declared figures are actually correct and whether the measures have also been implemented. A gradual transition can be achieved from a verification assuming treaty violations due to capacity deficiencies and a merely delayed implementation towards a denser verification system which also includes the possibility of intentional violations. In this study it is assumed that the material commitments of the highly industrialized member states of the FCCC will be tightened up both with respect to reduction commitments and also a determination of precise timetables with respect to achieving targets. It is also presumed that threshold countries and later also "developing countries" will undertake some commitments with respect to limiting emissions and protecting sinks. Recourse will probably be taken to the instrument of protocols, which has proved its worth in international environmental treaty law and ensures high flexibility by enabling rapid adaptations to new developments. The elements, techniques and methods of a graduated verification system comprising the steps of form and content verification will now be presented.

3.2.1 Review of emission inventories

International efforts towards developing the climate convention will in coming years concentrate quite essentially on creating the data bases. Verification in the sense of reviewing clear, verifiable environmental goals cannot be of significance yet since the climate convention does not contain any such goals. As a quantitative target for restricting GHG emissions it merely contains a target for "Annex I" countries of reducing their anthropogenic release of CO_2 and other greenhouse gases not included in the Montreal Protocol, individually or jointly, to the 1990 level. Jones [Jones 1993] draws attention to the voluntariness of the agreement between sovereign states which does not include any mechanisms for compelling compliance commitments. He designates the "real" environmental goal as that which the individual signatory states aim at themselves.

Nevertheless, verification is already of significance in developing the "Guidelines" for the declaration of national greenhouse gas inventories by IPCC/OECD [OECD 1993a] in a cautious manner taking into consideration current problems in introducing the convention and not yet referring to international treaty violations.

The declared goal is, first of all, improving the quality of inventories, in which connection the following is proposed in [Corfee 1994] in the first instance:

- eliminating simple errors based on misconceptions,
- verifying that consistent reporting procedures have been observed, and
- identifying the major uncertainties remaining after a third-party review.

Initial experience is now available in the form of two studies coordinated by the IPCC/OECD Secretariat. These involve

1. an in-depth review of 25 provisional national reports by an association of OECD, IEA and the Dutch National Environmental Institute (RIVM) as well as
2. a detailed "transparency study" by eight countries.

In the first case, it became apparent that the problems had been in part considerably underestimated, above all with respect to comparability and transparency. A positive aspect was that the countries concerned reacted constructively to enquiries and that in no case did the reviewing agencies experience a defensive attitude on part of the national experts they contacted. This interaction led to various improvements both of the data and also of the methods and has probably improved the quality of the final national reports.

As far as the transparency study is concerned, in which pairs of countries were to examine their respective reports on a voluntary basis with regard to reconstructibility, the greatest surprise was that only one pair of countries had actually cooperated. As a rule, the studies merely consisted of a comparison of their own national results with those which would have been obtained by applying the alternative IPCC methods, which was, however, only one of the tasks set. From this experience, Corfee-Morlot and Schwengels [Corfee 1994] draw the conclusion that - in contrast to previous INC discussions which had favoured a review by teams of national experts - verification should be the task of a transnational, central, well equipped secretariat.

This central agency is apparently increasingly favoured and within the framework of joint implementation could fulfil an essential function. This also expressed, inter alia, in [Beirat 1994], in which the Scientific Advisory Council on "Global Environmental Change" of the German Federal Government recommends that "a supranational institution (for example the FCCC Secretariat) should be entrusted with the promotion and verification of joint implementation projects".

3.2.2 *Plausibility control through simulation models*

One can attempt to verify declared data individually by investigating the process of their origin. An additional verification possibility arises if data are related to each other. This may involve cause and effect relations or else, for example, merely aggregation relations. If they appear to be quantifiable one can attempt to mathematically simulate them in a "model", which in the case of a more complex form is also known as a "simulation model". If declared values from the greenhouse gas inventory, the catalogue of implemented measures, or the national report within the framework of the climate convention etc. can be substituted for the variables of the model, or some of them, then fulfilment of the above-mentioned model relations provides an indication of the declaration's veracity. This therefore concerns a plausibility review. It may (and possibly must) make use of the interrelations of the declared data as well as their relation to undeclared data.

In verifying declared data with the aid of models it is assumed that the international verifying institution has models adaptable to the specific countries. Two cases must then be differentiated:

In the first place, it is conceivable that the country being reviewed has determined part of the declared data from source data by means of the same or similar models. If this is permitted in the relevant protocol of the convention and the country is committed to specifying the nature of the data generation and thus the models used, verification is then restricted (trivially) to reviewing these specifications. A continuation of this train of thought would be to agree on the use of certain models to compile the declaration. If, for example, impact data are expected in the declaration, then in view of the difficulties of impact analysis this would be worth considering, since otherwise in the case of data collection the required impacts would be filtered out from a wide range of interferences. With such an arrangement, the international verifying institution would have to ensure that the models were developed in accordance with the state of the art so that the declarations remain as realistic as possible.

In contrast, actual verification making use of models is applied in the second case now being discussed, namely if the declared values are directly determined, e.g. by measurements, individual estimates or surveys. However, the discrepancies discovered in the verification process are not only to be attributed to errors in the declared and additionally required (undeclared) data but also to errors in the procedure. Above all, the unreality of every model and the possibility of compensating for errors should be mentioned.

As mentioned above, verification with the aid of models can therefore only provide an indication of the truth but not a demonstration. A verification result deviating from the declaration will therefore not immediately lead to the declaration being considered untruthful. Above all, it will suggest the need for an in-depth examination, and in particular the use of other verification methods for control purposes. On the other hand, agreement with the declaration should not be overrated.

Models only give an incomplete picture of reality because simplifications are necessary for reasons of limited computing, storage or programming capacity, of manageability or the restricted area of investigation, or because knowledge of the relationships (given in the model as equations/inequations and parametric values) is deficient, or because many influences cannot be quantified. Frequently used simplifications - as also in the IKARUS optimization model discussed below - are linearization and time-independence because reliable, more realistic information is not available and non-linear or dynamic modelling would then simulate a pseudoreality. With time-consuming causal relations between variables, the static model naturally leads to a greater distance from reality on the part of the model, the greater the actual development is removed from a steady state. In contrast, it is largely possible to prevent errors being concealed by compensation if the opportunity is available of examining intermediate results.

The values specified in the declaration are distributed differently, depending on the model, between its inputs, intermediate results or final results. Input data generally have to be supplemented in order to permit computer runs. The verifying international institution must procure these missing values from publicly accessible statistics, its own surveys, estimates etc.

Apart from the appropriateness of the modelled structure and behaviour, a model is the more suitable for a certain verification task the more completely the declared values can be recovered in it, and the more easily accessible and more reliable the additionally required input variables are. Within the framework of this sketch, it is not possible to systematically examine existing models with respect to their verification capability, apart from the fact that the information to be declared has not yet been laid down. Nevertheless, on the basis of IKARUS model instruments the possibilities of verifying climate protection declarations will be made a little more concrete.

The IKARUS model instruments, whose structure and possible verification use are outlined in **Fig. 2**, were compiled with the intention of analysing the efficiency of greenhouse-gas-reducing measures and their economic impacts. Since both these measures and also their success will probably be described in the declaration to be verified the statically operating set of instruments can be used for an approximately steady state of the economy and, applying the additionally required variables (see above), for verification purposes. The entire energy supply system of the Federal Republic of Germany is modelled so that a great deal of published energy information (possibly after appropriate preprocessing) can be used as a control. Sector-specific technology models (called submodels) for electricity and district heat, space heat, industry and small consumers, as well as transport, provide the degree of detail which may be required for an appropriate description of greenhouse gas reduction measures. With a higher degree of aggregation, an overall energy economy/technical model ensures interlinkage of the subareas, but would not be operated here (as envisaged in the IKARUS Project) primarily as an optimization but rather as a simulation model. The demand for energy services is generated in special demand generators, which for their part derive their key data from an economic input/output model, MIS, with 15 economic sectors and in addition 9 energy sectors covered in detail. Demand modules for goods and services, for investments and capital stock are included. Population trends are predefined. International consistency is ensured by the adapted Manne-Richels model "Global 2100". These comprehensive instruments permit the inclusion in the verification process of many important variables which directly or indirectly influence emissions.

The verification requirements will now be discussed in detail. The declared information primarily involves:

1. data on the measures undertaken by the administration at a certain point in time to reduce GHG emissions, e.g. enactment of laws on regulative or free-market control,
2. data on the realization of measures at a certain time, e.g. degree of implementation of a mandatory thermal insulation standard for houses,
3. data on current values for energy consumption and emissions,
4. data on reduction targets and associated time horizons.

Whereas in the case of 1, 2 and 3, verification examines the veracity of data referring to the past, in the case of 4 it has to estimate the plausibility of data referring to the future, in particular the achievability of targets.

With respect to the subjects of these data, it can be said that the relations between 1 and 2 are largely determined by the behaviour of investors, availability of resources and efficiency of the industrial sectors in question, which involves both delays as well as, in general, only incomplete implementation of the targets, both of which depend on the appreciation and thus acceptance of the targets, and also on various types of boundary condition etc. The relations between 2 and 3 are mainly of a physical nature and not subject to delay so that they can be well simulated by static models. However, behavioural components cannot be completely ruled out here thus influencing the achievement of targets, such as the ventilation or heating behaviour of residents, in which case empirical averages can be assumed. The impacts of measures to be determined in connection with category 4 are related to 1 via 2 thus leading to delays. It is also true of all the relations mentioned that the declaration will probably be incomplete with respect to the specification of causes. Thus for example, the emission reductions achieved according to 3 do not only depend on measures implemented in the past according to 1 but also, for example, on "autonomous technical progress", on sectoral economic development etc.

Returning to the IKARUS system and similar approaches, it can be said that they may be applied for verification with respect to existing relations between the declared categories 2, 3 and 4 (where in the case of 4 the impacts to be compared with the targets are meant) if the additionally required, undeclared information can be procured elsewhere.

The above-mentioned "submodels" are primarily suitable for modelling relations between 2 and 3 since together they cover a considerable proportion of the energy system and also (in contrast to the model of the overall energy economy) permit nonlinearities, cover inventory changes and represent the technology in a very detailed manner so that the implementation of measures can be adequately simulated. Concerning the necessary degree of detail, it should only be mentioned that energy consumption and emission behaviour, e.g. of a heat source or a driving engine, do not only depend on design details but also to a high degree on the control system, apart from the behavioural component "operational mode" of the system. The inputs of these submodels are the technologies described in detail, their application characteristics and their distribution. The results are extrapolations of energy consumption and emissions for the industrial sectors covered. According to the present status of the instruments, sectors not included must be covered by the model of the overall energy economy operated as a simulation model with a considerably lower technical resolution.

For relations between 2 and 4, i.e. the measures currently implemented and the impacts estimated for the future, and thus a review of the plausibility of whether the declared targets can be achieved, it would be more appropriate to apply the model of the total energy economy combined with the macroeconomic input-output model so that the consistency of the individual developments is retained for future estimates. As a qualification, it should be noted that this consistency is only statically supported. The coarsening of the technology description associated with the model of the overall energy economy does not appear to be a serious obstacle to these estimates.

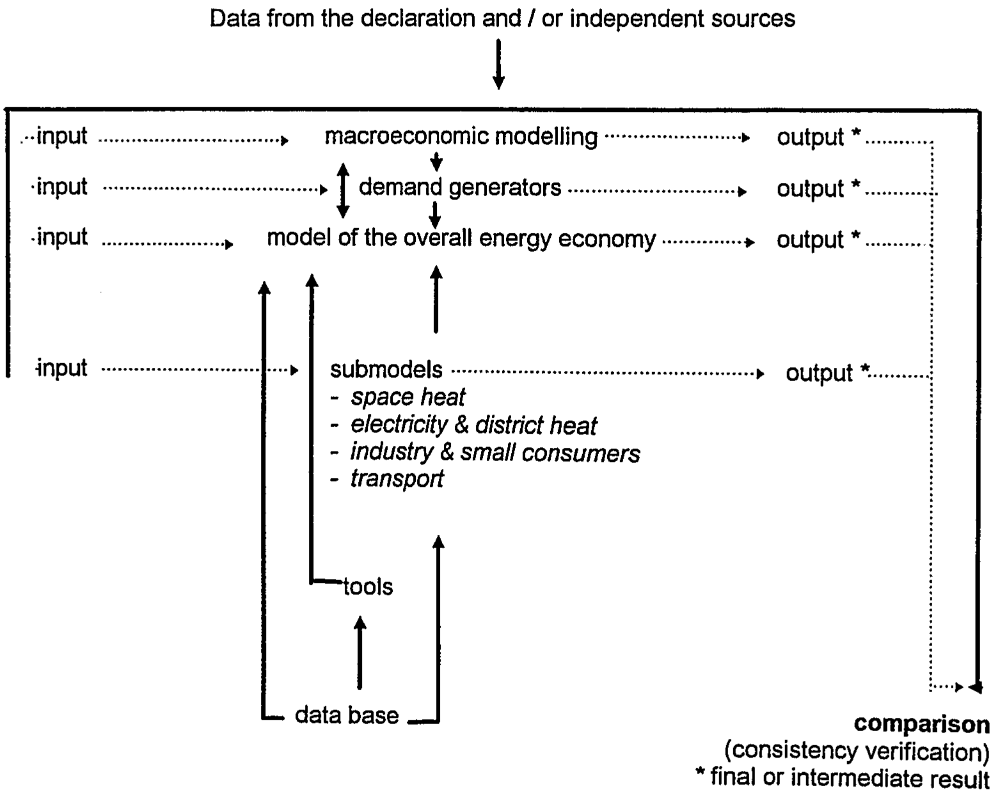


Fig. 2: On the possible application of the IKARUS instruments for consistency review within the framework of verification

Furthermore, there is also the possibility of using the submodels for differentiation purposes, which is, however, only meaningful if their detailed input information can actually be reliably estimated. The development of the models' exogenous data must be predefined. In applying the model instruments for this task it may even be meaningful, as envisaged in the IKARUS Project, to operate the model of the overall energy economy as an optimization model. An estimate is then obtained of whether in the most favourable case, i.e. with an optimum allocation of funds, the emission targets can be achieved, thus representing the upper limit of attainability.

By way of summary, it can be said that the application of mathematical models for verification tasks within the framework of the climate convention, if the necessary additional information can be procured, is possible to the same extent and with the same restrictions as for other tasks. The results must be applied with the necessary critical distance, taking into consideration the necessary conditions and avoiding overinterpretations.

3.2.3 Implementation control

Within the framework of the climate convention, the industrialized countries as parties to the treaty must

- lay down national strategies, programmes and measures for reducing greenhouse gas emissions,
- compile national GHG inventories,
- prepare reports on national measures and GHG inventories.

Reporting by the parties provides the Conference of the Parties with the opportunity of

- obtaining information on national measures and GHG inventories,
- becoming informed about the time sequence of their development,
- making comparisons with information from other parties and their own considerations,
- making estimates of conformities or discrepancies with respect to compliance with agreements or commitments.

With respect to intended verification, the question arises of whether mechanisms or instruments can be specified with which the correctness of national data can be judged on the basis of reports. The type and scope of controls would depend on the object to be investigated. In the case of implementation controls, the objects to be verified are the measures officially announced by a party within the framework of the climate convention.

Implementation is taken at this point to mean a process to be observed which is passed through one or more times before the measure in question is properly established. The aim of controls should be to determine with a degree of certainty on the basis of the reports whether implementation has taken place or the implementation process has been set in motion. This may be followed by an analysis of possible enforcement deficits and the effectiveness of measures in the sense of emission reduction or stabilization.

The essential condition for an appropriate verification by the Conference of the Parties is the application of appropriate information structures and the communication of corresponding information within the framework of reports by the parties. To this end, a conceptional problem-solving approach should be developed referring to the information and safeguards aspects of the implementation of measures.

3.2.3.1 Information opportunities

As is already the case today in the energy sector with the IEA/OECD, the Conference of the Parties could obtain a picture of the situation in connection with a party's measures from existing publications and their own experts - if necessary on site. Dispersed measuring stations or networks and/satellite observations are conceivable as further sources of information suitable for recording the impacts of measures.

According to the initial definition, the assessment should, however, depend on the available information communicated as a report by a party. Other - independent - channels of information are not considered in the first instance.

Over and above the mere naming of measures, further demonstrations of implementation are also required, which may concern the fact of whether a measure has been effectively implemented in the sense of the declared intention.

The information aspects of implementation safeguards make it necessary to envisage, to an appropriate extent, contents and structures for the information agreed upon and exchanged between the national level and international safeguards for reporting purposes (communication). A largely standardized form of report content and scope of reporting obligations is appropriate for reasons of comparability and transparency. The relevant information elements of significance in the structuring, realization and implementation of measures must be selected and laid down in accordance with conceptional approaches for implementation safeguards.

This includes the development of forms and instructions for reporting in detail in order to acquire the required information in a uniform and unambiguous manner. If the scope, content and periodicity of the reports are initially insufficient for detailed and comprehensive application in the verification methods proposed in the following, agreements may have to be reached to make additions and improvements more specific in steps.

In order to take the various properties of the measures into consideration, the reports will probably consist of standardized and measure-specific sections. The determination of the corresponding data structures with their attributes, characteristic features and ranges should be oriented towards the technical possibilities and limitations of the data. A suitable system of information management must be conceived on an international level for the totality of the information communicated ensuring the recording, management and evaluation of the information. Such a system can also be used to simulate and monitor the situation with respect to measures as already practised by international organizations in other sectors, in the course of which different problem areas can be considered providing the basis for specific perspectives and interests.

3.2.3.2 Catalogue of measures

It may be assumed that an overview of possible measures provides a precondition for determining the information to be communicated. It therefore seems meaningful to (successively) establish a complete and comprehensive collection of proposed and conceivable measures which may be used as a catalogue. A compilation of this kind can moreover serve as a starting point and reference for commitments and declarations (official statements) if it is recognized and updated in an international framework. The required regulative framework can be developed in the form of a taxonomy permitting the classification of concrete measures according to determinable properties.

As a means of GHG reduction/stabilization, measures are appropriate which bring about a change in technological and procedural structures and in patterns of human behaviour. The structuring, introduction and realization of measures expected to provide specific effects or impacts will depend on the boundary conditions and reduction potentials of the parties. In order to achieve the stipulated targets, measures of a fiscal, legal, regulatory, financial and administrative nature have been proposed in the highly developed industrial countries.

The measures may represent components of political programmes and strategies as required within the framework of the Climate Convention. An overview of the type, orientation and contribution to the target of the available possiblities of action forms one of the basic conditions for developing strategies. Furthermore, the introduction of the necessary (packages of) measures for individual economic sectors, energy carriers and plants should be accompanied by detailed conceptions of their practicability and efficiency.

As far as the Federal Republic of Germany is concerned, the application in particular of economic, fiscal and regulative instruments is under discussion. The following breakdown can be made for a general classification of the envisaged measures:

- free-market,
- regulative
- and other measures.

A catalogue of measures thus represents a list of measures and instruments capable of being used for GHG reduction. The list may serve as a clear basis for making a selection of measures. By way of example, a few measures will be mentioned in the following from a specific compilation [BMU 1993a] for the Federal Republic of Germany - now updated by National Report for the Climate Convention [BMU 1994a] as well as the Third Report by IMA CO_2 [BMU 1994b]:

- Thermal Insulation Ordinance. Amendment of the Ordinance within the framework of the Energy Savings Act which in future will be based on a low-energy-house standard both for new buildings and also more extensive renovations to existing buildings (heating energy requirements 54 to 100 kWh per m^2 and year, depending on the building type) [example 1]

- Energy Industry Act. The following basic points are to be considered in the planned amendment of this act: firstly, expansion of the target catalogue to include environmental protection and conservation of resources; secondly, equal consideration of these goals in all decisions by the Energy Supervisory Board;, thirdly, closer definition of the legal basis for authorizing the enactment of decrees in view of the target catalogue; fourthly, introduction of a uniform national licensing procedure for overhead power lines of at least 110 kV rated voltage (example 2); fifthly, the most extensive possible exploitation of deregulation potentials to support the utilities' entrepreneurial latitude; sixthly, the special energy supervisory activities should only be retained for electricity and gas to the extent that this is really necessary; seventhly, if a supervisory board has to be maintained then it must be bound to criteria ensuring the predictability of supervisory decisions.

- Transport taxes: first stage: annual motorway users' fee (example 3).

3.2.3.3 Control approaches

The control of implementation of measures makes use of information generated on the national level and subsequently communicated by reports. The reports must contain corresponding statements about national intentions within the framework of commitments and also indications of their realization. The examination of the completeness, transparency and reconstructibility of these statements on national procedures, particularly the implementation process, can be used as a methodological verification approach. The extent of certainty on the implementation of measures can be derived from the amount, degree of detail and quality of the corresponding information in the national reports. The assessment of compliant behaviour is thus based on the evidence and indications required for a corresponding appreciation of the report content. Over and above the announcement of concrete measures and the final declaration of their application, further information may be required depending on the type and scope of the verification methods.

