Report 1994:6

Joint Implementation Under the Climate Convention: Phases, Options and Incentives

by

A. Torvanger, J. S. Fuglestvedt, C. Hagem, L. Ringius, R. Selrod and H. A. Aaheim

CICERO
Center for International Climate and
Energy Research - Oslo

November 1994

The background for this report is the concern to develop criteria for the mechanism of Joint Implementation (JI) under the United Nations Framework Convention on Climate Change (FCCC), and the recent debate on such criteria. The work has been financed by the Norwegian Ministry of Finance, and the analysis project has been divided into two phases. For the first phase, the report 'What might be minimum requirements for making the mechanism of Joint Implementation under the Climate Convention credible and operational', was prepared by R. Selrod and A. Torvanger for the CICERO and Tata Energy Research Institute workshop on Joint Implementation in New Delhi, January 21-23, 1994. The present report has been prepared during the second phase of the project. We thank Carola Bjørklund and Ivar Isaksen for valuable contributions, Peggy Simcic Brønn for improving our English and Berit Nordlund for efficient typewriting assistance.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The aim of this report is to analyze the conditions under which Joint Implementation (JI) can contribute to a cost-effective abatement of global greenhouse gas (GHG) emissions. JI refers to policies and measures implemented jointly by Parties to reduce net GHG emissions contributing to meeting their national commitment under the Climate Convention. The overall conclusion is that JI is a promising mechanism under some circumstances.

Difficulties related to implementation and control of JI projects vary considerably and depend on what countries participate, how the project affects GHG emissions or sinks (for example through fossil fuel saving or through carbon sequestration in forests), and the institutional frames for JI. The simplest project type is fossil fuel saving between two countries with legally-binding emission commitments under the Climate Convention.

The main results from the analysis can be summarized in three points:

1. The Conference of the Parties (COP) to the Climate Convention should take steps to establish the institutional capacity necessary to initiate and coordinate a number of studies and pilot projects in regard to JI. This may help all Parties to examine and evaluate the possible benefits of JI and the question of how JI might best serve the objectives of the Convention. The potential problems related to implementation and control of the simplest JI project type are also found for the more complicated JI project types. Thus extra effort should be put into solving these basic issues.

2. Contracts between JI parties should include incentives for the host country to implement the project in an efficient manner. Contracts can reduce some of the problems that may lead to a reduced cost saving potential and difficulties in controlling the global GHG abatement effect of JI projects.

3. The establishment of a Clearinghouse or Credits Bank institution may significantly reduce some of the potential problems related to implementation and control of JI projects. These problems include asymmetric information and incentives that generate inefficiencies, the difficulties involved in measuring the global abatement effect of a JI project, and handling of risk related to uncertain cost per unit of GHG abatement.

1. INTRODUCTION

The United Nations Framework Convention on Climate Change (FCCC) was signed by more than 150 countries assembled at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in June 1992. The FCCC entered into force in March 1994 after fifty countries had ratified the convention. The FCCC establishes a global legal and institutional framework for how the Parties to the convention shall act with regard to global warming caused by greenhouse gases (GHGs). Under the FCCC, Annex I countries have agreed to adopt national policies and measures to mitigate climate change and have recognized the importance of establishing a goal of returning anthropogenic GHG emissions to 1990 levels by the year 2000.[1] However, the FCCC presently establishes no legally binding commitments to reduce GHG emissions. Until reduction targets are legally binding in terms of quantities and a time framework the FCCC's role in curbing GHG emissions will be speculative and the incentives for emissions reductions will continue to be weak and insufficient.

In 1992, the Intergovernmental Panel on Climate Change (IPCC) concluded that GHGs (*inter alia* carbon dioxide, methane, chlorofluorocarbons and nitrous oxide) are accumulating in the atmosphere due to human activities. The IPCC also concluded that the global mean surface air temperature has increased by 0.3 to 0.6^{o} C over the last century.[2] Many expect that a global temperature rise, due to the anthropogenically-enhanced greenhouse effect, will take place due to the observed on-going increase in the levels of GHG emissions.

Unless strong counteractive measures are introduced the expected emissions from the OECD countries in the coming decades, see Table 1.1, will quickly outgrow the political commitment to stabilizing GHG emissions made by this group of countries. Furthermore, the expected global growth of CO_2 emissions -- 21.7 billion tons in 1990, 25.1 billion tons in 2000, and 32 billion tons in 2010 -- makes the present commitments under the FCCC seem highly inadequate.

This gloomy scenario underscores the importance of developing effective mechanisms for GHG emission reductions under the FCCC.