A party's reporting should be based on three different conceptional steps differentiated according to the extent of safeguards or the number of information elements applied. Firstly, national reports on the application of a measure in some form or another may be sufficient. Secondly, a report would have to be made on the course of the implementation process at consecutive points in time in a structured/formalized manner. Thirdly, statements should be communicated on the verifiable effects of a measure on certain impact fields, making use of qualitative and quantitative indicators on agreed standards. These three steps requiring increasing communication efforts for a system of monitoring the realization of instruments and measures for reducing GHG emissions can be characterized as follows:

- unstructured concept (cf. declaration)
- time-structured concept (cf. phase method)
- content-structured concept (cf. cellular method).

3.2.3.4 *Verification possibilities*

The precondition for every type of verification is determination of the object to be verified. This should be the data supplied in the national reports or other information from the countries relevant for fulfilling the targets set in the convention. Within the framework of the climate convention, the member states commit themselves to present such reports at regular intervals. Verification will initially be of a more general nature, e.g. verification of the extent to which the national measures announced in the reports have actually been realized (implementation monitoring). However, a verification of numerical data from the national reports, such as the emission inventories of radiative-forcing gases, can in principle also be undertaken quantitatively. The corresponding data are usually taken from generally accessible sources such as statistics on the production and import of fossil fuels or the national energy consumption statistics. This logical chain cannot always be transparently retraced to the acquisition of the input data, i.e. quantitative determination of the volumes of fossil fuels used for combustion and the respective fuel composition. It is thus very time-consuming for these data acquisition steps to be reconstructed by an international institution, if it is possible at all.

It has been assumed to data that the agreed information is made properly available to the international safeguards organization in accordance with the parties´ commitments. In contrast, or as a supplement, international safeguards may also select the approach of collecting their own information. In accordance with the possibilities of enforcing information gathering, this information is to be found in an extension of the national reports as well as in the additional independent collection of information (impact analysis, intrusiveness, degree of detail). Further sources of data (monitors, measuring networks, satellites etc.) from the range of information and choice of information elements can then be taken into consideration in order to provide suitable information.

Verification is thus based on the review, comparison and evaluation of the available information. An essential prerequisite for the selection and orderly compilation of information elements is an appropriate structuring of information. In considering the information, different aspects can be regarded, a number of which are listed in the following:

- Official reports are information sources. They can be critically screened by means of specific control inquiries, by independent information, e.g. press, secrect service, by inspections and information from independent instutions such as UNO, non-governmental organizations (NGOs), chartered accountants, the "Council of Wise Men", trust company, fact-finding missions etc.
- Various collection methods comprise official determination methods, alternative determination methods, point measurements, measuring networks, airborne observation stations, remote sensing.
- Comparison with similar structures and standards (compatibility check) which may refer to: groups of countries, population figures, GNP, level of supply and saturation with technical systems, economic and energy supply structure, production and release processes, investment and subsidy expenditure, tax revenue.
- Comparison with existing information as well as background knowledge (plausibility): including transparency, comparability, reliability, validity and statistical methods.
- Information evaluation: reconstructibility, completeness, integrity, consistency, accuracy, range.

3.2.3.5 Information structures

Implementation safeguards concern information on the establishment, notification, structuring, classification and implementation of emission-reducing measures. Accordingly, the definition and structuring of information should be appropriately agreed for the purposes of reporting on the implementation of measures in the FCCC protocols and annexes. The implementation process can then be assessed by means of the defined information elements, taking into consideration features typical of the measures. The conceptional steps mentioned above should serve to obtain the necessary degree of certainty that the implementation of a measure has been performed in the sense of the commitment/convention.

Only the parties' own data on their compliance can initially be used as an information source. Surveillance will then aim at verifying the conformity of national data with the norms selected by the states or agreed upon within the framework of the convention. Considerations of plausibility and consistency, inferences by analogy as well as knowledge of the known subsequent effects can be used to assess the statements.

The compilation, integration and evaluation of information as part of international surveillance should be based on the following ordering and structuring modes in order to permit an evaluation of the implementation progress and draw conclusions on the performance and impact of reduction measures:

- catalogue of measures
- taxonomy
- commitment and declaration
- phase method
- cellular method.

3.2.3.6 Commitment and declaration

The minimum process of commitment and implementation required by safeguards can be covered by a concept which establishes the connection between national measures and international safeguards in a simple manner with modest efforts. On the one hand, a report is merely made on the measure envisaged to achieve the target. On the other hand, the current implementation and realization of the measure on the national level is declared. The basic data for verification are thus available without any further details being required.

This concept concentrates on a few data about the intended introduction of instruments which are then verified within a certain time horizon. The steps in this concept can be interpreted as follows:

- commitments, i.e. the establishment of strategies, programmes, measures to be performed on a national level;
- declarations, i.e. the communication of corresponding national data on measures and targets already undertaken or planned for the future;
- verification, i.e. the assessment of the national report on these strategies, goals and measures passed on to the international authority (Conference of the Parties).

Data, targets and commitments with respect to the reduction goals must be available as a necessary precondition for safeguarding national GHG emissions. The periodic declaration of country-specific GHG emission inventories and the announcement of measures to influence them serve to demonstrate that efforts are being made to achieve the goals. These data must verified at certain time intervals with respect to their approximation to the predefined target. As soon as the commitments and their safeguards are agreed in a convention by the parties, there will also be the possibility of international safeguards within the framework of the agreements.

It can be assumed that the commitments will be renewed, modified or extended in the course of time thus establishing dynamic behaviour with respect to declaration and verification. After national commitments in the measure sector have been specified, implementation safeguards may be oriented towards a general course divided into the following sections: formulation of policies and strategies, introduction of measures, resolution of laws and guidelines, enactment of decrees, performance of measures, observation of impacts, assessment of effectiveness.

3.2.3.7 Phase method

The phase model can be used to structure a process sequence. It subdivides the life of an overall process into individual sections (phases). The phases may be passed through once or several times during a life cycle. The completion of phases is marked (milestones) in order to assess the process of a development step and to decide on whether to continue with the next phase. This subdivision of the implementation process seems appropriate since indications of the time-specificity and periodicity of the verification of measures are already available in the wake of FCCC:

- dynamics and time horizon
- regular verification and adaptation.

The phases are formed from task-oriented sections in the course of a measure, the conclusion of which provides a starting point for safeguards or an indication of their fulfilment. In this connection, aspects have already been discussed such as how the realization of implementation safeguards can be undertaken within the framework of the concept of commitment and declaration: periodic commitments (strategies, programmes, measures, scope and details of sectoral strategies); verification of the resolution and introduction of corresponding steps (preparation process, announcement, formal shape, legal enactment, implementation of measures).

The concept can be extended by providing details of the progress of the process of implementing the measure at certain (fairly short) intervals and thus achieving an improvement in the supply of information for the safeguards authority. Modifications and revisions of the procedure must be reported again in the course of time. One possibility of the procedural definition of phases will be presented in the following describing the section-wise subdivision of the implementation process.

The procedural definition comprises the sections (phases) of consideration, planning (hearing), draft (proposal), presentation, consultation, preparation, formal shape, passage, legal enactment, introduction, implementation, realization, verification of realization, amendment. The examples mentioned have already passed through the following phases:
Example 1 - consideration, planning, draft, presentation, consultation, preparation, formal shape, resolution (19.05.1993).
Example 2 - consideration, planning, draft.
Example 3 - consideration.

A further possibility of subdividing the general time course into individual verifiable sections for improved control and transparency in the phase model is provided by the formulation of general development tasks. Considered as an object that passes through several development steps from the idea up to its realization, the following sections (phases) could be considered for an individual measure or package of measures. The impact-oriented definition comprises the following phases: source-specific problem definition; analysis of possible solutions and anticipated effects; design of the (elements of, package of) measure(s); formulation of the specific measure; introduction and implementation as well as enforcement; impact analysis, verification, evaluation; feedback with context, field; retention, modification or abolition of the measure.

3.2.3.8 Cellular method

A further conceptional step consists in deriving support from the observation of suitably selected impact fields. It is assumed that the general impact area of the measure contains identifiable fields on which information is available. It is then expected of a measure that its effects with respect to various elements of the impact area can be determined. The form, realization and implementation of the measure should then be accompanied by the designation of corresponding cells or impact fields of the environment or the impact area in order to permit an impact analysis and, if applicable, performance review (effectiveness and efficiency). The cellular method can be employed for implementation safeguards in order to make use of impact-orientation of the process of implementing the measure and to increase the information quality for safeguards. The concept of the cellular method is selected on the basis of grids, networks and tables in which a subdivision into cells is undertaken. Detailed statements in the sense of the cellular method can only be made by fixing impact fields for concrete measures. Some of the proposed measures with examples of impact fields and possible indicators will be presented in the following to give a rough sketch of the approach:

Example 1. Building type (impact field) and related indicators (number of new buildings per year and building type, number of renovations per year and building type, enclosed space: cm^3/year and building type, floor space: m^2/year).
Example 2. Licensing procedure (impact field) and related indicators: number of licensing procedures per year, of power lines constructed in km/year.
Example 3. Motorway tax disc (impact field) and indicators: number of motorway tax discs issued per year, revenue in DM/year.

On the basis of the three examples it can be seen that the measures are characterized by a direct impact with respect to CO_2 reduction, whose subsequent impacts are difficult to assess before implementation. Only a more detailed impact analysis of the application of measures can provide reliable information about their effects.

Approaches to implementation safeguards were considered in the present contribution mainly under the aspects of information and control. Various conceptual approaches were discussed which could be used to safeguard the implementation of measures with respect to GHG emissions as well as to the international safeguarding of these measures. This basis should make it possible to examine the acceptability and range of the conceptual ideas discussed as a function of the treatment of concrete measures and the empirical knowledge to be thus obtained.

3.2.4 Measuring and surveillance techniques

In this section, the attention is concentrated on techniques, technical systems and methods which can be directly applied for emission accounting - at least for large point sources - or else can make an indirect contribution to accounting. In order to explore the basic usefulness and the conceivable application potential of such techniques, direct measuring systems and their applicability for balancing CO_2 emissions were also investigated. It is very probable that this application option will not be applied as a general verification instrument under foreseeable circumstances. The use of direct measuring techniques would only be conceivable for measuring campaigns at large power stations for a limited period, for example within the framework of joint implementation. As will be shown, the utilization of (existing) measuring networks for air quality control is a verification instrument of only extremely restricted effectiveness, which could perhaps be used as an "attendant measure" for verification.

3.2.4.1 Application of measuring networks and dispersion models

Several measuring (monitoring) networks exist on the international level, largely on the initiative of UN suborganizations and special organizations [UNEP 1990; UNEP 1991; WMO 1991], whose members exchange information about the local quality of environmental media on the basis of voluntary cooperation or have information collected and evaluated by a central organization with the aim of compiling the most universal possible data base. These measuring networks are essentially restricted to environmental monitoring and their institutional organs do not provide any recommendations for measures to be taken. By means of the data base, the participants are able to make a comparative classification of the status of the environmental media in their own region and undertake measures to reduce pollution. Furthermore, the data base provides insights into the effectiveness of regional measures to reduce the pollutant input. The subject of the measurements is largely pollutant concentrations at predetermined locations as well as supplementary status parameters relevant for evaluating the pollution of environmental media (air, water and soil). The aim of these initiatives by the UN organizations is the protection of public health and ecosystems in polluted regions.

With a view to the verification of GHG emission inventories with aid of individual measurements at the source or with the help of measuring networks, interest is focused, in contrast, on the absolute emitted masses (quantity) of these gases released from the most productive sources in the region per time unit, e.g. per year. In principle, this could also involve an aggregration of sources from different emission sectors, to the extent that they are limited to a certain regional area. The difficulties in solving this task are immediately apparent.

3.2.4.1.1 Task of existing measuring networks

The range of tasks of some measuring networks is very extensive and comprises the acquisition of data on the quality of the environmental media of air, water and soil. In the medium of air, the subjects of the environmental measuring networks are above all the most important atmospheric pollutants SO_2, NO_x, CO, ozone, lead and aerosols. In relation to the number of measuring stations, the essential radiative forcing gases, carbon dioxide, CO_2, and methane, CH_4, have only been of minor significance to date. Most of the atmospheric pollutants investigated have only a limited residence time in the atmosphere, are precipitated out of the atmosphere at an early point, or are chemically converted and deposited, and thus only make a slight contribution towards changes in the average global atmospheric concentration. The major attention of these measuring networks is therefore mainly focused on local and regional impacts. The concentrations in the air and in precipitations are measured as well as their development over time and the prevailing meteorological data.

Emission inventories of pollutant sources are not the subject of these measurements. If they are available they are based on data from local or regional institutions, or the operators of the emitting plants themselves. With the aid of dispersion and transport models, emission inventories enable the expected distribution of pollutant concentrations over time and space to be calculated, taking into consideration the prevailing meteorological conditions. Vice versa, in the case of pollutants with a limited lifetime in the atmosphere and thus also a restricted range, conclusions may be drawn about the emission inventories of a region with the aid of dispersion and transport models. If there is only a single emitter for a specific pollutant in a region then it is also possible to estimate its emission inventory.

3.2.4.1.2 Function and technical form of measuring networks

The essential components of measuring networks are the actual measuring stations for data acquisition and the communication channels to the other measuring stations or a central institution for evaluation and further processing of the measured data. In principle, a central collecting point for the data is not necessary, although it is useful for coordinating the methods of data collection and the information derived from the data. The atmospheric measuring stations of the existing measuring networks are mainly located in very polluted industrial conurbations and in order to determine the natural background pollution, if this is possible at all, in regions far removed from human activities. Their major task is compiling data bases on pollution in the regions under consideration. Depending on the density of the measuring stations, atmospheric pollutant dispersion can be traced. Statements on atmospheric pollution, i.e. pollutant concentrations, on a regional scale can also be made with the aid of dispersion and transport models incorporating meteorological data.

Only the concentrations of individual atmospheric pollutants can be determined directly at individual measuring stations in a measuring network. Essential complementary data, apart from time and place, are all relevant meteorological data such as temperature, atmospheric pressure, atmospheric humidity, weather situation, solar radiation, wind velocity and direction. These data may be used as input parameters for dispersion models. The results of the model calculations enable rough conclusions to be drawn about the relative emission strength of a source. If several sources are present then it will probably only be possible to differentiate according to emitter in the most favourable exceptional cases, i.e. for pollutants with a short residence time in the atmosphere and correspondingly limited spatial dispersion.

The measuring stations have the task of providing the actual data. This may be undertaken by continuous measurements directly at the measuring location or else discontinuously by collecting air samples at the measuring location with a subsequent analysis of these samples in a laboratory. The latter method is particularly applied for concentration determination whenever the entire range of possible atmospheric pollutants is to be covered. In contrast, most meteorological data must be directly determined on site.

Established methods for continuous measurement are already available for a large number of atmospheric pollutants. If the most significant gases with respect to quantity and radiative forcing, carbon dioxide and methane, are to be detected by the existing measuring networks, then their concentration is largely determined by optical methods. The measuring methods[3] are essentially based on *non-dispersive infrared photometry* (NDIR). Alternative methods of concentration determination are frequently also available in analytical laboratories.

3.2.4.1.3 Models

---

[3] Cf. the contribution "Measuring Techniques for Radiative Forcing Gases" in the present report.

A consideration of the prevailing meteorological conditions and the chemical degradation ensures that the data are dependent on the quantities of pollutant emitted per time unit in the vicinity of the measuring stations. Nevertheless, the functional relationship may be extremely complex. The source emissions and the meteorological conditions are generally not constant but rather time-dependent variables. If the time course of these variables is determined by additional measurements then a functional relationship between the concentration data and the emissions can basically be determined, on condition that at least one measuring station is always in the region of the wind vane emanating from the source. In principle, this could be achieved by a high density of measuring stations. It would be possible to calibrate the model by making measurements in all conceivable emission and meteorological states. However, all possible states would also have to be exactly covered by measurements. Apart from the impracticability (due to the large number of measuring points in all three spatial dimensions) of such a calibration, it would undoubtedly be simpler to determine the emissions of each individual source directly at the source location.

Atmospheric dispersion or transport models are being developed in order to describe the spatial and temporal distribution of airborne matter emitted from a defined source, taking into consideration the respective meteorological boundary conditions. The attempt is therefore made to predict the concentration of these substances at each location within the range of these substances with the aid of models. This task is simplest when stable meteorological conditions prevail over a wide area.

The transport mechanisms in the medium of the atmosphere are essentially based on diffusion and convection, i.e. on being carried along in the air streams. Detailed knowledge of the meteorological conditions between the source and measuring location are required for reliable statements, which also includes the topological features of the earth's surface between the source and measuring location. Furthermore, consideration must be given to the atmospheric stratifications and the corresponding distribution of the pollutants both at the source and along the transport path to the measuring location, and also to exchange processes between the layers.

Conditions become more complicated if the substance in question is already present in the atmosphere as so-called background, independently of the source, which is particularly the case for long-lived gases of natural or anthropogenic origin. The complexity is further increased if several other sources with similar emissions additionally influence the concentration at the measuring location, particularly if anthropogenic and natural emissions are superimposed. Increasing the number of measuring stations with a suitable distribution corresponding to the local situation can provide further relevant information in this case. Model statements about regional air pollutant distributions can be qualitatively improved with the aid of this information.

From the aspect of verification, an inverse application of the dispersion and transport models would also be desirable, permitting conclusions about the absolute source inventory of individual sources on the basis of the concentration data for radiative forcing gases determined at the individual measuring points. For example, this problem gained particular significance in connection with the Chernobyl fallout. The conditions for estimating the source inventory were relatively favourable here since they involved a pulsed release of pollutants which do not occur in nature, or only in very small concentrations, and which can be detected with great accuracy, and which were largely completely washed out by precipitation and deposited at some measuring locations. Furthermore, the meteorological data were well known and information about the maximum source strength and the distribution of releases in the atmospheric layers at the source location was also available. It was possible to estimate the released inventories of individual radionuclides on the basis of model calculations. It has not yet been possible to independently verify the reliability of these estimated values since the complementary residual inventory is still not available in full and therefore an independent verification of the model statements has not been possible to date.

Conditions are considerably more unfavourable for the major radiative forcing emissions since the relevant gases, e.g. CO_2 and CH_4, have comparatively long mean residence times in the atmosphere and are thus able to intermix on a global scale. Furthermore, considerable natural inventories of these gases are present contributing to a high background concentration. The boundary conditions for model calculations are thus much more difficult to determine. On the transport path between the source and measuring location a volume element of the emitted gases loses a significant part of its information content with respect to the source. There are practical limits to compensating this information loss by the addition of further measuring points. The transfer of conclusions from individual measured concentration values to emission inventories with the aid of dispersion models therefore has little informative value and an estimate of the error bandwidth seems to be rather unreliable. Attempts at determining the origin of GHGs with the aid of isotopic analysis and the isotopic relations thus obtained and of separating the natural and anthropogenic fractions in this manner, or of drawing conclusions about the emitters, have not yet led to any useful results.

3.2.4.1.4 Evaluation

Strictly speaking, a system for verifying the emission inventories of radiative forcing gases requires a continuous measurement of the quantities released into the atmosphere, specified according to gas type. This is particularly true of sources whose operating behaviour depends on human behaviour or on technical requirements, that is to say where normal operation with emissions constant over time and in quantity is not the rule. Sampling measurements for verification purposes in the vicinity of individual sources therefore have little informative value if a verification of the emitters' operating states is not undertaken at the same time.

The transfer of conclusions drawn from atmospheric concentration values obtained from measuring networks to the emission inventories of individual sources or local source aggregations can only be of a qualitative nature even with favourable boundary conditions and the inclusion of detailed dispersion and transport models. Statements on tendencies can at best be made for a few individual substances on account of their favourable properties. The application of measuring network data and their further processing with dispersion and transport models does not seem to be an appropriate instrument for verifying the source inventories of the major radiative forcing gases.

3.2.4.2 Measuring techniques for radiative forcing gases

In order to assess the entire spectrum of possible verification measures with increasing verification density, it also appears helpful to discuss those verification methods which are based on direct and indirect measurements. The possible contribution from currently available measuring techniques to an independent verification of emission inventories in a dynamically developing climate protection regime will be investigated here. Such measures can, at best, only be considered on a large scale for an advanced stage of a climate protection regime. A comprehensive implementation of such measures would represent a state of high verification density.

In the case of the emission inventories, the object to be verified is the mass of radiative forcing gases emitted per year, broken down according to gas type and emission sector. The corresponding data in the national reports, as already mentioned, are gathered from economic or energetic statistics, which cannot always be transparently retraced to the collection of source data. An alternative to this procedure is the basic possibility of directly measuring the masses of major radiative forcing gases emitted per year.

In practical national emission monitoring of other atmospheric pollutants, corresponding to the Federal Emission Control Act (BImSchG), only the pollutant concentrations are recorded in mg/m^3. Verification is thus restricted to evidence that certain pollutant concentrations only exceed a predetermined limit in a certain fixed period with a limited frequency. However, the verification of emissions within the Framework Convention on Climate Change requires absolute emitted quantities. In the case of CO_2 verification for fossil-fuel-fired power stations, this also means, in addition to continuous measurements of CO_2 concentrations, recording the entire mass flow of the flue gases. Additional safeguards measures are therefore necessary in order to ensure that all the waste gas flows from a firing system are covered, that is to say the measuring point is not bypassed.

The further discussion will be restricted to CO_2 and CH_4 since according to the present state of the art a verification by measuring technology seems possible here to a limited extent due to their source characteristics.

3.2.4.2.1 Verification suitability

Approximately 80 % of anthropogenic CO_2 emissions originate from the combustion of fossil fuels, i.e. in the energy sector. Together with the other radiative forcing gases arising during the utilization of fossil energies, the CO_2 emissions from the energy sector are held responsible for approx. 57 % of the additional (anthropogenic) greenhouse effect [Lashof 1990]. Apart from CO_2, methane also plays a decisive role amongst the greenhouse gas emissions influenced by human activities from the aspect of quantity and radiative forcing. The most important contributions arise from coal mining, rice cultivation, stock breeding and domestic refuse dumps.

The wide range of source configurations becomes apparent even with this brief list. However, the possibility of making a selective quantitative record of greenhouse gases greatly depends on the nature of the respective source. The technical preconditions for verification directly at the source with the aid of measuring instruments are considerably restricted by the nature of the source configuration. From the aspect of verification suitability it is therefore meaningful to initially consider only those sources which make a major contribution to the total emissions of greenhouse gases and for which it appears basically technically possible, also with respect to economic considerations, to apply quantitative measuring techniques for verification purposes. These are all point sources, i.e. sources which release the radiative forcing gases into the atmosphere in a controlled manner and in line systems. The richest point sources for CO_2 are fossil-fired power stations and for CH_4 the waste air shafts of hard coal mines. The technical conditions for continuous and direct measurement of radiative forcing gases are most favourable here.

Apart from the above-mentioned point sources, there are a number of other source configurations which are less accessible, or not accessible at all, by direct measurement. For instance, the private household and transport sectors consist of a large number of small point sources which cannot be individually covered by measuring technology on account of their number. Such sources are aggregated to mass sources in conurbations. The third major source category comprises agriculturally utilized areas, which are therefore termed area sources.

Although emissions from these source configurations are also measurable, nevertheless this requires the assistance of models since the boundary conditions, which alter over time, cannot all be covered simultaneously by measurements. Measurements are restricted here to the determination of typical emission parameters and also typical boundary conditions. Together with the models, it is then possible to make an estimate of the annual emissions.

In the case of the agricultural areas, characteristic emission features and their annual variation can be measured for specific types of use. The measured data can be correlated with other emission-determined factors, such as soil type, application of fertilizer, vegetation sequence etc. As in the case of mass sources, it is frequently possible to compile emission inventories with the aid of models. The measured data may then serve as input values for model calculations or may be used to calibrate the models.

Apart from the strong point sources, it is probably not possible to balance the other sources by measuring technology due to their complicated characteristics. In this case, the potential of measurements is to be found in extending knowledge about the source features and based on this modelling a source with the goal of obtaining the best possible estimate for the source inventories.

3.2.4.2.2 Integration into existing measuring systems

It appears meaningful in designing a measuring procedure for verification purposes with radiative forcing gases at large point sources to make use of experience gained in implementing the provisions of the GFAVO (Großfeuerungsanlagenverordnung - Large Combustion Plant Ordinance), especially since measuring instruments are used here which, with respect to their technical design, could be used to measure at least CO_2 and CH_4 concentrations after minor modifications without a great deal of effort. Furthermore, the measuring instruments used in implementing the GFAVO are licensed throughout Germany. The modular design of these measuring systems permits them to be easily extended, e.g. to determine the CO_2 concentration.

Nevertheless, it must be remembered that there is an essential difference in the measuring philosophy for fulfilling the GFAVO and that for verification purposes. On the one hand, the conditions of the GFAVO are concerned with observing concentration limits which may only be exceeded by a fixed amount on a restricted number of occasions otherwise penalties will be incurred. On the other hand, measurements for verification purposes are interested in the overall quantity of radiative forcing gases, in particular CO_2, emitted into the atmosphere during a certain time interval with the aim of setting up a balance. Furthermore, it must be remembered that the institutional target groups for the respective data are probably different institutions and that for this reason a strict division might be desirable. The collection of data required by the GFAVO is undertaken solely on the basis of national legislation. In contrast, there is at present no legal framework for greenhouse gas emissions measured exclusively for the purpose of an independent verification. There is a need for regulation here in connection with anchoring international verification measures in national legislation. These considerations should therefore only include the measuring technology in the GFAVO provisions as a model, the institutional and organizational division (interface) should be discussed in connection with a possible implementation of a verification system.

With respect to the requirements in designing a measuring system for verification purposes, i.e. from sampling up to presentation of a digitized signal for the concentration of a radiative forcing component of power station emissions, conditions are found analogous to those for a system to record GFAVO-relevant pollutants. The extent to which one or more components for determining radiative forcing gases should be modularly integrated into the existing system or installed completely independently of it depends on whether interventions in the system, i.e. for calibration, can be coordinated on an organizational basis.

3.2.4.2.3 Requirements made on a measuring system for verification purposes

The analogy between measurements for verification purposes and those to fulfil the GFAVO requirements is restricted to concentration determination. As already discussed above, the differences between the two tasks are to be found in the volumetric flow rate measurement necessary for verification and in the treatment of the data. The technical possibilities of implementing volumetric flow rate measurements at point sources with large emission cross-sections are restricted. Most methods are based on an extension of classical measurement procedures. In current practice, volumetric flow rate measurements are only performed in exceptional cases and then only for a limited period. The major problem is the lack of knowledge about the representativeness of a parameter, e.g. a pressure value, determining the local volumetric flow rate measured at one point in the flow cross-section. According to experience, a gas flow in a stack has a certain velocity profile over the cross-section, whose maximum is usually at the centre. This velocity profile need not generally be rotationally symmetrical. Although it is technically possible to measure this profile with the aid of network measurements, nevertheless this is very complicated and is thus out of the question for verification measurements. The currently established methods have already been described in detail [Kolke 1993]. Their suitability for volumetric flow rate measurements are shown in **Table 7**.

A further, but less problematic, difference between existing emission monitoring systems and verification requirements is to be found in data evaluation. Whereas the GFAVO requirements are restricted to documenting concentration data, the aim of verification measurements is to record the quantities of a radiative forcing waste gas component emitted during a fixed period. To this end, the emitted greenhouse gas components must be calculated and incrementally cumulated with the aid of certain average concentration values determined at short time intervals (short in comparison to changes in the operating state) and average volumetric flow rates measured in the same interval. Accordingly, the difference in the two systems only affects the evaluation algorithm and does not make any special demands.

Existing emission monitoring systems contain, to a limited extent, measures designed to prevent a falsification of the results. This is generally achieved by sealing the measuring instruments. More extensive steps may possibly be necessary for verification measurements capable of revealing intentional interference in the entire measuring system from sampling up to the evaluating computer, at least retrospectively. The greatest possible transparency of the measuring system is of assistance here. There are numerous examples of possible authentication measures in the field of IAEA safeguards. In the same way as existing emission monitoring systems, measuring instruments envisaged for verification tasks should be subjected to a quality assurance programme. Although failure or malfunction of a measuring instrument would not have the same serious consequences as in the case of nuclear material safeguards, nevertheless frequent mismeasurements could undermine the credibility of a verification regime based on measuring technology. Furthermore, it could be conceivable that the functional status of the measuring system could be verified by remote interrogation. In the same way, the cumulative data could be transmitted at the end of a balancing period. Measures of this type could perceptibly relieve inspection efforts on site and inspections could possibly be reduced to random sampling. Public data networks, telephone networks or satellites could be used as channels of communication.

An alternative possibility basically consists in measuring emissions at a certain distance from the source. Corresponding systems are currently being developed or tested. These are essentially mobile systems capable of determining the pollutant concentration at a distance of several hundred metres after emerging from the source. Supplementary measurements of the gas velocity by laser anemometers could also permit a measurement of the volumetric flow rate [Tank 1991]. A development project with this aim in mind was sponsored by the BMFT between 1990 and 1992 [BMFT 1990]. The concentrations were measured with the aid of a modified Michelson interferometer in which the optical wavelength changes were not achieved by linearly sliding mirrors but by rotating retroreflectors. With broadband light sources, the result is an interferogram from which a wavelength-dependent spectrum can be calculated by a Fourier transformation. The measured volume is determined with the aid of the spectrometer field of vision and the geometrical position data of the measuring location determined relative to the emission location. It is also possible to measure the velocity at the gas outlet with a laser anemometer. In order to determine the volumetric flow rate it is only necessary to know the cross-section of the source opening.

3.2.4.2.4 Proposals for further development

There are a wide range of gas analysers available on the market to determine the gas concentrations. On the basis of experience in the field of emission monitoring, absorption photometers operating according to the NDIR principle also seem suitable for verification purposes. Corresponding photometers are also available for carbon dioxide and they are used for example in the global measuring network to determine the concentration of atmospheric CO_2. Since, like all other greenhouse gases, methane is infrared-active it can be detected by NDIR photometers. Appropriate gas analysers for this purpose are also commercially available.

As a competing instrument, in the past few years several designs of Fourier transform infrared spectrometers (FTIR) have been developed and, starting from the original Michelson interferometer, have been modified in such a way that they are of manageable size and have also proved their worth in field applications. The advantage of this technology is its ability to cover the entire infrared spectral range with one single measurement, i.e. to determine as many infrared active gas components as required simultaneously. Furthermore, FTIR spectrometers can measure both emission and also absorption spectra. However, the evaluation requires a powerful computer and, depending on the number of components to be analysed, complex evaluation algorithms to implement the Fourier transformations. FTIR spectrometers have already been tested in a combined heating and power station [Wülbern 93].

Both measuring principles, NDIR and FTIR, can also be used for all other greenhouse gases. Measuring techniques based on the FTIR principle already provide information about the greenhouse gas concentrations of all greenhouse gases with each measurement. Detection of a specific greenhouse gas essentially only depends on the evaluation algorithm.

Method	Absolute accuracy	Continuous measurement	Temperature dependence	Demands on flue gas	Design features	Calibration	Suitability for the task
rotating-cap anemometer network measurement	± 3 %	not possible (contamination)	no	dry, dust-free	only manual measurements	none	no
differential pressure measurement, pressure tube network measurement	± 3 %	not possible (contamination)	yes	dry, dust-free	requires effort in the channel	not applicable	no
differential pressure measurement WILSON pressure grid	approx. ± 4 - 5 %	yes	yes	not wet, without sticky particles	requires effort in the channel	pressure tube network measurement	in part
differential pressure measurement ITABAR probe	> ± 5 %	yes	yes	none	simple in the channel	pressure tube network measurement	yes
eddy frequency measurement VORTEX sensor	< ± 10 %	yes	in part (MB initial value)	none	easy to handle	pressure tube network measurement	yes
ultrasonic measurement	approx. ± 4 %	yes	no	none	easy to handle (probe contamination)	pressure tube network measurement	yes
laser-Doppler LDA network measurement	± 3 %	yes	no	fume-free	difficult traversing	none	yes
laser-Doppler LDA single measurement	< ± 10 %	yes	no	fume-free	easy to handle	none	yes
output measurement at suction draft	inaccurate	not possible (contamination)	no	homogeneous completely clean	-	-	no

Table 7: Established methods of volumetric flow rate measurement

Considerable development efforts would still have to be invested in volumetric flow rate measurements. In flue gas ducts with large diameters, the data obtained by classical methods involve very large errors. It may be presumed that estimates of volumetric flow rates by the plant operators, with the aid of operating parameters and fuel throughput, are of much higher quality than the results of corresponding measurements. Qualitatively comparable measurements (network measurements) can only be implemented with unacceptably great efforts and are not appropriate as a continuous method.

Optical methods, e.g. laser-Doppler anemometry, have a considerable development potential. It should be possible to modify existing systems in such a way that the averaged flue gas velocity can be determined via the cross-section of a flue gas duct.

When the problem of measuring the volumetric flow rate has been satisfactorily solved, a test programme should be implemented with a system developed from an existing emission monitoring system, e.g. by utilizing the existing sampling system. Such a system requires its own evaluation computer with corresponding software in order to calculate the accumulated output of radiative forcing gases from the measuring signals of the concentration measurement and the volumetric flow rate measurement in incremental steps. A suitable test field for the first field experiment would be a large coal-fired power station.

3.2.4.3 Satellite remote sensing systems

After the energy sector, other important sources of anthropogenic greenhouse gas emissions are destruction of forests (land clearing, burning off), agriculture (fertilizers, rice paddies, stock breeding), as well as landfills. If an agreement on specific goals for the reduction of GHG emissions from these emission sectors were to be reached then the problem of verification would also arise. This would apply equally to an agreed expansion of GHG sinks, for example by afforestation programmes. (The possibility of afforestation is already available within the framework of the net emission concept.) The question here is contribution which remote sensing by means of satellites could provide for verifying such agreements. Remote sensing does not at present play a part in monitoring the FCCC (not even for the verification of afforestation); the agreed systematic application of remote sensing would only be conceivable within the framework of a denser verification system.

3.2.4.3.1 Methods and procedures for determining emissions

Direct methods of determining emissions from the above-mentioned sectors (by means of techniques for measuring mass flow) cannot be applied in practice since the emission sources are characterized by large area, great number of emitters and in part intermittent character. The quantities of emissions released from these dominant diffuse or area emission sources must be calculated, i.e. indirectly determined. Nevertheless, measuring programmes on determining emissions from small, definable areas provide first indications of plausible estimates on which the calculations are based.

Such indirect methods of determining emissions are widespread and ideally based on two data sets: firstly, directly measured parameters and, secondly, emission factors. These indirect methods will be outlined very roughly with the example of determining CO_2 emissions released by deforestation. The destroyed areas are determined (in the ideal case) with the aid of measurements on the ground, from the air and/or from space.[4] The composition and quantity of vegetation per comparable unit area is then estimated. Depending on the age, density, species variety etc. of the vegetation, an estimated content of carbon stored in the biomass is allocated to the areas. If an oxidation factor (completeness of combustion) is taken into consideration, multiplication of these values indicates the released quantity of carbon, primarily in the form of CO_2 and CO.

In the case of such procedures, the uncertainty margins for emissions are rather large simply because the often very specific emission factors are not easy to determine and the effort required for their determination is considerable and continues to increase the more precise and specific the factors should be. This problem can be reduced by specifying emission factors upon which the states have reached mutual agreement, even if they only approximate to reality. This permits transparency and comparability of the emission calculations. The calculation of emissions by a country becomes more

---

[4] In practice, the data are not obtained area-wide for all forested areas in a country, or indeed in the world since the efforts required would be extremely great. Instead, the data are obtained from representative samples and extrapolated. For supporting institutions and methods of forest industry cf. the succinct representation in [Bundestag 1990].

complicated if the states declare their net emissions, that is to say if sinks are considered. Areas must be determined and factors specified for them as well, thus defining the removal of GHGs from the atmosphere per unit of time (e.g. year). These topics have been touched upon in connection with the Framework Convention on Climate Change and IPCC has presented proposals for such agreed emission factors [IPCC Draft Guidelines 1994].

From the perspective of verification, the determination of direct parameters is the decisive point in the process of verifying compliance. Great efforts must be expended here to verify the correctness of the national data. In contrast, if the emission factors are specified by mutual agreement, verification is restricted to merely reviewing the actual application of these factors in calculating the national declarations. Whether they are factually correct, i.e. whether the emissions factors indicate the actual quantity, for example, of carbon stored per unit (e.g. hectare) on a certain area is admittedly of significance with respect to the material regulatory goal of the convention[5] , but is irrelevant for verification purposes. Emission factors are conventions, laid down by mutual agreement, and as such are to be regarded as valid for the verification process.

Studies of global environmental change would be unthinkable without remote sensing satellites (cf. [CEOS 1992]), which may also make an important contribution to the verification process by providing direct parameters. They already do this to a certain extent: their sensors provide, e.g., data on the forestry sector (area and structural surveys, deforestation and afforestation, forest decline), land use (area structure), agriculture (agricultural structure, set-aside schemes, harvest estimates), nature conservation (identification and observation of protected areas), regional planning (infrastructure, planning of transport routes) and they are capable of identifying landfills. Their application for the verification of a climate convention (and of protocols), particularly in the forestry and agricultural sectors, would not be a basically novel task from the technical perspective (cf. [Hönsch 1992]; [Gastellu-Etchegorry 1991]). Nevertheless, this would require the solution of general problems of remote sensing and the fulfilment of specific demands on satellite systems and the politico-institutional boundary conditions for their application, and on the use of information thus obtained [Lanchbery & Salt 1993].

---

5 Such factors should be as precise as possible so that emission reduction strategies may be optimized.

A country's emissions cannot be balanced by satellite sensors. Sensors can at best determine the chemical composition of the atmosphere in a column of air since methods are not currently available by means of which conclusions could be directly drawn about the total quantity of GHG released by a country. The major strength of satellites is (amongst other aspects) the identification of areas and, to a certain extent, the discrimination of the features of specific, small-area objects or structures in these areas. Naturally, there are also inadequacies in the practical application of satellites for specific tasks, as shown by the lack of agreement about the size of the forest area destroyed in Brazil and other regions (cf. [Tropical Forests and Climate 1991]). For the satellite sensors are neither optimally designed for this task nor are the definitions of "forest", the survey methods or the methods of evaluating satellite pictures standardized (cf. [Kenneweg 1992]).

Even if the basic feasibility of monitoring forests by means of satellites for verification purposes has been demonstrated ([Lanchbery & Salt 1993]; [Hönsch 1992]), the general problems encountered by all users of satellite data with the information gathered by remote sensing systems should not be ignored and need to be solved on a national and international level.

- The data only in part satisfy requirements with respect to spatial, temporal and spectral resolution.
- The continuity of remote sensing is not guaranteed (primarily for cost reasons).
- Methods of data interpretation and classification are in need of improvement.
- Information on existing data sets and access to these data must be improved.
- In general terms, the interaction between the manufacturers and operators of satellites and the various user groups is still inadequate. Nevertheless, the necessity of paying greater attention to user interests in designing satellites has already been recognized.

In spite of these problems, satellites offer good opportunities of determining relatively reliable parameters, particularly for the emission sectors of forestry, land use and aspects of agriculture, for example about the area of forest destroyed. This ability influences the conception of a verification system.

3.2.4.3.2 Benefits and problems of satellite remote sensing systems

The Framework Convention on Climate Change stipulates that states should determine their emissions of GHG and declare them, if possible according to sectors, i.e. to disclose them to the international community of nations. Even if this is not yet a constituent part of contractual obligations, nevertheless as part of a fully developed climate regime the states should not just declare these (net) emissions but rather also the directly measured parameters on which they are based, i.e. the size of the deforested or afforested areas, tree species, size of the paddy fields, number and location of landfills. This information can basically be confirmed or falsified by satellite remote sensing (admittedly in combination with air- and ground-based activities). If there is a lack of this basic information then verification has no real starting point.

The critical variable in emission declarations is therefore the areas and their change, and this is the advantage of satellite remote sensing in comparison to other surveillance procedures.

All satellite observation systems for identifying changes on the earth's surface depend on the accuracy and reliability of the base line, from which changes (e.g. forest area, tree species) are determined. Such data are in part already available for the sectors of forestry and agriculture compiled above all by the United Nations Food and Agriculture Organization (FAO) (cf. [Tropical Forests and Climate 1991]). This is particularly true of the forest areas and in part of their status. If one turns to the technical side of verification capability then fulfilment of the verification task and solution of specific remote sensing problems requires a space-based verification system which should comprise at least two categories of satellite [Lanchbery & Salt 1993]. The first category continuously observes the earth's surface with low resolution, whereas the second provides discontinuous pictures of greater resolution to identify small-area changes. All satellites should be equipped with both radar sensors and also sensors to detect visible light and near-infrared. There are currently some operating satellites which fulfil these conditions in part (IRS, LANDSAT, Spot, ERS, with high resolution, and EOS, Meteosat, TIROS-N/NOAA with low resolution). An increase in the number of available satellites is in preparation within the framework of "Mission to Planet Earth" activities. The launch of Earth Remote Sensing Satellite (ERS) 2, serving amongst other aspects for global vegetation observation, planned for 1995 could also represent a module in such a verification system. **Table 8** summarizes the minimum requirements for such a satellite system.

The flow of information required to fulfil the verification task can be broken down into the phases of data collection, data processing and data evaluation. In the Vertic study [Lanchbery & Salt 1993], the problems to be expected in these three stages are discussed.

Data Collection Problems

The identification of areal forest destruction is relatively unproblematic. However, this is not the case for the observation of changes in forests due to selective deforestation. The specific removal of individual trees ist difficult or impossible to observe by means of satellite sensors since the sensor resolution is not high enough. A further problem is the differentiation between selective removal and natural tree death. In both cases, a specific assessment by air- or ground-based activities may be necessary. Furthermore, cloud cover, particularly in tropical regions, prevents continuous observation. It might be necessary to make increased use of radar satellites here. In the agricultural sector, it would require too much effort to count cattle etc. by satellite so that other procedures, such as statistical recording, should be preferred here. Radar sensors, in particular, are suitable for determining the area of rice paddies but they should be supplemented by measurements in the range of visible and infrared light.

TASK	SENSOR TYPE	NUMBER OF SATELLITES REQUIRED	SATELLITE TYPE
infrequent observation with high resolution	visible / infrared radar	1 . 1	IRS, JERS, LANDSAT, SPOT MOS ERS, JERS, Radarsat
frequent observation with low resolution	visible / infrared radar	1 1	EOS, FY-B, METEOSAT, TIROS-N, NOAA ERS (?)