---

[1] Annex I countries include 24 OECD countries (except Mexico) plus 12 countries from Central and Eastern Europe with 'economies in transition'. For a list of Annex I countries, see Annex 1 in this report.

[2] IPCC (1992).

Table 1.1 World CO_2 emissions (gigatonnes CO_2 per year)

Group of countries / year	1990	2000	2010
OECD	10.4	11.8	13.4
Former Soviet Union (FSU) / Central and Eastern Europe (CEE)	4.8	3.9	4.6
Rest of the World (ROW)	6.5	9.4	14.0
China	2.4	3.4	5.0
East Asia	1.0	1.7	2.6
South Asia	0.7	1.0	1.7
Other	2.4	3.3	4.7
World	21.7[a]	25.1	32.0

[a]Equal to 5.9 gigatonnes carbon per year GtC / yr.
Source: IEA (1994)

The cost of reducing the GHG emissions varies considerably across countries. Countries in which electricity supply is mainly based on nuclear or hydro power have smaller potential for reducing GHG emissions than countries in which electricity supply is based on fossil fuels. The costs of emissions reductions thus vary considerably as some countries might switch from coal to gas in power plants at a low cost, while others will have to reduce, e.g., transport activities at a high cost. To require the same reduction in all countries would therefore be unreasonable, because the cleanest country would have to pay the highest price. Moreover, it would not be cost-effective, because the clean country could reduce an equivalent amount of global emissions of GHGs in another country at a lower cost.

All countries attempt to make the most out of their financial resources, a viewpoint which also is endorsed by the FCCC.[3] Being a petroleum exporting country which meets all its domestic electricity demand with hydro power, it is not difficult to understand why Norway introduced the concept of Joint Implementation (JI) into the negotiations on the FCCC. JI aims at reducing the cost differences of GHG reductions among countries by separating the commitment of each country party with regard to limitation of net GHG emissions from the implementation of measures.

The basic argument behind JI is straight forward: The country that pays for abatement abroad (investing country) yields a net benefit, while the country carrying out the emission reduction (host country) gains from local environmental improvements and reduced problems from global warming. In addition, the host country may benefit from

[3] Art. 3.3.

the transferred technology at no cost. JI may thus reduce the costs of achieving a GHG emissions reduction goal, but does not necessarily lead to lower global emissions. The global emissions depend on the targets that countries set for themselves. However, by reducing costs the obstacles for executing a global environmental policy become smaller, which again may have implications for the goals. Hence, various aspects of JI examined in this report might, if they are not addressed in an adequate way, reduce the attraction of JI as an instrument for reducing global GHG emissions.

By lowering the cost of curbing climate change at no expense for developing countries JI may contribute to achieving sustainable development, as emphasized in '*Our Common Future*' by the World Commission on Environment and Development, commonly known as the Brundtland report.[4] Although this report focuses on the costs of climate measures, it should be kept in mind that the reason why costs are considered is that one expects a net benefit in terms of a better environment in the long run. The decision to be made by states is a matter of balancing economic cost and environmental benefits. A reduction of costs will enhance the net benefit of climate measures. However, no attempts to weigh costs and benefits are made in this report.

The FCCC establishes a number of important principles to guide the Parties in implementing the provisions and achieving the objectives of the framework convention. It should be noted that the concept of JI is not defined precisely in the FCCC, and criteria for JI projects are not defined either. It is nonetheless evident that the concept of JI refers to activities through which one or more countries (the investing country) contributes to reduction of GHG emissions by paying for a emissions-reducing or sink-enhancing project in another country (the host country), and that this activity is credited against legal commitments under the FCCC.

According to the convention, Art. 4.2,[5] the Annex I countries, the industrialized countries including those countries that are undergoing the process of transition to a market economy, can pursue JI with other Parties to the Climate convention. These countries might be categorized as follows:

- the Annex II countries (the OECD countries except Mexico),[6]
- the Annex I countries
- non-annex countries (developing countries).

Since the fall of 1993, the JI concept has been discussed at the meetings of the

---

[4] World Commission on Environment and Development, (1987).

[5] Art. 4.2 (a) reads: 'The developed country parties (...) commit themselves specifically as provided in the following (...) These parties may implement such policies and measures jointly with other Parties and may assist other Parties in contributing to the achievement of the objective of the Convention'. Furthermore, it reads that '(...) The Conference of the Parties, at its first session, shall also take decisions regarding criteria for joint implementation (...)'.

[6] For a list of Annex II countries, see Annex 1 in this report.