Table 8: Minimum requirements for a satellite system

Data Processing Problems

These problems are not of a basically novel character but the cost of installing such a system to process large data quantities is very high. Even today the quantities of data provided by scientific, non-military satellites exceed that which can be used. As both operators and users of satellites have recognized there are already considerable "data graveyards", which threaten to continue growing since the information supply from satellites continues to increase. There are estimates according to which at the start of the 21st century such satellites will provide one terabyte of information per day. In order to be able to utilize the information at all, the greatest priority should be given to the specific data processing, evaluation and provision of user-specific information.

Data Evaluation

In order to determine changes an exact definition must be given of what is to be designated as such. For this reason, input data about areas and their utilization must be precise. It is also necessary to determine the frequency with which changes are measured. If the intervals are too long then a small, correctable alteration may turn into an unacceptable change. On the whole, a data evaluation system based on digitized, three-dimensional information about forests and agricultural land use seems particularly suitable to compare data obtained at different times and draw reliable conclusions.

3.2.4.3.3 Technical aspects

Apart from the geometrical resolution of satellite pictures, the spectral resolution also plays a significant part in verifying land use and particularly in the differentiated allocation of vegetation cover. Of the civilian satellites in operation to date, Landsat 5 TM provides the most useful data for this purpose with respect to spectral resolution. In addition to the three spectral channels in the visible region, Landsat 5 TM has four further channels in the infrared part of the spectrum providing essential additional information to determine the vegetation status of the observed section of the earth´s surface. In this way, different reflection properties in the invisible region can be used to represent surface cover which cannot be differentiated in the visible region by allocation to a certain colour or grey level.

In each spectral region a picture is composed of individual points (pixels) for which a corresponding intensity value, representable by grey levels, is individually stored on a scale of 256 channels. This intensity value is a measure of the reflectivity of the object field observed on the earth's surface corresponding to the pixel. If one considers the frequency distributions of the grey levels in all available channels then correlations are observable for many objects which cannot be differentiated in the visible region alone permitting conclusions to be drawn on the type and state of vegetation. Corresponding investigations were performed by Klaus and coworkers [Klaus 1994] in a test area near Bonn, where in addition to Landsat 5 TM data aerial photographs and reference information obtained on the ground were also available. Average grey values for the individual spectral channels were calculated for specially selected test areas of known area coverage. Various functional linkages of these average grey values for different channels permit the compilation of so-called vegetation indices characteristic of a certain land use form. The possible functional linkages are differentiated by the level of accentuation or suppression of various undesirable interferences which differ from case to case. The calculated vegetation indices can be represented again on a 256-level grey value scale and by a pixel-wise adaptation to the aerial photograph they can be combined into a synthetic satellite image in which features of special interest are accentuated. The fluctuations, measured in the form of the standard deviation, of the synthesized grey values provide, furthermore, a measure of the homogeneity of the area coverage. The following figure gives an example of the frequency distributions of the grey values for a certain vegetation index in the labelled test regions.

If the allocation of the vegetation indices and the corresponding actual area coverage have been fixed by verification on the ground then this provides a type of calibration. Due to different external factors of influence, such as different exposure conditions or vegetation forms, it appears necessary to undertake an on-site calibration if the described method is used in other regions.

For verification purposes it would be desirable to have universal vegetation indices. The great variability in the possible area coverage in various regions of the world makes it necessary to determine the most appropriate vegetation index or a combination of several indices for one region by determining and evaluating reference areas scattered throughout the world. The application of neuronal networks would be conceivable here, which on the basis of the information obtained in the reference areas, learn the ability to apply the respective optimum vegetation index. This all comes down to recognizing patterns with a variable appearance. Some of the algorithms have already been tested in practice, e.g. in recognizing handwriting. A research project is currently being jointly performed in this field by the University of Bonn and the Programme Group Technology Assessment at the Research Centre Jülich.

3.2.4.3.4 Political and economic aspects

This type of space-based system for verifying the compliance of states displays a number of features with important political and economic implications. First of all, it must be clarified whether it is necessary to entrust an international organization with the task[6] of implementing verification with its own satellites or whether in view of the growing number of national satellites it would not be more appropriate to make use of their information. Practical considerations and the minimization of cost are points in favour of the utilization of satellites already installed even if they are not optimally tailored to verification purposes. The necessary information could conceivably be purchased from the satellite operators if required. A more acceptable approach is the evaluation of pictures and information at an international safeguards organization in order to ensure independence and comparability. Such a verification system should also include agreements between an international organization entrusted with this task and the states granting the organization the right, if required, to itself gather further clarifying information in the country concerned. This requires close cooperation with the competent national agencies. It seems imperative to achieve a fair distribution of costs between the states, who must fund the construction and operation of the satellite monitoring system, and existing systems should be integrated as cost-effectively as possible. On average, these satellites only remain operational for a few years so that there is always a danger that the design and operation of a new satellite monitoring system specifically constructed for verification purposes would come to grief due to high costs. It cannot be expected that complete global surveys of the forests and their changes could be implemented frequently and regularly. Surveillance will have to be restricted to hot spots of forest destruction and selected regions in other emission sectors.

---

[6] Whether the establishment of a comprehensive verification organization is necessary at all is discussed elsewhere. It would be conceivable that essential work on procuring the information necessary for verification could be delegated to existing organizations engaged in collecting similar information (for example the FAO but also other organizations and research institutes with remote sensing programmes).

Since, as discussions in the run-up to the Rio Conference (UNCED) have shown, a number of states have considerable reservations both about obligations on the protection of forests and also concerning satellite remote sensing by an international body, it seems meaningful to develop an evolutionary concept based on existing activities to determine the status of the global forests (e.g. compilation of inventories by the FAO), to first implement individual projects in order to dispel scepticism about monitoring and develop incentive systems encouraging countries to participate in agreements and verification measures. Such incentive systems should not only include programmes on the protection and sustainable utilization, e.g. of forests (cf. [Tropenwaldbericht 1993]), but also the more extensive transmission of such information arising from remote sensing to the cooperating countries. This would not only provide them with assistance in implementing their national climate protection policies[7] , but also their economic development projects, such as exploitation of raw materials, could be implemented more efficiently and in an environmentally friendly manner. In this connection, it would also be meaningful to reinforce the capacities of national space institutions in order to identify and enlist new user groups for satellite information [Lanchbery et al. in preparation].

3.2.5 Digression: joint implementation and verification

The achievement of the goals of "reduction of greenhouse gas emissions" and "sustainable economic development" requires large amounts of capital which have to be raised primarily by the industrial nations. National budgets will not suffice to comply with this task. In order to use the available capital as efficiently as possible and to raise additional capital for the achievement of the goals of the climate convention, the basic principles in (Art. 3(3) of the Climate Convention) implicitly point the way to the concept of Joint Implementation (JI), i.e. joint action by states for the implementation of policies and measures. At least amongst the industrialized states, this concept is receiving increased interest since it seems to represent a cost-effective way to realize at least part of the national commitments on emission reduction. However, it has not yet been

---

7 This does not only refer to countries of the "South", which experience considerable problems in the internal enforcement of their policies, for instance on the protection of national parks or areas of indigenous population. Satellites could also help to monitor, for example, compliance with the limit envisaged by the Canadian government of restricting clear-felling areas to 60 hectares (currently up to several thousand hectares).

possible to win international agreement for such a procedure and to agree on the basic features - let alone details - of JI. For although in parts of the political and economic discussion the concept was basically welcomed, nevertheless the proposals for defining the boundary conditions for practical application display numerous points of disagreement [Loske & Oberthür 1994], although JI basically offers advantages to all those involved. The following consideration will therefore only deal with a subaspect, inasmuch as this is linked to the possibilities of the climate goals realizable in connection with JI. The term JI will be used restrictively here and exclusively applied to agreements between states.

3.2.5.1 *Basic principles of the JI concept*

The concept of Joint Implementation in connection with the Framework Convention on Climate Change proceeds on the economic maxim that given resources should be used to achieve the greatest possible effect in view of the basic goal which, in the present case, is a reduction in global greenhouse gas emissions. This is based on the justified assumption that the costs per avoided mass unit of emitted greenhouse gases or greenhouse gases additionally bound in sinks will vary greatly from state to state. This particularly true if industrialized countries are compared with "developing countries".

The emission of greenhouse gases into the atmosphere has so far been free of costs from an economic point of view. Tools for the enforcement of obligations undertaken upon accession to the Framework Convention on Climate Change with respect to a limitation of emissions are regulatory or fiscal measures at the national level, which allocate a monetary value to the quantity of emitted greenhouse gases. Regulatory as well as fiscal measures for emission reduction assign a value to the emitted mass unit of greenhouse gases which, in the first case, may be determined by threatening production restraints and, in the second, by taxation. The mass unit of greenhouse gases saved is thus given a capital equivalent and provides an incentive for investments in measures reducing emissions. In industrial countries with highly developed technologies, the potential for low-cost reduction measures (no regret) or those achievable with a limited capital input will probably be exploited before long. From a global perspective, it therefore appears meaningful to achieve a much greater effect with the same capital input in another state with unexploited low-cost savings potentials. In consideration of the capital input, the provider of capital will be credited a percentage of the emissions saved in the receiving country against savings obligations in the donor country. With respect to CO_2, this principle is termed *carbon offsetting*.

The expectation that the JI concept will provide an effective incentive for wide-ranging global emission reductions is not so much based on the implementation of individual JI projects, but rather on the perspective of a progressively developing global market whose actors are providers of capital looking for emission rights on the one hand and sellers of emission rights on the other. At the end of such a development, a comprehensive market could be established in the sense of a *comprehensive approach* including all greenhouse gases, considering sinks in addition to sources and involving all member states of the Framework Convention on Climate Change. However, such an approach must never lose sight of the ultimate goal of global emission reduction.

While the basic idea of joint implementation appears simple and clear, there is at present no distinct picture concerning detailed practical application, especially with a view to the comprehensive approach envisaged.

For example, the acquired right to unreduced emissions on the part of the provider of capital after having exploited all low-cost reduction possibilities in his own country conflicts with the seller's obligation to make corresponding relative reductions on his territory. This becomes a problem when the receiving partner is a developing country whose emissions are likely to rise in the course of its economic development. This state then runs the risk of being restricted in its future economic development by selling its emission rights. This risk should be minimized if a limitation of the national reduction commitments in the donor state capable of being fulfilled by JI projects to a defined fraction of its overall commitments is agreed upon globally in a mandatory manner. However, a precondition for this is the commitment, at least by the donor states, to observe quantitative upper emission limits within a certain time frame.

3.2.5.2 Framework criteria for JI

Although the basic idea of JI is simple, its application implies a complex comprehensive concept. The secretariat of the International Negotiation Committee (INC) has put up for discussion a proposal for framework criteria to be fulfilled by a JI project. The aim of these framework criteria is to avoid undesirable developments in connection with JI. It is difficult to evaluate these framework criteria with a view to possible consequences since no extensive experience is so far available. Some aspects of the framework criteria for JI have been discussed in detail in recent publications, see e.g. [Kuik 1994], and at the Groningen International Conference on Joint Implementation [Spradley 1994]. These aspects will therefore only be mentioned in **Table 9** but not discussed in detail.

Compliance with the framework criteria for JI should be a prerequisite for the pro rata crediting of emission savings on foreign territory against the obligations of the provider of capital. An essential criterion is the requirement of actual and measurable results relative to the goal of the Framework Convention on Climate Change, compared with defined reasonable reference values. No problems should arise for states with clear reduction commitments in contrast to those without any obligation to reduce emissions or those who are even entitled to emit additional amounts of greenhouse gases as part of their foreseeable economic development. In these cases, the reference values can only be based on future internationally recognized projections within the scope of economic development planning as drawn up, for example, by IWF or the World Bank. However, an investor in a JI project wants to be certain about the equivalent value in the form of a reduction credit before making any investment. The prospect of an uncertain investment could reduce the incentive for participation in JI projects. Lost investments in JI projects could discredit the whole JI concept. Investment protection measures are therefore conceivable, but this would not fulfil the goal of an optimum allocation of resources set by the Framework Convention on Climate Change. Projects only allowing a precise quantification of the reduction effect after their completion could be the basis for speculative investments with prospects of future profit, but also a risk of loss.

In order to provide as many chances for JI as possible, efforts are being made to establish a comprehensive JI regime, i.e. including all greenhouse gases, sources and sinks and, if possible, the participation of all signatory states to the Climate Convention. This comprehensive approach increases the complexity of a developing regime and makes it more difficult to set up detailed guidelines for the implementation of concrete measures. Excessively narrow framework criteria could be counterproductive in that they deter potential partners from participating in JI projects.

1.	JI exlusively refers to joint action in the implementation of policies and measures but in no case to a modification of commitments by one of the parties involved.
2.	JI is not the same as providing support for other parties.
3.	JI is voluntary action on the responsibility of two or more parties; this action should be performed by the governments in question or with their agreement.
4.	JI should be carried out in connection with measures in one's own state.
5.	JI should be of advantage for all countries involved and in keeping with their national priorities for sustainable development.
6.	JI activities should provide actual and measurable results relative to reasonable basic assumptions.
7.	JI activities should be evaluated both with respect to their economic and social impacts as well as to environmental effects.
8.	JI activities should, if possible, be accompanied by measures for ensuring long-term environmental advantages.
9.	JI activities may concern any greenhouse gas or any combination of greenhouse gases.
10.	The parties should primarily pursue JI activities resulting in a restriction of emissions.
11.	The advantages of JI may be divided between the parties involved.
12.	Every party involved in a JI activity must communicate relevant information on this topic to the Conference of the Parties.

Table 9: Criteria proposed by the INC Secretariat

3.2.5.3 Problems of Quantification

The main problem seems to be the quantifiability of effects aimed at by the Climate Convention, at least for part of the possible JI projects, since these effects should be ultimately creditable against a defined monetary service or in the equivalent form of a transferred economic service. These difficulties increase in proportion to the comprehensive nature of JI projects, i.e. including all greenhouse gases as well as sinks in addition to sources and permitting JI projects between all categories of states.

In order to include all greenhouse gases (comprehensive approach), internationally recognized equivalence values (global warming potentials) must be defined for radiative forcing greenhouse gases. However, this is in any case required for future commitments also comprising greenhouse gases other than carbon dioxide and containing concrete emission reduction goals. The same applies to the establishment of uniform quantitative evaluation criteria for sinks.

The third problem area already mentioned above comprises JI projects involving states with quantified emission reduction goals, e.g. industrialized countries on the one hand and developing countries without obligations or even entitled to increasing emissions within the scope of their economic development on the other.

In the first instance, there is no reference basis whatsoever for quantifying the emission reduction achievable by JI projects. Apart from simple cases, such as replacement investments using modern technology, the evaluation of a measure can generally only be based on the targets of economic development plans. If the planning targets are not reached or are exceeded, a new evaluation of the creditable emission units could become necessary ex post.

3.2.5.4 Need for verification and verification measures

The crediting of saved emission units or greenhouse gas units additionally bound in sinks against investments in corresponding measures can only be effected with the consent of the members of the Framework Convention on Climate Change or an institution acting on their behalf. Every partner in a JI project must furnish the necessary information to an institution still to be determined, in accordance with standards to be defined and by analogy to the parties' obligation to present reports as part of the Climate Convention. Reporting on JI projects may be undertaken in connection with national reports within the Framework of the Climate Convention, although sufficient transparency should separate the JI-related information from information on other national measures. To the same extent as in connection with the verification of national reports, independent verification could also be required here although the organizational and technical possibilities, apart from JI projects of low complexity, e.g. the replacement of old inefficient power stations by more modern ones, cannot be defined in advance but must be specifically adapted to each individual project. A more complex situation is encountered, for example, if investments for modernizing a natural gas industry are to be credited against emission reductions of CO_2 in the donor state. A verification regime based on evolutionary development and increasingly stringent commitments in the course of time, as well as on the technical possibilities of evaluation, also seems to be appropriate for JI.

The basis for a verification of JI projects, as of national reports, is the contents of reports presented by the project partners involved. These reports should be based on uniform methods of inventory determination for sources and sinks, e.g. on OECD or IPCC guidelines. In this case, too, the first step could be a verification of the consistency and plausibility of the reports presented by the project partners involved and a comparison with the contents of national reports and of additionally available information. If the receiving partner in a JI project is a developing country, the national report will probably be the essential basis for verification of the reference values used to determine the creditable emission units.

The application of further verification measures should decisively depend on the specific design of each individual JI project, i.e. on whether sources and sinks, radiative forcing gases other than carbon dioxide, locally limited or nationwide impact regions are included.

Technical verification measures are currently only available to a limited extent. As in the case of inventory taking, their application potential depends on their suitability for verification, i.e. on the characteristics of the sources or sinks under consideration. In connection with JI projects, the verification of land use by satellite or aircraft observation will probably be of significance [Lanchbery & Salt 1993]. The discrimination ability of satellite images is currently not really sufficient to differentiate the characteristics of different vegetation types for verification purposes so that supplementary verification on the ground is still considered necessary. Direct measurements of emitted gas masses (quantities) [Lauppe 1994] can only be performed at present for point sources, i.e. power plants, industrial plants and to some degree for locally limited sources such as coal mines or coal extraction and oil or gas fields as well as refuse disposal sites.

Apart from the specific source or sink characteristics, the suitability of JI projects for verification decisively depends on the possibility of clearly delimiting the effects of a project from the impact of other national measures and other JI projects to be implemented in any case.

Stage	Task	Solution
1st stage	analysis of the reduction potentials of techniques and measures in a JI project	• estimates • model calculations - energy economy - sector-specific
2nd stage	establishment of specially adapted balancing for techniques and measures in a JI project	• quantities of GHG emission reductions • time perspective • costs
3rd stage	verification of implementation on the basis of the national report	• comprehensive verification

Table 10: Graduated concept for the verification of Joint Implementation

A graduated concept oriented towards the time phases of a JI project is proposed as an approach for JI verification measures. The verification intensity should similarly be adapted in stages with increasing emission reductions achievable by JI and the associated crediting. **Table 10** shows a rough graduated concept. A comprehensive verification procedure is envisaged in stage 3, whose basic elements can be seen from Fig. 4 in the final chapter. **Table 11** attempts to describe in more concrete terms verification possibilities as examples of possible JI measures. It becomes apparent that verification will probably be particularly difficult and expensive if on the basis of individual decisions and preferences concerning the handling of technology etc., which is provided within the framework of JI, the savings effect may be cancelled or reduced. Verification will then require considerable efforts in order to estimate the impacts of individual behaviour fluctuations on the (savings) target. This may also lead to considerable problems in crediting the savings achieved by JI measures.

Emission sectors and sinks *energetic*	*nonenergetic*	Examples of measures in JI projects	Possible verification measures
extraction of primary energy		sealing of gas pipelines, methane separation in hard-coal mining	balancing, random in-situ verification, acquisition by direct measurement
power stations		new power plant technology, modification of the fuel mix	direct measurement, process simulation + calculation
industry	industry	innovative conversion and production processes	process simulation, direct measurement
households		introduction/promotion of energy-saving cookers	indicator analysis: - sales figures - pattern of use
small consumers		introduction/promotion of energy-saving lamps	indicator analysis: - sales figures - pattern of use
waste disposal technology	waste disposal technology	modern refuse incineration, utilization of landfill gases	direct measurement, modelling + measuring
	agriculture forestry	change in land use afforestation	on-site verification + remote sensing

Table 11: Examples of JI projects and possible verification measures

Two examples, if modern power station technology is supplied then it is to be assumed that a company run on good business principles will aim at optimum operation of this power plant technology. In this case, verification concentrates on establishing the actual status before and after modernization. Later operation does not need to be monitored. Such optimizing behaviour cannot necessarily be assumed for individuals, e.g. those using energy-saving lamps. They may keep the lamps on longer since their consumption is so low thus eliminating part of the savings. If the supplier (or funding state) declares a *theoretically* derived savings unit (or part of a unit) then it may happen that verification, which attempts to compare the *actual* effect with this declaration, discovers a difference. Can this difference be subtracted from the supplier's credit although he is not responsible for it ?

In order to avoid such problems, JI should primarily be applied to such cases where the results can only be influenced by individual decisions to a minor extent. This also reduces the demands made on verification.

3.2.5.5 Evaluation

The incorporation of the JI tool into a global greenhouse gas reduction strategy offers the possibility of also raising private capital for individual emission reduction measures in addition to national expenditures, combined with the intention of achieving maximum effects with limited resources from a global aspect. The corresponding design of a JI regime should be evolutionary and, in the course of time, merge into the *comprehensive approach.*

The possibility of an independent verification, not only for implementation control of measures under JI projects, but also for the quantitative verification of the effectiveness of measures, is of essential significance for the functioning of such a regime. The intensity of verification measures should be oriented towards verification requirements, which will presumably increase with growing flows of capital, and towards the availability of instrumental and technical methods. The selection of JI projects should be made dependent on the feasibility of effective and economical verification measures. From this point of view, all measures in the sector of power plant technology and industry, as well as primary energy production, appear suitable.

4. Institutional Aspects of Verification

Verification includes the institutional facilities and organizational provisions on a national and international level which serve to prepare the declaration and the verification activities related to it.

All considerations concerning a verification concept for the Framework Convention on Climate Change proceed from a two-stage design of the verification system. The FCCC also envisages such a structure: determination of the national emissions is delegated to the competent national institutions and organizational units. The data thus obtained are communicated to an international institution (national declaration), which is then essentially concerned with verifying these reports. A differentiation must be made on the international level between a technical process and a political verification process which are allocated to different institutions. "Technical" verification is the mission of a dedicated verification body which has the tasks of:

- receiving the national declarations,
- verifying these declarations with respect to completeness and plausibility,
- calling for additional information from the member states, and
- summarizing the results in a technical report to the Conference of the Parties.

As the political decision-making body, the Conference of the Parties has to undertake a political assessment - based on this report - of (non)compliance with the Convention. In the states party to the FCCC, provisions must be made for drawing up the national report, i.e. compiling information, processing it in the form of country reports and then passing it on. A national "organization" (infrastructure) is necessary to draw up this report, whose actual form can, however, generally be decided by the states themselves. Responsibilities for this task were not laid down in the climate convention, nor can it be made binding for all states.

The FCCC does not only (in effect) commit the states in group 1 to reduce GHG emissions but also to formulate national strategies and policies for climate protection and to introduce corresponding measures. These commitments are also subjected to international verification, which, however, is restricted to an assessment of whether the parties have undertaken such steps (implementation safeguards). To this end, information on the realization of the corresponding laws, ordinances etc. can be gathered by the states, the impacts observed and the effectiveness estimated.

Within the framework of efforts by IPCC and OECD to achieve uniformity of methods for the reporting system on national GHG emissions (inventories) to be established worldwide, a verification of these reports is also envisaged. However, IPCC and OECD concentrate on violations due to false or incomplete national declarations, which are an expression of a lack of capacity on the part of the states. In this respect, verification should have an implementation-oriented and corrective effect. With the current status of material commitments in the FCCC, major emphasis is given to this form of supportive implementation monitoring. Nevertheless, over and above the unintentional errors and falsifications in the information to be communicated, we do not rule out the possibility that states or actors in the states in question deliberately falsify their emission data. As already discussed, this is not completely improbable if the provisions are tightened up by amendments to the FCCC itself or by means of protocols. Furthermore, a game-theory investigation shows that within the framework of joint implementation, whose usefulness basically starts with the Climate Convention, both partners could be interested in a false declaration [Walker/Wirl 1994]. As a countermeasure for intentional deceptions, verification must become more intensive and detailed in order to be in a position to expose such violations. For this reason, the applicability and usefulness of intrusive verification instruments is being examined, which would lead to a higher verification density. The spectrum of verification possibilities may then range from an estimate of the completeness and comparability of the national reports up to and including a critical analysis of the information communicated. In addition to a detailed analysis of the reports, further verification methods may be applied requiring extensive access to the national information gathering and information processing systems. Should this not be sufficient then, if necessary, further information channels will be required based on the verification elements of surveillance and measurement.

With higher verification density, demands on the national organization and on the international review body entrusted with verification also increase. Declarations by the states should then also, for example, contain information on the information gathering and processing paths so that, if applicable, inspectors commissioned on an international level with verification of the declaration can make specific inquiries. Pointers for estimating the reliability of the information could thus be obtained. A well-structured organizational infrastructure with precisely defined tasks would have to be provided on both sides for such extensive verification activities.

4.1 National surveillance system

As a consequence of FCCC membership, organizational provisions must also be made in the Federal Republic of Germany to ensure the realization of and compliance with the commitments undertaken in the Convention as well as institutional support for the reporting system. For pragmatic considerations, the organization and functions of a national surveillance system for GHG emissions should be largely conform to existing federal and subsidiary structures of environmental legislation and safeguards in Germany and the European Union.

In the course of the further progress of integration within the EU on the basis of the Maastricht Treaty, it would be *conceivable* that within the framework of the FCCC (and protocols) the EU would not only draw up one report on common GHG emissions but that this report would also take the place of the national reports. This - rather improbable - possibility has not been systematically studied with respect to its impacts on the national systems. However, indications point to the fact that even in this case information on the EU member states would primarily be transmitted to the EU via national information channels or institutions, whose role would thus not be diminished in this respect.

A national safeguards system should be in a position to reconstruct GHG release processes to such an extent that the effectiveness and impact of measures to reduce or stabilize emissions can be monitored and evaluated in detail. Furthermore, it would probably be the mission of a national or regional system (within the framework of the European Union) to provide adequate proof of compliance, in case of doubt, with the aid of its documents on reporting, production, use and operating procedures.

The reliable data sources include (in the old) federal states of the Federal Republic of Germany, the energy balances on the macrolevel of the national economy [Fritsche 1992]. These data provide an adequate information basis for determining the energy-related GHG emissions since the energy flows have already been observed for years both in the production as well as the conversion and consumer sectors in order to assure the energy supply.

4.1.1 *Emitter structure*

The basis of a comprehensive emission determination is given by the completeness of coverage for all emission-relevant processes, accuracy in determining the associated mass flow rates and representativeness in defining the emission factors. Appropriate structuring of the area to be studied forms a decisive precondition for the degree of detail of any possible statements with respect to the objects under surveillance. An extensive fine-structuring of the data bases and the data collection on a national level by means of appropriate object definitions therefore appears both meaningful and necessary. Since the data for individual cases cannot simply be determined or defined, uncertainties may result in verifying whether the target has been achieved. The national surveillance system therefore has the task of compensating for such deficits and bridging the gaps in the system. In this task, the OECD/IPCC classification should be applied as far as necessary, thus ensuring structural uniformity, transparency of content and ease of information handling in the national reports.

4.1.2 *Aspects of a national GHG surveillance organization*

The national system should enable a whole package of targets to be fulfilled, going beyond reporting to the international community on greenhouse gas emissions. This system should receive comprehensive and detailed information on GHG release processes on national territory. (The inclusion of emissions occurring outside national territory but directly attributable to the state has not yet been clarified internationally.) In this connection, it appears meaningful to link this task to existing systems and requirements. For example, there are already systems for environmental monitoring and reporting concerned with the compilation of information on environmental pollution by atmospheric pollutants, but which would have to be correspondingly "upgraded". The range of tasks can be regarded within the following boundaries:

- identification of all sources and data for GHG emissions;
- verification and evaluation of efforts to reduce or stabilize GHG emissions.

Taking into consideration the specified requirements (gathering and transmission of information), five essential spheres of action can be identified to achieve the efficiency required of a national GHG surveillance organization. These comprise the fields of *development of methods, safeguards methods, information management, information dissemination and evaluation of effectiveness.*

The sphere of *development* includes both the creation of the necessary conditions for implementing the surveillance system as well as the permanent further development of its elements in accordance with the state of the art:

- The first mission in this connection is standardization. Apart from the technically admissible designs of the emission sources (e.g. standards, guidelines) and the requirements for restricting environmental pollution, special agreements are required in the field of methods, processes and information. Efforts should be made to achieve a harmonization between existing methods and processes for the calculation, collection and transfer of information on other atmospheric pollutants for safeguards on national emissions. All relevant institutions should participate in achieving generally applicable and binding agreements on the organizational and operative implementation or enforcement of surveillance measures in an orderly and appropriate manner in order to establish a uniform basis.

- Secondly, standards must be established. Attention is focused here on the definition of reference values and processes. Reference and guide values enable deviations from the terms of reference (requirements) to be determined. Boundary, maximum, average, total values etc. can be established for the plants or processes causing the emissions. Recourse can be taken to experience, the state of the art or to agreements. This task also includes rules and methods for calibrating measuring instruments. It should thus be possible to make reliable statements with respect to comparability, information content, reliability etc. in evaluating data from measuring and monitoring.

- Emission-relevant objects and activities can be licensed, i.e. it may be made binding that they fulfil technical and process-related conditions and requirements. A new criterion could be compliance with certain GHG emission limits, in the course of which a differentiation can be made between operating licence, licensing by the surveillance authority and authorization, within the framework of which responsibility and obligation to exercise due diligence passes to the operator. All facilities, devices, processes and goods making a major contribution to GHG emissions could be licensed for the national market after exhaustive examination or under certain conditions. Licensing may be oriented towards process-related characteristic data and emission limits. Measurements to determine the emission situation can be performed by authorized agencies. The measuring methods/measuring stations may be licensed.

- Definitions, classifications etc. must be selected and justified (data structures) for a description of the object-specific source data. The features should be uniformly determined for reasons of comparability, and must be specified together with their range of values. The interfaces with the data bases must be examined and set up with respect to compatibility, validity, completeness and reliability. Due to its complexity and the possibly large number of actors involved, this task must be regarded as a consensus-oriented process capable of achieving compromise.

- Practicable and regulated collection methods are required in order to permit an appropriate acquisition of data and information. Methods are oriented towards information generation, the available data formats, the established data structures, the possibilities of data transfer as well as the existing aggregations and aggregation stages. Suitable data carriers and adequate collection formats for the regular flow of information must be established by the investigators and applied as correctly as possible. Technical details for data surveillance tasks such as inspections, reports, verification of the book and operating records must be laid down.

- Computer methods in the form of accepted data processing models could be used for the aggregation and evaluation of the information on hand. The utilization of computerized calculation models can also be envisaged for processing emission data generated on the microlevel as well as for calculating emission inventories from energy consumption statistics. To this end, agreement must also be reached on uniform evaluation principles and standards (cf. standardization). Since aggregations from (unreliable) primary data are frequently used, statistical test methods should be applied to assess the propositions.

- The informational and organizational structure of the national surveillance system should be subjected to a corresponding verification and assessment (evaluation) procedure during its development and adaptation phase. Primarily the data and information on which this system is based should be verified with respect to usefulness, practicability, context, quality etc. Accepted evaluation procedures should serve for a rational consideration of the surveillance measures, their goals and efficiency.

Monitoring the GHG emissions represents a permanent task for the national surveillance system in order to ensure compliance with current limits, regulations and commitments. Detailed coverage of the emission values and subsequent aggregation according to emission sources, energy sectors etc. forms an essential basis for surveillance measures. The necessary harmonization (target/performance relation) of the terms of reference defines the further tasks and subsequent activities:

- The necessary precondition for comprehensive and complete surveillance measures is inventory taking, i.e. a determination of the population of sectors, subsectors, emission sources or emission-relevant activities to be monitored. Calculation or estimation of the emission sources as well as the measurement, or a different form of determination, of the emission data provides the inventory of national emissions to be monitored by the surveillance system. Various procedures and methods, corresponding to the source definitions, can be used for this purpose, such as the application of key variables based on national primary and secondary data sources (e.g statistics).

- As part of the reporting obligations, operator and association reports and statistics as well as notification of changes to inventory management are envisaged at certain intervals (reporting). Harmonization of the structures and categories (cf. standardization, data structures) facilitates the assessment of reports both on a national and also an international level. As a function of the emitter structure and/or the error range of the emission sources and data, the reporting system may display various degrees of detail. In accordance with the experience obtained, an increasing density of the reporting systems (more extensive, in-depth) may be desirable. Report verification and monitoring can then also be performed on an object-specific basis.

- Detailed surveillance measures require that the data from the operator, producer or user can be verified by (at least) one further actor in accordance with the existing regulations or the assigned credibility. The specific, random control or inspection of the licensing values, the characteristic data or verification of the operating records (e.g. tachograph etc.) can be performed as a function of the emission sources. The inventory data of the surveillance system can be compared with the currently determinable data by independent measurements etc. (e.g. also by environmental measuring and monitoring systems).

- The results of on-site inspections should be combined with the inventory of emission data and emissions in the form of inspection data or results as surveillance messages. A comparison with the inventory data may lead to the detection of deviations and to a correction of the inventory. Feedback to the operator (polluter) should be ensured.

- The surveillance system should also permit an assessment of the validity of its information inventory so that data on the credibility of the data sources and on the quality and error range of the data bases are required (validation). Verification of plausibility and consistency should be performed with respect to the evaluation of the inventory and the inspection data. Furthermore, estimates are required of the error propagation for the aggregation procedures.

- The inventory data represent the most important precondition for the national declaration, the forms of international reporting as well as the verification of emission inventories. They may provide the basis for monitoring the actual development of the GHG emissions. It should be possible to retrieve and evaluate the inventory of emission data and sources in an appropriately aggregated and informative form at any time, in which connection accessibility for (international) third parties may also possibly be selectively granted.

- Taking into consideration the quality of the information, deviations from or violations of commitments can be determined and revealed with the aid of surveillance measures. In the case of continuous, accumulated demonstrable violations of the agreements, sanctions may be considered by the safeguards authority or another body appointed for this purpose. Suitable procedures should ensure the stipulation and enforcement of sanctions.

Well-ordered *information management* represents a central mission for surveillance in order to make available up-dated and comprehensive monitoring knowledge. The acquisition, storage, updating and evaluation of the necessary information can be performed by modern data-processing-aided methods. These methods enable a specific selection, accumulation and aggregation of information even from large data inventories. Information management includes the following aspects:

- Although the availability of the required data should normally be assumed, situations may arise in which appropriate access is made difficult because of the inadequate accessibility of the information sources due to legal, organizational, operational or other regulations. For reasons of data protection or national jurisdiction, it is even possible in the Federal Republic of Germany that the available information cannot be evaluated.

- The various surveillance principles and approaches should be supported by recording the various objects in the population to be monitored. Within the framework of an object-oriented perspective, details of the surveillance measures should be oriented towards the agreed definitions of the emitter structures and object-specific characteristics of the emission sources. Registration should ensure that these object categories and objectives are incorporated in the surveillance system together with the licensing data as well as the producer, operator and user data.

- In connection with registration, corresponding descriptions are required for the plants etc. providing more detail on the emission source (technical facility description). If a licensing procedure is mandatory, these characteristics should be appended to the licences as documentation. In relevant cases, it should be possible to obtain this information for operation from the operating manual, environmental protection manual or from the quality manual/emergency manual.

- The admissible emissions are laid down with the licence or approval as characteristic or licensing data as part of the technical facility description (predefined reference/design values). The actual emissions within a period of time should be appropriately determined for the monitored facilities and reported by the operator etc. These data can be supported by documents, such as operating and book records, which may also be used in the inspection, verification and evaluation of the emission declaration.

- Changes in the operational status of a plant should be reported to the competent bodies by means of modification notices, if they influence the emission declaration. Data on any changes must be processed in order to maintain the status of the inventory.

- Quantitative data from various information sources, such as inventory management, reports, inspections, may differ from each other even if they concern the same facilities. Apart from system-related tolerances, errors and uncertainties are possible resulting from the methods and processes of information determination. The investigation and clarification of such deviations (anomalies, discrepancies etc.) are among the essential tasks of a surveillance system. On the one hand, it would have to be established whether a deviation can be attributed with (statistical) certainty to a violation of commitments; on the other hand, the consistency of the data must be maintained within the framework of inventory management. A more precise verification can be achieved by an audit or by statistical calculations.

On the national level, the diffusion of innovative techniques and methods of GHG reduction or stabilization should be prepared and supported by *information dissemination*. Apart from the legal guidelines, directives and regulations, which are in any case known to the user, a wide range of instructional information should be made available to influence behaviour:

- An important mission is the dissemination of knowledge on new techniques or the state of the art for the spectrum of potential users (e.g. GREENTIE - Greenhouse Gas Technology Information Exchange, initiated by the International Energy Agency and OECD). The information can be spread through the corresponding media and via existing channels. Information about the application of new technologies, particularly their contribution to the GHG reduction potential as well as their subjective perception by the user, may initiate or reinforce strategies aiming at a change of behaviour.

Advisory services should refer to suggestions for emission-reducing measures and the application of specific techniques. The justification for the positive effects of new technologies could be based on the extensive know-how provided by the evaluation of the information inventory available in the surveillance system. Details of successful possibilites of GHG reduction can be obtained from the entirety of information available by means of longitudinal considerations (time series), which may also provide feedback for the advisory services.

- Furthermore, direct support is required for the application of new techniques. The provision of suitable human, technical and investment potential may be regarded as a necessary prerequisite. A major contribution can be provided by the training and secondment of experts.

The *evaluation of the effectiveness* of energy-policy measures could be undertaken on the basis of the collected information inventory of a surveillance system based on an adequate data basis for reliable jugdements. An internationally agreed catalogue of possible measures performed by an independent, neutral body may make an essential contribution towards a generally accepted evaluation. The following must be considered in an evaluation of effectiveness:

- The formal introduction of individual measures (e.g. laws, directives, official gazettes etc.) may become an object of implementation checks. After a certain time it should be possible to estimate the effectiveness of a measure on the basis of the emission data. An exhaustive assessment should include the concomitant monitoring of the economic environment (e.g. price relations, shopping basket, relation to cost of living etc.) in order to evaluate the subsequent impacts.

- A suitable combination of measures (package of measures) may possibly be easier to implement and can achieve greater effectiveness than individual measures (synergistic effect). On the one hand, a consideration of the pros and cons (trade-off) and a possible balancing of burdens and relief (e.g. yield-neutral) could be performed and, on the other hand, compensation possibilities could be envisaged. A review of the quantitative emission curves taken from the data base of the safeguards system may be of assistance in subsequently justifying measures.

- The acceptance of compulsory measures representing a serious intervention in the individual´s self-determination behaviour (e.g. speed limit) could be problematic. The information basis of the surveillance system can provide indications of whether the degree of potential reduction of GHG emissions is commensurate with the level of intervention.

4.1.3 Organizational provisions

Organizational provisions must be made for monitoring the implementation of and compliance with the agreements reached in the Climate Convention for the Federal Republic of Germany. In order to solely satisfy the obligation to present reports, the reporting system has to be backed-up by appropriate organizational and mission structures on a national level. Furthermore, the national monitoring system could fully cope with the above-mentioned tasks (cf. Functions).

In establishing the organizational structure, it appears meaningful to incorporate existing institutions and take them into consideration in allocating tasks. The participation and cooperation of the institutions should be oriented towards their statutory mandate and to the possible contribution they are capable of making to the joint target of comprehensive and detailed monitoring and surveillance of all GHG release processes in the Federal Republic of Germany. The selection of exploitable information will be based on reliable information sources also including, apart from their own surveys, data from operators, licensing and municipal authorities, interest groups, statistical bureaus etc.

In setting up or allocating various organizational units to the functions of the national authority, existing structures and inherent structural features should be exploited as optimally as possible. The possibility of conflicts of targets and interests which could lead to collision or blockade tactics among the participating institutions must be considered. In allocating functions to the corresponding institutions, a distribution among the following groups should be made: government agencies (e.g. licensing, supervision, sanctions etc.); semi-public, private-sector and neutral authorities (e.g. measurement, expert opinions, review, estimates, assessment, support, training etc.); non-profit organizations actively pursuing environmental goals (e.g. public relations, defining problem areas etc.). The (subsidiary) principle of staggered responsibility could be applied for the cooperation of the executives. This means that decisive contributions to the surveillance mission would be provided on both a municipal, local and district level. The following examples of governmental agencies can be mentioned: heads of district administrations, trade supervisory officers, local authorities, regional agencies for emission protection, statistical bureaus, licensing authorities, Federal Environmental Agency (UBA), Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) etc. The following neutral agencies would come to mind: national research centres (GFE), technical control boards (e.g. TÜV, DEKRA etc.), industrial standards institutes, DIN standards committees (e.g. coordinating office for environmental protection at DIN), Stiftung Warentest (consumer goods testing foundation), experts etc. The following interest groups could also be mentioned: Institute for Energy and the Environment (IFEU), industrial associations (e.g. BDI), nature conservation groups (e.g. German Association for the Environment and Nature Conservation - BUND), consumer organizations etc. The approach taken by those involved should depend on the possibilities for cooperation and consensus, the significance of the environmental protection concept, as well as the priorities in reducing/stabilizing the relevant GHG emissions. A procedural model can thus be developed also taking into consideration, in addition to the apportionment of tasks, the phases required for structuring a national monitoring system for GHG emissions. Existing concepts from the international sector could be harmonized (cf. International Institutions).

4.2 Tasks and structures of international verification

The "counterpart" of the national systems is the international verification system. In principle, in developing this system there is the option of allocating the organs and functions of verification to a new organization or to existing organizations. The decisive factor seems to be whether work can be carried out in, as far as possible, a technical and nonpolitical manner in collecting, processing, harmonizing and technically evaluating information on national emissions, greenhouse gas sinks and implementation steps by the national legislation. In the discussion of the institutional form of a climate convention in the past few years, as a rule world organizations such as UNEP and WMO have been mentioned, as well as organizations yet to be established, which would also be responsible worldwide. In view of the fact that basically all countries will be affected by the climate changes predicted in model calculations, it appears self-evident that executive authorities acting worldwide should be entrusted with the institutional functions. There is also the possibility of assigning verification tasks to a number of international organizations.

A broad consensus is now in favour of the Subsidiary Body on Implementation being responsible for the politically sensitive task of verifying the national reports within the FCCC framework. It is open to all parties and, if one compares its position with the Implementation Committee of the Montreal Protocol [Lang 1994], it is a working group with very restricted competence, which does not work independently but rather under the supervision (and probably de facto under the direction) of the Conference of the Parties. There is still a long way to go before achieving such an independent examination of compliance as is already the case today in the Montreal Protocol. Relevant "technical" problems in connection with the analysis of states' behaviour in the FCCC, for example methodological questions connected with preparing the national reports, will probably be dealt with by the Subsidiary Body for Scientific Technological Advice. The evaluation of the results of the activities by both bodies is undertaken by the Conference of the Parties, which thus takes on the central political assessment and decision-making function [Victor/Salt 1994]. To this extent, there is no basic discussion about the organizational structure of verifying national reports in the FCCC, even if major aspects of the mission still await specific definition. The outstanding questions are to be answered at the first Conference of the Parties in Berlin.