Intergovernmental Negotiating Committee (INC), an interim meeting forum examining and renegotiating issues of relevance to the FCCC. The first Conference of the Parties (COP) will take place in Berlin in March-April 1995, and is expected to begin deliberations on the issue of JI. Among the issues to be discussed are the definition of JI, the conditions under which JI projects might be carried out, crediting of the investing country for emissions abatement in the host country, and other relevant issues.

It seems likely that the FCCC will develop through the following four phases in the future:[7]

- phase I, similar to the present situation, is one in which no countries have - legally binding commitments,
- phase II is the phase where all Annex II countries have legally binding commitments,
- phase III is the phase in where all Annex I countries have legally binding commitments, and
- phase IV is the phase where all countries have legally binding commitments.

It is not certain when the FCCC can be expected to develop from phase I to phase II, and it is even more uncertain if, and when, the FCCC might develop from phase II to phases III and IV. But phase II does not have to be very far into the future. At present, there is broad support within the INC for initiating negotiations on a global warming protocol specifying strengthened commitments at the first meeting of the COP. Should negotiations on a global warming protocol be initiated in March-April 1995, it is not unlikely that they might be completed in 1997 or 1998.[8] This report focuses on JI under phase II conditions.

Outline of the report
Chapter 2 discusses different institutional frameworks for JI projects. In chapter 3, some possible motives behind climate policy are addressed from a welfare theoretical perspective. In the main chapter 4, some analyses of JI contracts, incentive problems and uncertainty are presented. In chapter 5, scientific knowledge of GHG sources and sinks is assessed with regard to possibilities for monitoring of various JI project categories. Chapter 6 presents a brief discussion of the incentives for private enterprises to undertake JI investments. Chapter 7 discusses monitoring and control procedures and a possible institutional framework for JI projects. Chapter 8 summarizes the main findings of the report.

[7] A phased development of JI is discussed in Vellinga and Heintz (1993).

[8] Kåre Bryn, Head of the Norwegian Delegation to the INC, in *CICERONE* (1994), no. 3, pp. 1-2.

2. INSTITUTIONAL ARRANGEMENTS FOR JOINT IMPLEMENTATION

Before an international cooperative arrangement for JI can begin to function, the COP will in all likelihood have to decide on a definition of JI. At present the objectives of and criteria for JI projects may be variously combined. The objectives of JI and the FCCC may not be identical and, in the case that they are not, the COP's definition of JI will establish specific objectives of JI. Principal among the objectives that have been discussed so far are identifying and initiating cost-effective opportunities for reducing GHG emissions, supporting sustainable human and economic development, and encouraging participation of private capital in JI projects.[9] The issue of encouraging participation of private enterprises in JI projects is touched on in chapter 6.

The JI project criteria that finally are agreed upon will determine when a country might act as an investing or a host country, and in what way states, private enterprises, international organizations and non-governmental organizations (NGOs) might participate in JI projects. The final choice of such criteria will determine the strength of the incentives to initiate JI projects and will accordingly determine how powerful JI will be as an instrument for reducing global GHG emissions.

As pointed out in chapter 1, the FCCC is ambiguous with respect to defining JI, and many possible arrangements to institutionalize JI have been proposed and considered since the concept of JI appeared for the first time in the context of global warming and climate change. Proposals have ranged from purely bilateral arrangements that involve no international institution or organization to a global Credits Bank.[10] The advantages of establishing a market place for JI projects have also been examined. It is assumed in the discussion below that JI projects will be institutionalized within the FCCC. However, the degree of institutionalization varies considerably.

The bilateral JI arrangement is one in which an investor and a host country agree on an investment project. How project costs and GHG emissions abatement credits are shared is left to the two countries to decide. The project is reported to the COP by the two countries.

More complex bilateral arrangements are also possible. Proposals for a 'Clearinghouse' are based on the perceived need for a 'market place' for JI projects.[11] The Clearinghouse collects information on potential JI projects and brings together investing and host countries, serving as a mediator. Furthermore, the Clearinghouse may control the information given on JI projects, especially with respect to the effect on GHG emissions. A global Clearinghouse would most probably be institutionalized within the United

[9] Ramakrishna (1994), Wexler et al. (1994).

[10] Hanisch et al. (1993), Mintzer (1994).

[11] Confer the discussion in Hanisch (1991) and Hanisch et al. (1992).

Nations system.

A more complex and ambitious version of a multilateral arrangement is the establishment of a Credits Bank for investments in JI projects.[12] Investing countries could make deposits in the bank and receive credits for GHG emissions abatement. The bank will evaluate investment projects suggested by potential host countries, and the bank decides in which projects it wants to participate. Based on a portfolio of investment projects and their features with respect to costs and GHG emissions abatement, the bank will calculate the average interest on the deposits, namely the amount of credits due for each amount invested. By taking the average over the many projects the risk in terms of uncertain emission abatement effect and credits given is shared among investing nations.

Any of the above arrangements for JI projects will have to be institutionalized within the broader international framework defined in the FCCC. At present, as pointed out already, several ways of institutionalizing JI are possible within the FCCC. A broader concept of JI includes a regime in which private enterprises, international organizations, regional economic organizations, multilateral funding mechanisms and NGOs might be involved in one or more project-relevant activity.

Regional and Global Regimes

The future JI regime should be designed so that it features the institutional options that are considered most attractive. As mentioned already, different types of JI regimes are possible under the FCCC. Regimes, either regional or global, and group-specific commitments have recently been under consideration. A global JI regime based on group-specific commitments may be most advantageous. When building a JI regime within the FCCC, two groups of countries are essential, namely a group investing in JI projects and a group of countries in which JI projects are carried out. Those two groups obviously would reflect the distinction between countries acting as investing or host countries.

Regional regimes regulate behavior and activity within a regional area. Membership is usually restricted to those countries that belong to the region with which the regime is concerned. Compared to global regimes, one significant advantage of regional regimes is the relative homogeneity among its members. Members of a regional regime are likely to be relatively alike in terms of level of economic development and therefore in terms of willingness to pay for environmental protection. In the context of the FCCC, groups reflecting regional configurations of countries that make group-specific commitments to participating in JI projects represent a real opportunity for building a JI regime. Furthermore, due to their common history a number of historical ties often exist among countries in a region, and regional groups might benefit from already existing institutions and organizations. Specifically, it might be advantageous that arrangements for monitoring and verifying JI projects be embedded in regional

[12] Hanisch et al. (1993).

governmental arrangements.

Because there is a large variation in GHG emission reductions costs between countries, cost-effectiveness implies larger reductions in some countries than in others. In case countries with relatively lower GHG emissions reduction costs do not become party to any international arrangement to control GHG emissions, a significant potential for cost-effective emission reductions or carbon sink enhancement will not be taken advantage of globally. Countries with such potentials, such as Eastern Europe and developing countries, are accordingly being considered as a group of countries in which JI projects could be carried out. At the same time, the European Union (EU) and the OECD countries are being considered as groups of countries which might invest in JI projects. As Table 2 depicts, the OECD countries have also been considered as a group in which JI projects might be carried out.

Table 2.1 The basic design of a global JI regime

Group of countries / Role of countries within a JI regime	Group of countries investing in JI projects	Group of countries in which JI projects are carried out
OECD	x	x
Former Soviet Union (FSU) / Central and Eastern Europe (CEE)		x
Rest of the World (ROW)		x

A global JI regime, which would make it possible for JI projects financed by the OECD countries to be implemented in the former Soviet Union, the Central and Eastern Europe or the Rest of the World (ROW), holds the biggest potential for JI as an instrument for global GHG emissions reduction. Before such a JI regime can take effect, however, the FSU / CEE and ROW must willingly cooperate in implementing JI projects, reducing GHG emissions, and the OECD countries must willingly invest in such projects.

A global JI regime is one that is open to all those states that are willing to accept the membership conditions of the regime. Within a global regime there will be a large variation in GHG emissions reduction costs between countries; this makes a global regime attractive to both investing and host countries, at least from a pure cost-effectiveness perspective. In its most simple form, a global regime will determine JI criteria that apply to all regime members and group-specific commitments will accordingly be ruled out. But a global regime does not have to impose uniform behavioral rules and standards on regime members. Within a global regime some countries could be bound by one particular set of rules, while another group of countries could be bound by a different set of rules. By establishing non-uniform rules it might become possible for diverse groups of countries to become *de facto* and *de jure* members of a global regime. In other words, a global JI regime could be based on groups reflecting regional configurations of countries that make group-specific commitments to participating in a JI regime. Furthermore, concern for political and economic feasibility supports such a regime-building process. The distinction between phases I, II, III, and IV, see chapter 1, implicitly recognizes that it should be expected that a global regime of uniform rules and commitments will be preceded by a phase of non-uniform rules and commitments.

The principal limitation of any global JI regime is the heterogeneity of members as well as the high number of regime members. Everything else being equal, countries at different levels of economic development are less alike in terms of resources available for environmental protection and, therefore, are less alike also in terms of their willingness to pay for environmental protection. This might also influence the attractiveness and willingness to undertake JI projects. A second, somewhat different, limitation of global regimes concerns the decision rules used by many global regimes. Often global regimes use decision rules which are slow and cumbersome in practice.