As a consequence of the evolution of a dynamic climate protection regime with protocols, more stringent commitments and an extension of obligations to limit GHG emissions to include further countries, it would be conceivable that more, and also broader-based, tasks and authority to act would be necessary for the international verification bodies. In the search for organizational features, two ideal extreme forms of a verification organization would be conceivable: a decentralized, emission-sector specific system or a centralized, hierarchical organizational system responsible for GHGs in general.

The difference between the two organizational models is to be found in the fact that in one case the states' compliance is verified both with respect to the Framework Convention as well as to the protocols in one uniform organizational structure, whereas in the other case the respective protocol provisions are verified by the special verification organizations and only the political assessment of their results is coordinated on the level of the Framework Convention. However, a superordinate verification agency would also be conceivable as an organ of the Framework Convention, whose activities would have to be implemented by cooperation and coordination with the protocols of the Climate Convention. The technical efficiency of such an institution would permit rapid, time- and resouce-saving information collection, information processing, structuring of information flows and finally information evaluation. Proposals allocation the verification of commitments to the protocols would perhaps enjoy greater acceptance on the part of the member states. At least the final stage in the verification process, the political assessment of the collected and processed national data, should be undertaken in a transsector manner by the institutions of the Framework Convention.

Since almost all environmental media are characterized by one common feature - the ability to have a transboundary impact, also frequently on a large scale - a certain organizational superstructure on environmental media-specific international problems is recommendable. Consequently, organizations separated according to environmental media would be preferable to a central environmental body.

Various model concepts can be developed for verification with respect to the structure of the organization and the communication lines for international surveillance. As already mentioned, two different models are conceivable: a centralized hierarchical model (Model 1) as well as the contrasting example of a decentralized emission-sector-specific alternative organization (Model 2), see **Fig. 3**.

Model 1 assumes a verification system which regards the convention and protocols as a unified set of agreements. It therefore represents the verification process in a linear organizational sequence with a hierarchical institutional structure. A joint verification system of this type would require the unanimous consent of the respective parties in order to realize verification or surveillance of the implementation of commitments in a joint system. Major restrictions would arise for this system if at the outset various framework agreements were required for the individual sectors influencing the anthropogenic warming of the earth's atmosphere as emission sources or greenhouse gas sinks.

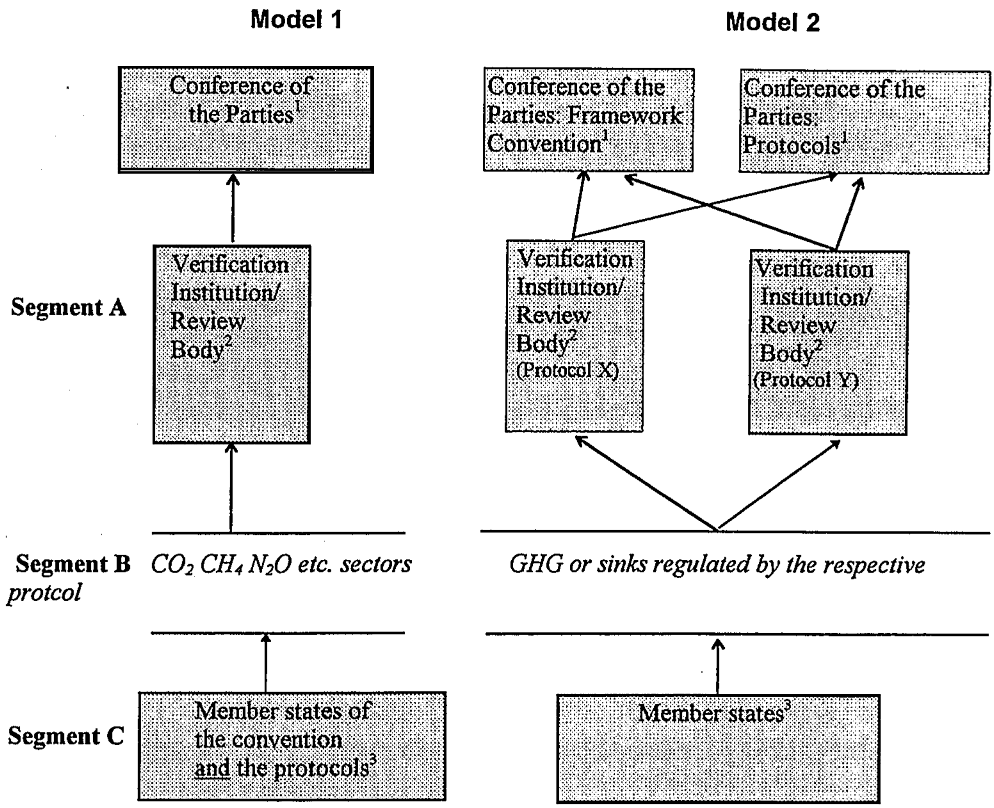
It is characteristic that the national sector is not included in the organizational sequence (national declarations in segment C), that, furthermore, all information relevant for the greenhouse effect (from segment B) is fed into the sequence of segment A (centrality of data collection and processing), and that finally the information flow in segment A proceeds in a strictly linear bottom-up manner. All sequence steps and communication channels in segment A are within the sphere of an international climate institution. An international verification body receives the national reports on emissions or implementation, verifies the completeness and plausibility of these reports, and communicates the results of this review to the Conference of the FCCC Parties.

A proposal entrusting the Conference of the Parties with operative technical verification and monitoring tasks must meet with reservations. Although as the supreme decision-making body of the Climate Convention, the Conference of the Parties deals with all important topics (and makes decisions, submits assessments), nevertheless it may be assumed that the Conference of the Parties hardly has the necessary time to effectively undertake such time-consuming occupations as the verification of national reports. Furthermore, the Conference of the Parties is not a body which is permanently in session, but meets periodically (i.e. probably annually). It is thus clearly more appropriate to entrust a specialized and permanently operative body (e.g. the so-called "Review Body") with verification and implementation tasks. However, it should be emphasized that the political assessment of the results which is the final stage of the verification process should in any case come within the competence of the Conference of the Parties.

In contrast, Model 2 emphasizes decentralization. In this model as well, national authorities declare data on emission sectors and greenhouse gas sinks to an international verification institution. An essential difference is to be found in segment B of the system where only one sector is represented. In this example, verification is undertaken in a decentralized manner as part of the protocols to a framework convention and ideally only deals with one sector, one sink or one GHG.

The flow of information from the Review Body of a sector-specific agreement to the Conference of the Parties of a convention on comprehensive climate protection is naturally no longer possible if various conventions exist or are planned from the outset. The aim should in any case be an organizational structure enabling a political evaluation of the national reports on the implementation or development of emissions from individual trace gases and sinks in an integrated form by a responsible body such as the Conference of the Parties.

Information channels and rights are regarded as important starting points for organizational and institutional provisions and preparations for a verification system. These information channels and information rights may exist independently of and parallel to a verification system in a system for monitoring the environmental climate medium and its important subsectors.



[1] Political assessment; [2] Technical assessment, data-processing, data acquisition;
[3] Declaration of national data.

Fig. 3: Models of an international verification system

Model 1: Centralistic, single-line structure of the verification system.

Model 2: Decentralized structure of a verification system
after: [Comes 1992]

Activities on observing the relevant environmental media (climate, tropical forests, land use etc.) are also termed monitoring. The organization plan for information flows in a climate monitoring system proceeds in a manner similar to that in a verification system. The segment designated B in the organization plans of the centralized (Model 1) and decentralized (Model 2) verification systems is in this case relatively insignificant. Data acquisition or collection still proceeds at measuring stations located on the territory of the national states or else the objects to be monitored are on national territory. Nevertheless, in the case of environmental monitoring there is usually no or only little resistance to providing data.

Enhanced environmental consciousness increases the parties' willingness to include more extensive commitments in the protocols. A verification of compliance over and above implementation safeguards by bilateral or multilateral safeguards or else by an international organization can only be established as verification if correspondingly accepted. Furthermore, the idea of self-regulation for national measures and national declarations on topics of relevance for international environmental protection treaties cannot be dismissed out of hand.

5. Considerations on International Verification Acceptance

It was apparent to anyone with personal or scientific experience of the negotiations on drawing up the FCCC and discussions in preparation for the first Conference of the Parties that regulations and measures for verifying compliance attracted hardly any or, as soon as they became more intrusive, no consensus or were indeed vehemently rejected. International verification has enjoyed little acceptance to date. This is probably also true of most of the methods and techniques described in the previous chapters. Can this acceptance be increased ?

The (international) acceptance of verification in the climate issue area depends on three "systemic" factors:

- the *significance of the issue area* and the density of the material contractual regulations, i.e. their content,
- the general *estimation of compliance* on the part of the states by the respective actors as well as the estimation of the cause of violations,
- the "*political culture*" of a country, its understanding of sovereignty and experience with verification.

Situation-specific factors are also involved and must be analysed from case to case.

The interaction of these factors may lead to both identical and also different concepts of the role of verification and a willingness, ranging from congruent to contrary, to accept verification. However, the factors do not all act in the same direction, i.e. conflicting goals are conceivable and not all factors are regarded by the actors as equally important, or their significance may change during the political process. For example, considerations of sovereignty may receive great weight under domestic pressure but be of minor significance in the case of little domestic interest and a greater preference for verifying the compliance of other states. The sequence of the three factors tends to reflect their relevance, with the first two factors being necessary conditions but the third merely a sufficient condition. Nevertheless, only a concrete and systematic investigation can determine their actual influence in the political process. The situation-specific factors must also be taken into consideration.

Acceptance problems only arise for verification if these factors have a different weight in the relevant states and do not all act in the same direction. If all parties either unanimously require verification or reject it, then there is no problem. The problem arises from the different notions of the necessity, weight and intensity (density) of verification, which are the results of these three factors and impinge on each other in the international political process. Acceptance problems therefore result if some states desire (a certain density of) verification, while other states reject it.

If one takes previous insights about the acceptance of verification as a basis, largely originating from arms control [Chayes 1993, Efinger 1990], then everything seems to indicate a clearly different willingness to undertake verification commitments arising from the three "systemic" factors and concrete, specific political configurations at the time of negotiations on conventions and their verification rules. Roughly three groups of states emerge, which accept verification to different extents:

- The willingness of the group of OECD states is most highly developed, since they already have a lengthy, close incorporation in international agreements and some experience of verification.

- The states in transition from planned economies, which in the past demonstrated a somewhat reluctant or unsympathetic attitude to verification. This was particularly true of the USSR until well into the seventies. Nevertheless, the attitude of these European states, partly including Russia, is approaching that of the OECD countries or in the case of some central and eastern European countries is already identical. Furthermore, some of the "southern" countries seem to be moving towards this group of cautious proponents of verification, at least in some points.

- The majority of "southern" countries. On the one hand, they are only marginally incorporated in conventions with verification commitments, and on the other hand they have very strong sovereignty reservations which preclude verification.

The composition of these three groups varies, i.e. learning processes take place, and even within the groups the willingness to accept verification is not identical. One merely needs to recall the lack of willingness on the part of the USA to accept fullscope safeguards within the framework of the Nonproliferation Treaty. Nor is the verification acceptance by a state identical in all issue areas, and may indeed vary within one issue area. All previous experience in discussions on the Framework Convention on Climate Change and preparations for the first Conference of the Parties in Berlin shows that a similar, even if somewhat more complex structure, of different degrees of acceptance for verification measures can be perceived in the issue area of climate protection. Nevertheless, the sting is taken out of the problem due to the *generally low* demands on verification of compliance made in the Framework Convention on Climate Change.

5.1 Analysis of governing factors

Re 1: The significance of the issue area and the density of material contractual regulations

The acceptance of verification is decisively influenced by estimates of the need for verification and the verification density considered necessary by the political actors. Game-theory investigations provide initial insights into the issue area of arms control [Efinger 1990] and climate protection [Efinger/Breitmeier 1991]. The demand for and willingness to undertake verification commitments tends to be higher in issue areas of great significance for national policy than in issue areas of lower priority. If security problems are involved then the desire for more, and more precise, information on the actual behaviour of other states is considerable and, if national technical means are inadequate, leads to an agreement on bi- or multilateral verification. Naturally, each state would prefer that only its counterpart should be verified. However, in an international system in which as a rule reciprocal commitments prevail in worldwide conventions, the price of verification is one´s own acceptance of verification commitments. If, therefore, national actors desire a political regulation of an issue area regarded as important by them then they are subjected to equivalent commitments and if they are of the opinion that the success of the regulation depends on agreed international verification then they must also be willing to accept verification themselves. In the present, non-hegemonic international system it is no longer conceivable that there could be two classes of verification as in the Nonproliferation Treaty. Whoever demands verification for others but does not accept it for himself, loses credibility, relinquishes political influence and prevents treaty agreements.

It may be assumed that most of the important decision makers in almost all countries do not perceive the climate issue as a direct security-relevant problem. Although an economic dimension was added to the concept of (international) security after the first oil crisis and today many sectors of declaratory policy and some scientists emphasize the "ecological dimension of security", not least with a view to the consequences of the climate problem, nevertheless practical action by states and international law demonstrate that this perception does not prevail and that the climate issue area tends to be regarded as a rather secondary topic with only slight, very long-term direct relevance to security [Fischer 1992, Daase 1992]. Estimates of the significance of a violation of the Framework Convention on Climate Change must also be viewed against this background: relative to the individual event, it would be of less objective significance than a violation of treaties on arms control. "Clandestine" emissions of several million tonnes of C would therefore be of marginal significance in view of global anthropogenic releases in the order of six billion tonnes of C. A verification system for a climate convention therefore need not display the same density as considered necessary for arms control, where every nuclear missile and every carrier system counts. Only serious, permanent violations would probably represent a major problem. The desire for verification is thus less pronounced and, correspondingly, the acceptance question requires a low-key discussion. A medium-level need for verification can only be analytically derived in perspective lying somewhere between arms control or disarmament (high) and previous environmental protection conventions (low) [Efinger/Breitmeier 1990].

In summary: since the political relevance and regulation density of the climate protection issue area is still fairly low, the "demand" for verification also remains slight. This is also shown by previous activities within the FCCC, which concentrate on "supportive implementation surveillance". Where there is hardly any verification there will hardly be any conflict. For this reason a *serious* acceptance problem is not yet perceptible.

Re 2: Perceptions of compliance by states and estimation of the causes of violations by the actors

The perception of the general verification problem and its causes by government actors is also of significance for the acceptance of verification [Mitchell 1992]. This concern, firstly, the mutual estimation of motives for and interest in a convention by the respective actors ("outsider image") and, secondly, the "self-image" of national interests, i.e. the estimation of the significance of verification for enforcing one's own interests. The effective verification of a convention may be judged to be of central national interest. It has been indicated above that the majority of states fulfil most of their contractual obligations, in part also in the environmental sector, more or less reliably even if the reasons for this are controversial. Furthermore, violations are not only committed intentionally but can often be attributed to a lack of capacity and delays in realization arising from a number of causes. It is apparent that the actors' perception of the reasons for violations is also influenced by their willingness to accept verification. If actors from country A wish to monitor the other states B, C ..., which basically appear "suspicious" to them then, as a rule, they cannot avoid also subjecting their country, at least formally, to the same verification rules. This will be the case simply because actors from other states, even if they assume that other countries comply with the treaty, will nevertheless insist on verification for reasons of political symmetry. In practical implementation, differences in the frequency of verification measures and intensity may arise between countries even though a multilateral verification organization, as can be seen from the example of the IAEA, would have to pay great attention to the aspect of formal non-discrimination.

The intensity of verification is also influenced by such perceptions. If noncompliance is regarded above all as a consequence of inadequate capacities and a time lag then one must assume an interest in a less dense, corrective and not - as in the case of intentional violations - unmasking verification system, which will probably receive greater acceptance simply because the administrative and other costs will be relatively low and because the assistance of third-party states in constructing a verification system will be easier to achieve due to the lower costs. The "manual" for emission declarations developed by the OECD and IPCC in connection with the Framework Convention on Climate Change already represents an attempt to prevent such unintentional violations. The intergovernmental conflict about the necessity and practical application of such a system is therefore smaller, and consequently also the acceptance problems. But this is not universally the case; it can be seen from a number of environmental conventions that many states with a lack of capacity are reluctant to admit this - compared with international treaty violations - actually quite harmless inadequacy in order to avoid losing prestige. They therefore have a generally negative attitude even to fairly trivial verification demands [Ausubel/Victor 1992].

In summary, the climate convention contains several regulations to prevent or eliminate unintentional violations. This corresponds to the trend in international conventions whereby agreements with the aim of identifying capacity shortages and time lags have become standard and receive increasingly broad acceptance. Furthermore, there is only rudimentary experience with "verification", i.e. with systems and methods concerned with verifying the correctness of the declared data themselves. These systems remain almost exclusively limited to the OECD states and other European countries (see below).

Re 3: The influence of political culture and domestic factors

Domestic and foreign policy are closely linked and the respective strength of these two factors, whose impacts may be antithetical, can only be determined by a concrete policy analysis. In the case of economically and politically influential states, however, internal political processes tend to gain the upper hand in determining political goals whereas in the case of small, economically weak states external forces are more important. Nevertheless, the result of a political process cannot be predicted by the solution of an "equation with two unknowns" because "compulsion" is not an objective category. If a country regards itself as compelled to accept something put forward by an external force (e.g. the demand to reveal compliance) then this is not predefined objectively but is rather dependent on the state´s ability and willingness to accept defeat. Maintenance of national sovereignty may mean so much to the actors that they are prepared to accept high political and other costs in order to avoid giving way to external pressure. Particularly the "sovereignty-phobia" encountered in many "southern" countries and also in the remaining planned economies generally reduces their acceptance of verification. This may be observed throughout almost all issue areas although this phobia repeatedly collapses in the face of problems regarded as important. One example is the regional verification system for nuclear material concluded between Brazil, Argentina and the IAEA within the framework of the Treaty of Tlatelolco for reasons of regional stability and cooperation, although both states have a basically sceptical attitude to verifaction.

This strong emphasis on sovereignty, particularly in the "south", can also be explained by these countries´ lack of experience with verification. Compared, above all, with European OECD states, the density of incorporation into international treaties is low for these countries. Furthermore, they are not party to most of the treaties with, rather more prominent verification activities[8], or are, as in the Non-Proliferation Treaty or the chemical weapons convention, little affected by verification activities in practice. They still have to "learn" how to deal with verification and experience the (relatively slight) depth of interventions in their sovereignty.

This is aggravated by the fact that in most of these countries social groups (NGOs) who regard verification as a strengthening or guarantee of their interests in the solution of an internal problem (e.g. environmental pollution) are missing or are still weak. In contrast to OECD states these groups have little influence on policy and in view of the

---

8 Above all, the arms control treaties within the framework of the Conference (now: Organization) on Security and Cooperation in Europe (OSCE) and the closely associated Convention of the Conference for Confidence Building and Disarmament in Europe; furthermore multilateral environmental treaties such as the Geneva Convention, its protocols and the Antarctic Convention.

dominance of traditional interest groups their political relevance is marginal. Furthermore, the sovereignty concept is much more emphasized by "southern" than by "northern" NGOs. This hampers the formation of coalitions, as became apparent during prepartions for the Rio Conference [Oberthür 1993].

In summary: in the political system and its guiding norms, there is a structurally anchored reluctance in many states, particularly in the "south", to accept serious verification commitments since the latter are regarded as a curb on sovereignty. However, there are also first indications here of learning through cooperation.

As a *result* it can be established that the willingness to accept verification commitments is only well developed if a favourable constellation arises: an issue area has a high priority for all important states, there is interest in (and a possibility of) regulating the problem by a consensus, there is more or less agreement on the need for verification, potential motives for violations and thus on the "density" of verification and domestic considerations do not stand in the way. At the same time, unmistakable progress has been made in international policy. The basic necessity of verifying compliance is accepted today by considerably more states than was the case in the past.

These conditions do not yet prevail, or only in part, in climate protection so that it is not surprising that there is as yet no "problem with the acceptance of verification". There is no serious, let alone a universal, verification system in the Framework Convention on Climate Change. Even the commitment to provide reports differs for states in groups I, II and the majority of "southern" countries and no verification of the data is envisaged. Therefore there is no acceptance problem in the strict sense. Present and foreseeable verification is largely oriented towards violations resulting from capacity shortages or time lags in realization. One reason for this is also the low regulation depth of the Framework Convention on Climate Change, which only contains a few, fuzzily formulated material commitments without any time schedule thus providing few starting points for verification. However, if a dynamic climate regime should develop and protocols with extensive, precisely timed and onerous commitments on the reduction of greenhouse gases should be agreed then a greater need for verification would probably arise and elements of intentional violation would also have to be increasingly considered. Verification density would increase and the correctness of national data on emissions etc. would become an issue. The acceptance problem would only then really crop up. It lies dormant in the clauses of protocols conceivable in future and will be awakened if they and related verification systems become a subject of serious discussion. This will probably be particularly true of direct measurements of emissions at large point sources and satellite surveillance (possibly to a lesser extent in joint implementation programmes).

5.2 Considerations on acceptance in a developed climate regime

Strict material commitments in treaties are *necessary* for verification, without them there is no object to be verified. Such commitments are only envisaged by states if they regard this as a really urgent problem also for their country and their interests. Discussions on the acceptance of verification in climate protection therefore also require insights into the interest of the states in climate protection. Only in connection with this interest can the *sufficient* conditions for accepting verification be considered, which are to be found above all in the process of domestic policy.

Whereas for the OECD states and also as a tendency for transition economies, greater acceptance for the verification of climate agreements can be accepted, this must be regarded with greater scepticism for the third group, the "southern" countries. This is shown by analyses of the Chinese, Indian and Brazilian climate protection policy - central for the entire "south" - and their hesitant attitude to "restrictions on national sovereignty" and the comparatively small experience of these countries with international environmental cooperation and even with simple reporting systems on the implementation of agreements. As shown in **Table 12**, the integration of these countries into the set of international environmental treaties displaying some approaches to verification is relatively weak. Much still remains to be learned about international cooperation.

By way of summary it must be noted that before posing the question of the acceptance of verification (and receiving the answer) the question must be put of the content and acceptance of the *material* regulations of the convention. Verification will only have an object if the states' commitments are substantial, capable of receiving consensus and placed within a time frame. However, even then there need not be any verification or acceptance problem. The optimum situation from the perspective of actors interested in minimizing costs is a constellation where *everybody* pursues one goal and *no one* distrusts the other. A contrary situation arises if *some parties* require a substantial convention with dense verification and *others* demand the opposite.[9]

Serious acceptance problems are to be expected in particular if the former states attempt to force the latter to relinquish their demands. Between these two poles there are situations in which, for example, everybody wants the regulation but some states want no or only weak verification. The states demanding dense verification must then decide whether the agreement on the material regulations remains meaningful from their point of view if verification is dispensed with.[10] For it is possible that in spite of some violations the effect of the convention may be regarded as positive on the whole. (In the same way, effective verification says nothing about the value of a convention measured against the extent to which a problem is solved: a convention with inadequate commitments may be easily verifiable but does not present a satisfactory regulation of a problem area).

Country	Environmental Convention		Organizations
	ratified	signed	
Brazil	19	7	11
China	10	11	8
Germany	25	15	19
UK	24	13	21
India	18	5	13
Russia	22	10	10
USA	23	9	21

Table 12 The integration of states into international environmental protection
Membership of important multilateral treaties and organizations on environmental protection

[9] Naturally, the logical extreme would be "nobody wants anything" - but in that case there would be nothing to discuss!

[10] The question arises for the second group of whether they can afford to let the agreement collapse.

The initial political situation for the climate issue is still fairly clear: no important actor really wants binding, extensive commitments within a fixed time frame. For this reason the discussion of the acceptance of verification remains necessarily somewhat abstract. Instead, the discussion must concentrate on future material regulations and the possibilities of developing them further. Undoubtedly, willingness to accept effective verification will not arise of its own accord. However, in this case the first two governing factors mentioned at the beginning will exercise a stronger effect and clearly show the necessity for verification and also increase its acceptance. However, it may also be supposed that in the course of a further development of the Framework Convention on Climate Change into a real "regime" a number of intrusive verification concepts could be sacrificed to sovereignty reservations. Thus, for example, a broad application of direct measuring systems as well as a worldwide international satellite surveillance organization could meet with resistance for this reason. Nevertheless, a whole range of future options is conceivable below this level if the climate problem becomes a real issue.

Cost is an important factor for acceptance: on the one hand, this is true of the cost of domestic implementation of the convention. Experience from other environmental conventions shows that the willingness to accept costly commitments is influenced by the level of the GNP per capita. **Table 13** demonstrates this for the complex convention on the prevention of marine pollution by dumping from ships. Even the costs of national monitoring of this implementation and the possible costs of international verification may have a deterrent effect on some countries. If the significance of this aspect is to be reduced for climate protection then the verification costs for poorer countries should be reimbursed at least in part, verification systems should make use of existing structures and systems or multifunctional services as far as possible, i.e. they should not only serve for verification but also for the performance of other tasks. An (international) satellite verification system can also provide information on resource planning and management, for instance.

Group of Countries	MARPOL 73/78 Annexes I	II	III	IV	V
developed market economies	92	92	77	50	85
(former) planned economies	48	48	39	39	42
developing countries > $ 1500 /capita	53	53	25	22	28
developing countries $ 500-$1500/capita	26	26	21	21	24
developing countries < $ 500/capita	20	20	12	10	12

Table 13 Ratification of the MARPOL Annexes by states according to group of countries
(Percentage of states from the respective group)
As of: 31.5.93; source: Peet 1994; the figures refer to the per capita gross national product in current US dollars

6 A Graduated Verification System: Summary and Outlook

Verification is defined as a political process by of means which the parties to a convention wish to obtain "certainty" on whether the contractually agreed norms, regulations and targets are complied with by all parties or whether they have not been observed (noncompliance). Use is made of technical and other instruments, procedures and methods for this purpose. Based on this understanding of verification, a graduated verification system is developed in the present study. Graduated means that there may be different degrees of "certainty" towards which the system is oriented. The degree which appears appropriate must be established and further developed in the course of a dialogue between the parties to a climate convention.

6.1 Demands arising from the need for verification

A need for verification arises if the governmental actors are not prepared to rely on a mutual assurance of compliance with contractually agreed norms etc. The need for verification is decisively influenced by the causes which, in the actors' view, are decisive for noncompliance on the part of the other parties. The reasons may be:

- *A lack of capacity* in implementing treaties and *time lags*, i.e. a lack of ability to implement the commitments in spite of good intentions.
- *Intentional violations*. These represent an intentional, considered act of government policy to achieve advantages or avert disadvantages which (subjectively or objectively) could result for the state from its commitments.
- A third cause of violations, which can be located somewhere between the other two, can be termed *unwillingness*, a lack of readiness to implement commitments. Nothing is falsified here, nor is there a lack of ability to implement the commitments but rather a passive refusal (without letting this become too apparent) to initiate the necessary steps, or of not performing them with the required firmness of purpose. The national reports are correspondingly inadequate.

The need for verification is currently low in the issue area of climate protection, and this springs from the expectation that violations only arise due to capacity shortages or time lags. OECD and IEA activities on verifying national reports also seem to be based on this assumption. It is fairly improbable that intentional violations will result within the framework of the FCCC and violations due to unwillingness are not to be expected since the material regulation depth of the Framework Convention on Climate Change is not very great and it only contains a few fuzzily formulated commitments for just one group of states, without moreover any time frame. More extensive national voluntary obligations on climate protection are only political and not binding commitments according to international law so that they are not subjected to verification. The FCCC therefore does not provide any reason for falsification and there are few starting points for verification.

Nevertheless, if, as demanded by many scientists and some countries, a dynamic climate regime should develop and protocols with extensive, precisely timed and onerous commitments to reduce greenhouse gas emissions should be agreed for more countries, a need for verification would probably arise, which would then also have to increasingly consider elements of unwillingness and intentional violations. This does not only lead to an increased need for verification but also poses the question of institutional consequences. It could then prove necessary to establish a special organization to undertake verification tasks on an international level, beyond the terms of reference of the FCCC. This organization would receive the national reports by the states, in which they describe what they have done and achieved, or intend to achieve, in the climate protection sector, and would verify these reports. Models could be the Vienna International Atomic Energy Agency or the organization currently being established to monitor the prohibition on the production and possession of chemical weapons.

If the dynamic development of climate protection is in the realm of the possible or is politically desirable, then a graduated verification system would suggest itself and would be adaptable to this dynamic situation. The system should comprise three stages oriented to the three causes of noncompliance and based on the following central positions:

1st Stage: The verification organization takes cognizance of the states' declarations with respect to their GHG emissions and climate protection measures. Verification is only carried out concerning the formal correctness and completeness of the information, its content is, however, not verified. The organization believes the states' declarations.
2nd Stage: The verification organization makes use of additional generally available information to verify the consistency and plausibility of the information provided.

3rd Stage: The organization verifies the correctness and completeness of the submitted declarations on the basis of additional information obtained independently.

Fig. 4 illustrates the structure and content of this graduated verification system. The stages correspond to the three causes of noncompliance. If apart from unintentional violations intentional violations are also assumed then additional verification methods and techniques must be applied, which may be very intrusive and thus express high verification density. This is particularly true of on-site inspections and direct, selective measurements of GHG emissions. In Fig. 4, the verification density thus increases from left to right.

In this graduated model verification serves various purposes. It may aim at drawing the attention of well-intentioned states to gaps and problems in realizing the agreements and therefore offer them assistance in overcoming these weaknesses. Secondly, verification may contribute towards identifying reluctant states and leading them back to the straight and narrow. Finally, verification may deter violations by the (latent) threat of detecting intentional violations, making them public and thus possibly initiating sanctions.

Reasons for verification		Lack of capacity, time lags	Inaction in implementation	Intentional treaty-violations
		Elements of Verification		
SECTOR	energy	* formal review * review of consistency and plausibility	* analysis on the basis of additional open information * macro-/micro-modelling	* measurements * on-site inspections * implementation control
	forests and land use		* analysis on the basis of information accessible to the public	* selective remote - sensing * on-site inspections
	agri-culture		* analysis on the basis of information accessible to the public	* remote sensing * on-site-inspections
	climate protection measures		* implementation control * macro-/micro-modelling	* implementation control on the basis of additional information * on-site-inspection
Functions of verification		corrective and supportive	detective and promotional	detective and deterrent

Fig. 4: Elements of a graduated verification system

6.2 Quantitative and qualitative climate protection goals

Climate protection measures and targets comprise two levels, both of which are the object of declaration and verification.
The quantitative level refers to the compilation of greenhouse gas inventories, for which certain terms of reference are necessary and have already been agreed within the Framework Convention on Climate Change. These inventories are the basis for stabilization or reduction targets, which can then be laid down on a time axis.

Furthermore, there is a qualitative level with a view to measures and policies for climate protection. This describes the sequence, implementation and expected impacts of the measures and policies concerning the emissions of greenhouse gases.

A double goal thus arises for verification: on the one hand, of ensuring a verification of the implementation of measures and policies (implementation monitoring), and on the other hand, of guaranteeing the verification (also central in other verification fields) of the quantitative targets of commitments.

6.3 Qualitative level - measures and policies

The national declarations also contain information on measures and policies which the states intend to implement to limit or reduce their GHG emissions. These are also subjected to verification. Verification is graduated here to the extent that over and above the formal verification or rough estimation of consistency and plausibility, systematic, in part formalized, verification of the data is made by recourse to more sources of information and to complex methods, in the case of increased verification density.

6.3.1 Verification of the information basis for measures and policies

A wide range of national measures or policies are being discussed for the reduction or stabilization of greenhouse gas emissions including, for example, measures in the household sector to improve thermal insulation, speed limits or specifying the average fuel consumption of new motor vehicles (fleet mix). The principle of joint implementation also belongs in this category. In analysing the information provided by states on such measures and policies, it is important to identify their legal status, i.e. are laws and directives involved or merely non-binding guidelines. Knowledge of their status is a necessary condition for a more extensive evaluation and estimate of their enforcement and effectiveness.

6.3.2 *Verification of implementation*

There are two concepts for analysing the enforcement of measures by means of implementation monitoring. The first approach is to analyse whether the time targets for realizing a measure have in fact been fulfilled. The second method of implementation monitoring is based on indicator analysis. In order to assess whether measures have been implemented suitable indicators are identified providing appropriate indications. Thus, for example, in order to estimate whether energy-saving measures have actually been implemented in the thermal sector, sales of insulating material can be used as an indicator, or sales of energy-saving domestic appliances in order to estimate the reduction of electricity consumption.

6.3.3 *Verification of the impact of measures*

In order to plan a measure and estimate its impact with respect to the reduction of greenhouse gas emissions, as well as the efficiency and costs required to achieve this reduction, it is necessary to perform extensive and methodologically transparent analyses. One possibility is provided by sector-specific computer models, such as the submodels of the IKARUS instruments for industry, transport or small consumers and households. These simulation models enable reduction potentials and the costs of measures to be assessed in the energy sector. The question of whether and to what extent these measures have actually taken effect can only be determined on the basis of current statistics or actual emissions, but in any case only ex post facto. This leads to the question of verifying quantitative data on GHG emissions.

6.4 Review of quantitative commitments

Quantitative commitments are at the core of agreements, and measures and policies must also finally be reflected in quantities, i.e. in amounts of GHG emissions. The graduated verification of these figures set out in the national reports is at the heart of verification.

6.4.1 Formal verification

Formal verification involves the correctness and completeness of the form in which information is provided by the states. This form must, for example, satisfy certain predefined demands with respect to category and sector formation. Thus, for example, the question arises within the Climate Convention of whether all greenhouse gases have been covered, whether the various relevant sectors have been properly described and whether an aggregation can be adequately reconstructed. A formal analysis also includes verification with respect to arithmetic errors.

A further aspect of formal verification refers to the data collection procedures and methods. It must be established whether given standards have been appropriately considered and the extent to which individual elements of these procedures, e.g. emission factors for CO_2, can be internationally accepted, and whether they are transparent or not.

6.4.2 Verification of content using information from published sources

A large number of data bases on atmospheric pollutants and also greenhouse gases are available within the framework of the UN, OECD, or EU. Information from these data bases can be used to verify the consistency of national declarations. Further relevant information available in national data banks concerns export or import data on fossil fuels, information on population trends, energy consumption, industrial development or volume of traffic in a country. These data can also be used to verify the plausibility of greenhouse gas emissions. Computer models linking all this information and considering both the energy and also the economic aspect can be applied for the national or regional analysis of the greenhouse gas situation. Examples are the IMAGE or IKARUS models.

Information available internationally from measuring networks for determining the concentration of atmospheric pollutants can also, to a limited extent, provide indications which can be used to verify the declarations by states on the fulfilment of their commitments as part of the Climate Convention. Internationally available satellite pictures provide a great deal of information by means of which climate protection measures in the agriculture or forestry sector can be analysed.

6.4.3 Verification of content with information obtained independently

The two stages in the verification of declarations described so far have been exclusively restricted to a formal verification by the international surveillance organization and to the use of information already available from other data international bases. A new stage in the verification process would also include the autonomous and independent generation of information by the international surveillance authority itself.

This independent generation of information includes, for instance, the random sampling of emissions of greenhouse gases by various measuring techniques. This could comprise the measurement of emissions at large coal-fired power stations in order to verify emission factors and to assess the credibility of national declarations for emissions from such plants. Remote sensing (combined with on-site inspections) can be applied for verification purposes in the sectors of forestry, land use and agriculture if special agreements on GHG limitation or the expansion of sinks have been resolved. A further important method of obtaining information can be visits to national institutions of importance for monitoring greenhouse gases. Such inspections could include, for example, an energy-generating plant where greenhouse gases are emitted (on-site inspections). Such inspections could also include visits to the "national authority" responsible for compiling the national report in order to obtain insights into the way it works, its information sources and data processing.

Information is the keystone of a verification system. This is true both of the national declaration and also of verification. Nevertheless, the mere quantity of data etc. provided is not a criterion for the quality of the national report nor is the quantity of information obtained independently an indication of the effectiveness of the verification system. A flood of trivial information may indeed hamper verification. The decisive aspect is that the verification organization provides a data plan which must be filled in by the states and which is optimized for verification purposes. The organization must concentrate on the verification of key information.

6.5 Acceptance of graduated verification systems

The initial political situation is still quite unambiguous for the climate issue area. Really binding, extensive and scheduled commitments to reduce GHG emissions cannot (yet) be politically achieved for a large number of states. The discussion of the acceptance of verification is therefore necessarily abstract since weak material regulations do not leave much room for verification. Even the need for verification seems low as yet. Political attention must be directed to future material regulations and their possibilities for further development. The willingness to accept effective verification will undoubtedly not be automatic. However, the necessity for verification will become clearer and its acceptance will grow. It may, nevertheless, also be assumed that as part of the further development of the Framework Convention on Climate Change into a genuine "regime" a number of intrusive verification concepts will be sacrificed to sovereignty reservations. For this reason alone (quite apart from the question of cost) a broad application of direct measuring systems or specific remote sensing by states as *explicit* internationally agreed measures for the verification of commitments to climate protection will probably meet with resistance. Nevertheless, even below this level a great deal of that depicted in Fig. 4 can still be realized if the climate problem really becomes an urgent political topic.

References

Adams 1993 — Adams, H.W.: Der "gerichtsfeste" Zustand einer Anlage - Umwelthaftung und Dokumentation (II); in: Blick durch die Wirtschaft, 26. Feb. 1993.

Ausubel/Victor 1992 — Ausubel, J.H., Victor, D.G.: Verification of International Environmental Agreements. In: Annual Review of Energy & Environment, 17, 1992, pp. 1-43.

BMFT 1990 — BMFT-Verbundprogramm "Schadstoffe in der Luftfahrt", 1990.

BMU 1991 — Der Bundesminister für Umwelt, Naturschutz und Reaktorsicherheit: Beschluß der Bundesregierung vom 7. November 1990 zur Reduzierung der CO2-Emissionen in der Bundesrepublik Deutschland bis zum Jahr 2005; BMU, Bonn, März 1991.

BMU 1992a — Der Bundesminister für Umwelt, Naturschutz und Reaktorsicherheit: Beschluß der Bundesregierung vom 11. Dezember 1991: Verminderung der energiebedingten CO_2-Emissionen in der Bundesrepublik Deutschland; BMU, Bonn, Sept. 1992.

BMU 1992b — Der Bundesminister für Umwelt, Naturschutz und Reaktorsicherheit: Bericht der Bundesregierung an die Kommission der Europäischen Gemeinschaften über das nationale Programm zur Reduzierung der energiebedingten CO_2-Emissionen und anderer Treibhausgase bis zum Jahr 2005; BMU, Bonn, Mai 1992.

BMU 1992c — Der Bundesminister für Umwelt, Naturschutz und Reaktorsicherheit: Gliederungs- und Inhaltsraster für Nationalberichte (country studies) gemäß der Rahmenkonvention zur Klimaveränderung; BMU, Entwurf G II 5 - 45131/2.1, Bonn 12. Nov. 1992.

BMU 1993a — Der Bundesminister für Umwelt, Naturschutz und Reaktorsicherheit: Einzelmaßnahmen im Rahmen des CO_2-Minderungsprogramms; BMU - N II 5 - 40105-5/0, Bonn, As of: 15 June 1993.

BMU 1993b — Antwort der Bundesregierung: Umsetzung der Empfehlungen der Enquete-Kommission "Vorsorge zum Schutz der Erdatmosphäre" durch die Bundesregierung; Deutscher Bundestag 12. Wahlperiode, Drucksache 12/4280, 05.02.93.

BMU 1993c — Der Bundesminister für Umwelt, Naturschutz und Reaktorsicherheit: Klimaschutz in Deutschland Nationalbericht der Bundesregierung für die Bundesrepublik Deutschland im Vorgriff auf Artikel 12 des Rahmenübereinkommens der Vereinten Nationen über Klimaänderungen; BMU, Bonn, 1993.

BMU 1994a — Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit: Erster Bericht der Regierung der Bundesrepublik Deutschland nach dem Rahmenübereinkommen der Vereinten Nationen über Klimaänderungen; BMU, Bonn 22. August 1994.

BMU 1994b — Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit: Beschluß der Bundesregierung vom 29. September 1994 zur Verminderung der CO_2-Emissionen und anderer Treibhausgasemissionen in der Bundesrepublik Deutschland auf der Grundlage des Dritten Berichts der Interministeriellen Arbeitsgruppe "CO_2-Reduktion" (IMA CO_2-Reduktion); BMU, Bonn 1994.

Brenton 1994 — Brenton, T., The Greening of Machiavelli. The Evolution of International Environmental Politics. London 1994 (The Royal Institute of International Affairs).

Brieda 1993 — Brieda, F., G. Eichmüller: Handbuch zur Erstellung von Emissionserklärungen; 2. Auflage, Materialien, Umweltbundesamt/TÜV Rheinland (E. Schmidt Verlag), Berlin 1993.

CEOS 1992 — Committee on Earth Observations Satellites: The relevance of satellite missions to the study of the global environment. UNCED Conference Rio de Janeiro 1992, prepared by BNSC, London 1992.

Chayes 1993 — Chayes, A. & Chayes, A.H. (1993): On Compliance, in: International Organization, 47, 2/1993, S. 175-205.

Climate 1992 — Climate Change Policy Initiatives: Update; IEA - International Energy Agency, Paris, 9.3.92.

Corfee 1994 — Corfee-Morlot, J., Schwengels, P., Verification, Evaluation and Monitoring. In: Katscher u.a. (Eds), 1994, pp. 75-92.

Comes 1993 — Comes, S., Umweltmeßnetze: Hilfsmittel der Verifikation in einem Klimaregime, Berichte des Forschungszentrums Jülich, Jül-2741, Jülich 1993.

Comes 1992 — Comes, S.: Institutionelle Fragen der Verifikation im Zusammenhang mit einer internationalen Klimakonvention. Bericht des Forschungszentrums Jülich GmbH Jül-2641, Jülich 1992.

Daase 1992 — Daase, C.: Ökologische Sicherheit: Konzept oder Leerformel? In: B. Meyer & C. Wellmann (Red.), Umweltzerstörung: Kriegsfolge und Kriegsursache. Frankfurt/M. 1992 (ES), S. 21-52.

ECE 1987 — Economic Commission for Europe: National Strategies and Policies for Air Pollution Abatement; Results of the 1986 major review prepared within the framework of the Convention on Long-range Transboundary Air Pollution, United Nations, New York 1987.

Efinger 1990 — Efinger, M., Vertrauen ist gut, Kontrolle ist besser. Entstehungsbedingungen effektiver Verifikationsregeln im Politikfeld "Sicherheit". Dissertation, Eberhard-Karls-Universität Tübingen, Tübingen 1990 (manuscript).

Efinger/Breitmeier 1991 — Efinger, M. & Breitmeier, H., Zur Theorie und Praxis der Verifikation einer globalen Klima-Rahmenkonvention. Forschungszentrum Jülich GmbH, Jül-2642, Jülich 1991.

Enquete 1990 — Dritter Bericht, Enquete-Kommission "Vorsorge zum Schutz der Erdatmosphäre" zum Thema "Schutz der Erde"; Deutscher Bundestag, 11. Wahlperiode, Drucksache 11/8030, 24.5.90.

Enqute 1990 — Dritter Bericht, Enquete-Kommission "Vorsorge zum Schutz der Erdatmosphäre" zum Thema "Schutz der Erde"; Deutscher Bundestag, 11. Wahlperiode, Drucksache 11/8030, 24.5.90.

EPA 1990 — United States Environmental Protection Agency, Netherlands Ministry of Housing, Physical Planning and Environment (VROM): International Enforcement Workshop, Proceedings, Vol. I + II; The Netherlands, Utrecht, May 8-10, 1990.

Fischer 1994 — Fischer, W.: Institutionen; in: IKARUS - Instrumente für Klimagas-Reduktionsstrategien, Teilprojekt 9: Verifikationsmaßnahmen, Dritter Zwischenbericht, November 1992-Dezember 1993, Programmgruppe Technologiefolgenforschung, Jülich 1994

Fischer 1992 — Fischer, W.: Klimaschutz und internationale Politik. Die Konferenz von Rio zwischen globaler Verantwortung und nationalen Interessen, Shaker-Verlag Aachen, 1992.

Fischer 1991	Fischer, W.: The Verification of a Greenhouse Gas Convention - a New Task for International Politics?, in: J. B. Poole (Ed.), Verification Report 1991, London/New York 1991 (VERTIC & The Apex Press), pp. 197-206
Fischer et al. 1991	Fischer, W., di Primio, J.C., Stein, G.: Verifikation einer internationalen Klimakonvention; Forschungszentrum Jülich GmbH, Jahresbericht/Annual Report 1991, Jülich, Oktober 1991.
Fischer et al. 1989	Fischer, W., J.C. di Primio, G. Stein: A Convention on Greenhouse Gases: Towards the Design of a Verification Regime. Research Centre Jülich, KFA 1989.
Fritsche et al. 1992	Fritsche, U., F.C. Matthes: Analyse von Datenbasen zu klimarelevanten Emissionen in der Bundesrepublik Deutschland; Internationale Treibhausgasverifikation Nr. 1; Forschungszentrum Jülich GmbH, Programmgruppe Technologiefolgenforschung, Jül-2614, Mai 1992.
Gastellu-Etchegorry 1991	Gastellu-Etchegorry, J.P.: Satellite Remote Sensing for Agricultural Projects. The World Bank, World Bank Technical Papers 128. Washington D.C 1991.
Görgen 1993	Görgen, R.: Energiestatistik in Deutschland Aufbau, Problemlagen und Verbesserungsmöglichkeiten; in: Energiewirtschaftliche Tagesfragen, 43. Jg. (1993), Heft 7.
Greene 1992	Greene, O.: Ozone Depletion: Implementing and Strengthening the Montreal Protocol. In: J.B. Poole & R. Guthrie (Eds.), Verification Report, London (Vertic), 1992, pp. 265-274.
Grubb 1990	Grubb, M.: Energy Policies and the Greenhouse Effect, Vol. One: Policy Appraisal; The Royal Institute of International Affairs, Dartmouth, 1990.
Grubb 1991	Grubb, M. et al.: Energy Policies and the Greenhouse Effect, Vol. Two: Country Studies and Technical Options; The Royal Institute of International Affairs, Dartmouth, 1991.
Hönsch 1992	Hönsch, H.: Remote Sensing Satellite Data as an Instrument to Verify a Greenhouse Gas Convention - A Case Study in the Brazilian Amazon, in: di Primio/Stein (Eds.) 1992, S. 155-166.

IPS 1982	Kognitive Systemanalyse, Konzeptverarbeitung und Verhaltenssimulation; Zusammenfassender Abschlußbericht zum Projekt "Verhaltensbestimmende kognitive Elemente im nichtnumerischen Modell"; Institut für Angewandte Systemforschung und Prognose e.V. (ISP); Hannover, Okt. 1982.
INC 1994	Possible Criteria for Joint Implementation, in: Intergovernmental Negotiation Committee for a Framework Convention on Climate Change, Ninth Session, Geneva 7 - 18 February 1994
IPPC 1990	IPCC, Climate Change. Cambridge 1990 (Cambridge University Press).
IPCC 1992	IPCC, Climate Change. The Supplementary Report to the IPCC Scientific Assessment. Prepared by IPCC for Working Group 1. WMO/UNEP 1992.
IPCC 1993	IPCC, Preliminary IPCC National GHG Inventories: In-depth Review, Part III. OECD/IEA. Paris Aprol 1993.
IPCC 1994a	Greenhouse Gas Inventory Reporting Instructions; IPCC Draft Guidelines for National Greenhouse Gas Inventories. February 1994. Vol. 1: Reporting Instructions; Vol. II: Workbook; Vol. III: Reference Manual.
IPCC 1994b	Radiative Forcing of Climate Change. The 1994 Report of Scientific Assessment Working Group for IPCC Summary for Policymakers. WHO/UNEP 1994.
Jänicke 1993	Jänicke, M.: Über ökologische und politische Modernisierung, in: Zeitschrift für Umweltpolitik & Umweltrecht, 16, 2/1993, S. 159-175.
Katscher et al. 1994	Katscher, W. et al.: (Eds.): Greenhouse Gas Verification - Why, How and How Much? Proceedings of a Workshop, Bonn April 28-29, 1994. Konferenzen des Forschungszentrums Jülich Band 14. Jülich (KFA) 1994.
Kenneweg 1992	Kenneweg, H.: Stellungnahme zur öffentlichen Anhörung der Enquete-Kommission des deutschen Bundestages "Schutz der Erdatmosphäre" am 16. und 17. Januar 1992.
Klaus 1994	Klaus, D. et al.: Application of Digital Satellite Imaginary for the Verification of GHG Agreements, in: Katscher et al. 1994, S. 155-166.

Kolke 1993	Kolke, Reinhard: Darstellung und Bewertung von Methoden der Volumenstrommessung an Rauchgasen fossil befeuerter Kraftwerke im Rahmen der Verifizierungsmaßnahmen (TP 9) des IKARUS-Projektes, Interner Bericht des Forschungszentrums Jülich, 1993.
Kom 1992	Kommission der Europäischen Gemeinschaften: (Vorschlag für eine) Entscheidung des Rates über ein gemeinschaftsweites Beobachtungssystem zur Messung der Emissionen von CO_2 und anderen Treibhausgasen; KOM(92) 181 endg., Brüssel, 1. Juni 1992.
Kotov 1994	Kotov, V.: Implementation and Effectiveness of International Environmental Regimes during the Process of Transformation in Russia. Working Paper, WP-94-1994. International Institute for Applied Systems Analysis (IIASA). Laxenburg 1994.
Kuik 1994	Kuik, O., Peters, P. and Schrijver, N. (Eds.): Joint Implementation to Curb Climate Change, Dordrecht/Boston/London (Kluwer Academic Publishers), 1994.
Lang 1994	Lang, W.: Verhinderung von Erfüllungsdefiziten im Völkerrecht. In: Hengstschläger, J. u.a. (Hg.), Für Staat und Recht. Festschrift für Herbert Schambeck. Berlin 1994, S. 817-835.
Lanchbery/Salt 1993	Lanchbery, J., Salt, J.: Limiting Climate Change. Verification of compliance with treaty commitments to limit greenhouse gas emissions from forests and land use by remote sensing. Forschungszentrum Jülich (KFA), Jül-2824, Okt. 1993.
Lanchbery i.p.	Lanchbery, J. et al.: Verification in a climate protection regime: Role and limitations of space based remote sensing. In. D. Sloggett (Ed.), Reference Handbook for Remote Sensing. (Ellis Horwood Library of Space Science and Technology), in preparation
Lashof 1990	Lashof, D.A. und Tirpak, D.A. (Eds): Policy Options for Stabilizing Global Climate, Report to the Congress, US Environmental Protection Agency, report 21P-2003.1, Washington, D.C. , USA, 1990.
Lauppe 1994	Lauppe, W.-D. : Measuring Techniques for Radiative Forcing Gases, in: di Primio u.a. International Greenhouse Gas Verification - Elements and Institutions -. Forschungszentrum Jülich (KFA) 1994, S. 28-41.

Loske/Oberthür 1994	Loske, E./Oberthür, S.: Joint Implementation under the Climate Change Convention, in: International Environmental Affairs, 6, 1/1994, S. 45-58.
Messer/Ziesing 1992	Messer, R., H.-J. Ziesing: Aktueller und längerfristiger Bedarf an energiestatistischen Basisdaten; Gutachten im Auftrage des Bundesministers für Wirtschaft; Berlin, Juni 1992.
Mitchell 1992	Mitchell, R.B.: From Paper to Practice: Improving Environmental Treaty Compliance. Thesis, Harvard University, Cambridge/MA (manuscript), 1992.
Nitschmann 1993	Nitschmann, J.: "Die Betriebe sind überfordert" - Landesregierung plant grundlegende Kursänderung in der Umweltpolitik; Rheinische Post, 10.04.93.
Oberthür 1993	Oberthür, S.: Politik im Treibhaus. Die Entstehung des internationalen Klimaschutzregimes (Edition Sigma), Berlin, 1993.
OECD 1991	OECD/ OCDE: Estimation of Greenhouse Gas Emissions and Sinks; Final Report from the OECD Experts Meeting, 18-21 Feb. 1991, Prepared for Intergovernmental Panel on Climate Change, Revised August 1991.
OECD 1993a	Towards Guidelines for Reporting - Status of IPCC/OECD Recommendations on Reporting National GHG Inventories. Room Document 4, OECD-Experts Meeting on Communications and Review of National Programmes to Reduce GHG. Geneva 1993.
OECD 1993b	Communication of Information under the Framework Convention on Climate Change. Work Plan and Draft Structure and Main Issues of the Final Report. Prepared by the OECD Secretariat, Revised, July 1993.
Peet 1994	Peet, G.: International Co-Operation to Prevent Oil Spills at Sea Not Quite the Success it Should Be, in: Bergensen, H.O./Parmann, G. (Eds.), Green Globe Yearbook 1994. Oxford 1994 (Oxford University Press), S. 41-54.
di Primio/Stein 1992	di Primio, J.C./Stein, G. (Eds): A Regime to Control Greenhouse Gases, Proceedings of a Workshop, Konferenzen des Forschungszentrums Jülich, Band 10, KFA-Jülich GmbH 1992.
Rittberger 1990	Rittberger, V. (Hg.): Theorien der Internationalen Beziehungen (Westdeutscher Verlag), Opladen, 1990.
Sands 1993	Sands, P.: Enforcing Environmental Security: The Challenge of Compliance with International Obligations, in: Journal of International Affairs, 46, 2/1993, S. 367-390.

Schafhausen 1992	F. Schafhausen: Internationaler Klimaschutz - Länderpositionen und Debatte um Klimaschutzinstrumente; in: Energiewirtschaftliche Tagesfragen, 42, 8/1992.
Schutz der tropischen Wälder 1990	Schutz der tropischen Wälder. Eine internationale Schwerpunktaufgabe, Eds: Deutscher Bundestag, Ref. Öffentlichkeitsarbeit. (Zur Sache, 1990,10), Bonn 1990.
Spradley 1994	Spradley, Jr., J. R.: Business Criteria for Joint Implementation, in Groningen International Conference on Joint Implementation, Groningen, The Netherlands, 1-3 June 1994.
Tank 1991	Tank, Volker, Michelson Interferometer für die Gasanalyse in der Umwelttechnik, Technisches Messen 58, 1991, 9, S. 335-338.
Tropenwaldbericht 1993	Tropenwaldbericht der Bundesregierung. Schutz und Bewirtschaftung der Tropenwälder, Bonn, März 1993. (Bundesminister für Ernährung, Landwirtschaft und Forsten).
Tropical Forests 1991	Tropical Forests and Climate, Special Issue of Climate Change, 19, 1-2/1991. Guest Editor N. Myers.
UBA 1989	Umweltbundesamt: Luftreinhaltung '88, Tendenzen - Probleme - Lösungen; E. Schmidt Verlag, Berlin 1989.
UBA 1992	Umweltbundesamt: Jahresbericht 1991; Berlin, 1992.
UBA 1992 a	Umweltbundesamt: Daten zur Umwelt 1990/91; E. Schmidt Verlag, Berlin 1992.
Übing/Kropp 1990	Übing, D., L. Kropp: Environmental Laws and their Execution in the Federal Republic of Germany; in: EPA 1990, pp. 53-72.
UNEP 1990	United Nations Environment Programme (Eds), GEMS Global Environment Monitoring System, Nairobi 1990, S. 14 ff.
UNEP 1991	United Nations Environment Programme (Eds), Urban Air Pollution, Nairobi 1991.
Utsch 1993	Utsch, M.: International Agreements: Incentives for cooperative and non-cooperative behaviour. In: W. Kuckshinrichs / W. Pfaffenberger / W. Ströbele (Eds), Workshop on the Economics of the Greenhouse Effect. Konferenzen des Forschungszentrums Jülich (KFA), Band 13/1993, S. 97-114.
VDI-GET 1992	VDI-Gesellschaft Energietechnik: CO_2-Minderung durch staatliche Maßnahmen? - Instrumente/Wettbewerb/Akzeptanz; VDI-Berichte Nr. 997, VDI-Verlag, Düsseldorf 1992.
Victor 1994	Victor, D.G, Overview: Verification of International Environmental Agreements. In: Katscher u.a. (Eds) 1994, pp. 47-61.

Victor/Salt 1994	Victor, D.G, Salt, J.E.: „From Rio to Berlin: Managing Climate Change, in: Environment, 36, 10/1994, S. 6-15, 25-32.
Walker/Wirl 1994	Walker, I.O./Wirl, F.: How effective would Joint Implementation be in stabilizing CO_2 emissions?, in: OPEC Bulletin, 25, 10/1994, S. 16-19 + 63.
Wasserman 1990	Wasserman, C.E: An Overview of Compliance and Enforcement in the United States: Philosophy, Strategies and Management Tools; in: EPA 1990, pp. 7-45.
Weidner et al. 1993	Weidner, H., Zieschank, R., Knoepfel, P. (Eds): Umwelt-Information. Berichterstattung und Informationssysteme in zwölf Ländern. Berlin, 1992.
WMO 1991	World Meteorological Organization (Eds): The Global Atmosphere Watch, Fact Sheet No. 3.
Wülbern 1993	Wülbern, K.: Fortschritt in der Gasanalytik, UMWELTMagazin, Mai 1993, S. 148-149.
Young 1992	Young, O.: International Environmental Governance: Building Institutions in an Anarchical Society. In: Science and Sustainability. International Institute for Applied Systems Analysis (IIASA), Laxenburg, 1992, p. 245-268.

Monographien des Forschungszentrums Jülich

1 Pharmakologische Untersuchungen in vitro –
Alternativen zum Tierversuch
E. Weber (Hrsg.) (1990)

2 Ozon in Deutschland
Die Belastung durch Ozon in ländlichen Gebieten
im Kontext der neuartigen Waldschäden
D. Kley, H. Geiss, T. Heil, Ch. Holzapfel (1990)

3 Risiko-Konzepte
Risiko-Konflikte
Risiko-Kommunikation
H. Jungermann, B. Rohrmann und P.M. Wiedemann (Hrsg.) (1990)

4 Energiequellen und Energietechnik
M. Pollermann, W. Litzow (1991)

5 Neue Energieträger für den Verkehr
Methanol und Alkoholgemische
B. Höhlein (1991)

6 Computergestütztes "Molecular Modelling"
Alternativen zum Tierversuch
E. Weber (Hrsg.) (1991)

7 Information und Kommunikation
in der naturwissenschaftlich-technischen Forschung
Haben wir die richtigen Bibliothekskonzepte?
E. Lapp, W. Neubauer (1992)

8 Fortschritte in der Energietechnik für eine wirtschaftliche,
umweltschonende und schadensbegrenzende Energieversorgung
K. Kugeler, H. Neis, G. Ballensiefen (Hrsg.) (1993)

9 Die CO_2-Problematik
Sachverhalte, Zusammenhänge, Hypothesen, Argumente
herausgegeben von H. Neis (1993)

10 Das Klimasystem unserer Erde
Ch. Holzapfel (1994)

11 Ohne Energie geht nichts
M. Pollermann, W. Litzow (1995)

12 Der Schutz der Meere in der internationalen Politik
Nachhaltige Entwicklung und die Ozeane
W. Fischer (1995)

13 Computergestützte Analyse energiebedingter Klimagasreduktionsstrategien
IKARUS. Instrumente für Klimagas-Reduktionsstrategien
Abschlußbericht Teilprojekt 1 „Modelle"
J.-Fr. Hake, R. Heckler, Ch. Holzapfel, P. Jagodzinski, H. Kollmann, W. Kuckshinrichs, P. Markewitz, D. Martinsen, D. Müller, M. Walbeck
(voraussichtlich 1995)

14 IKARUS-Datenbank – Ein Informationssystem zur technischen, wirtschaftlichen und umweltrelevanten Bewertung von Energietechniken
IKARUS. Instrumente für Klimagas-Reduktionsstrategien
Abschlußbericht Teilprojekt 2 „Datenbank"
H.-J. Laue, K.-H. Weber, J. W. Tepel
(voraussichtlich 1995)

15 Fossile Energieträger und erneuerbare Energiequellen
IKARUS. Instrumente für Klimagas-Reduktionsstrategien
Abschlußbericht Teilprojekt 3 „Primärenergie"
J. Diekmann, M. Horn, P. Hrubesch, B. Praetorius, F. Wittke, H.-J. Ziesing (1995)

16 Energieumwandlungstechniken als Elemente von Minderungsstrategien energiebedingter Klimagasemissionen
IKARUS. Instrumente für Klimagas-Reduktionsstrategien
Abschlußbericht Teilprojekt 4 „Umwandlungssektor"
U. Fahl, D. Herrmann, A. Voß (1995)

17 Energieverbrauchsstrukturen im Sektor Haushalte
IKARUS. Instrumente für Klimagas-Reduktionsstrategien
Abschlußbericht Teilprojekt 5 „Haushalte und Kleinverbraucher", Sektor „Haushalte"
S. Kolmetz, L. Rouvel (1995)

18 Energieverbrauchsstrukturen im Sektor Kleinverbraucher
IKARUS. Instrumente für Klimagas-Reduktionsstrategien
Abschlußbericht Teilprojekt 5 „Haushalte und Kleinverbraucher", Sektor „Kleinverbraucher"
S. Kolmetz, L. Rouvel, G. Bressler, W. Megele, H. Bradke, E. Jochem, D. Köwener, M. Patel (1995)

19 Hauptbericht Industrie – Energieeffizienzpotentiale, Produktstrukturwandel und Produktionsentwicklungen bis 2020
IKARUS. Instrumente für Klimagas-Reduktionsstrategien
Abschlußbericht Teilprojekt 6 „Industrie"
H. Bradke, W. Eichhammer, E. Jochem, M. Patel
(voraussichtlich 1995)

20 Klimagasrelevante Energie- und Kostenstrukturen im Straßen-, Schienen-, Schiffs- und Luftverkehr
IKARUS. Instrumente für Klimagas-Reduktionsstrategien
Abschlußbericht Teilprojekt 7 „Verkehr"
J. Brosthaus, R. Kober, W.-R. Müller, H. Waldeyer (1995)

21 Querschnittstechniken – Sektor und branchenübergreifende Techniken zur Energieumwandlung
IKARUS. Instrumente für Klimagas-Reduktionsstrategien
Abschlußbericht Teilprojekt 8
„Querschnittstechniken"
H . Schaefer, V. Schäfer (1995)

22 Vereinbarungen zum Klimaschutz – das Verifikationsproblem
IKARUS. Instrumente für Klimagas-Reduktionsstrategien
Abschlußbericht Teilprojekt 9 „Verifikation"
W. Fischer, H.-J. Hoffmann, W. Katscher, U. Kotte, W.-D. Lauppe, G. Stein (1995)

23 Energiestrategien für den Klimaschutz in Deutschland – Das IKARUS-Instrumentarium
IKARUS. Instrumente für Klimagas-Reduktionsstrategien
Zusammenfassender Abschlußbericht
H.-J. Hoffmann, W. Katscher, G. Stein
(voraussichtlich 1995)

24 IKARUS. Instruments for Greenhouse-Gas Reduction Strategies
Summary
by H.-J. Hofmann, W. Katscher, G. Stein
(voraussichtlich 1995)

25 Agreements on Climate Protection – The Verification Problem
IKARUS. Instruments for Greenhouse-Gas Reduction Strategies
Final Report Subproject 9 "International Greenhouse Gas Verification"
by W. Fischer, H.-J. Hoffmann, W. Katscher, U. Kotte, W.-D. Lauppe, G. Stein (1995)

ISBN 3-89336-175-8