But the combined effect of unevenness of concern for environmental protection, unevenness with regard to ability to pay for environmental protection, and large variation in GHG emissions reduction costs might make a global JI regime an attractive option. Compared to less-than-global institutional arrangements, the divergence and unevenness among countries are bigger within a global regime, a factor that makes the global regime more attractive to investing countries that are willing and eager to finance the most cost-effective JI projects available, and to host countries that are able to supply the most cost-effective projects. Significantly, a global regime is therefore also to be preferred from the perspective of getting the most possible GHG emissions reductions for the invested resources. Briefly returning to the issue of the objectives of JI projects, in addition to the attractiveness of cost-effectiveness, it is perhaps just as important that a global regime creates an opportunity to assist the highest number of host countries in becoming more energy efficient and ultimately in achieving a sustainable human and economic development.[13]

[13] Parikh (1994).

3. MOTIVES AND ECONOMIC EFFECTS OF JOINT IMPLEMENTATION

The argument in support of JI takes the minimization of cost for one country that commits to an emission target as its point of departure. In a future, more mature regime to combat global environmental problems, a system of tradeable permits could replace JI. If all countries in the world set emission targets and JI is accepted (Phase IV) there is no economic reason why tradeable permits should be rejected. Tradeable permits do not require as much control from the third part as JIs, since emissions monitoring is sufficient. Under such circumstances, tradeable permits are therefore preferable compared to a JI regime. For the same reason, tradeable permits rather than JI are advisable between countries with commitments, i.e. within a 'bubble' for GHG emissions.

JI can therefore be regarded as an intermediate arrangement in a world where some countries commit to targets and some do not. The mixture of commitments with respect to combatting global warming among countries raises the question of what the overall global effect of such a regime may be. In other words, it is important to discuss how robust the so-called 'win-win' argument is. Some developing countries and non-governmental organizations are skeptical of the arrangement and have raised different arguments against JI. In this report, a number of these pros and cons will be analyzed. However, it is important to emphasize that the different problems that are discussed may relate to different frames under which JI may be initiated. In particular, it is important to clarify a country's motivation for the implementation of a climate policy before one discusses the problems.

If a country regards a reduction in its contribution to global warming as a gain of welfare, more of the available resources can instead be utilized for consumption and investment. In addition some of the released resources will be used for further abatement since lower emissions will add to welfare. From this perspective, and provided that JI does not have a negative net effect on the host country, JI typically leads to a Pareto improvement.[14]

In a dynamic perspective the effect is more ambiguous. Within a simple economic growth model the increase in investments triggers economic growth. If the emissions are related directly to the production output, enhanced growth may counteract the effect of more abatement. Under conventional economic assumptions the marginal utility of consumption and emission reductions is decreasing, while the marginal cost of abatement increases relative to the marginal productivity of capital. Under these circumstances, the effect of an increasing stock of capital will gradually outrange the effect of the increase in abatement efforts in the long run. This again results in an

[14] A Pareto improvement implies that the available resources are reallocated such that the welfare for someone improves, but no-one's welfare declines.

increasing rate of growth in consumption. Thus, JI may lead to higher emissions compared with domestic abatement without JI in the long run.

This conclusion rests critically, however, on the set of assumptions about the effect of abatement and the macro production function. It is not evident that standard assumptions based on static reasoning applies in the long run. One slight extension of the analysis would be to include environmental feedback on economic activities by means of a ’damage function’. If this function is progressively increasing with increased emissions, the positive long-term effect on emissions mentioned above would be moderated and maybe reversed.

It may, however, be unreasonable to put emissions into the welfare function to explain the motivation for a climate policy. This assumes that governments in industrialized countries really act as if increasing emissions reduce welfare, even if they know that the ability to control the global problem by controlling their own emissions is negligible. Another reason for caring about emissions is to give a signal about the willingness to act, for instance as a response to international pressure. Then, the target is probably better represented by an explicit (exogenous) limit to emissions, and the welfare depends on consumption only. This implies that an indirect cost is imposed by the explicit target which restricts the possibility to achieve maximum welfare. As opposed to the previous model, therefore, a country could increase its level of welfare if it managed to slacken the target. JI might open the possibility of doing so if a country manages to attain more credits than it actually pays for.

Compared to a case where emissions affect welfare directly, it is, however, easier to predict the emissions of greenhouse gases when the targets are explicitly given. Future emissions will be known if the target is given, and no one tries or manages to ’cheat’. In the first case, future emissions depend on measures such as future marginal productivity of capital, intertemporal elasticity of substitution, the second derivatives of the emissions function and other aspects. These measures are very hard to assess. Thus, to the international society, given targets may be more attractive than relying on each country’s worries about its own emissions. But there is clearly a dilemma here. Explicit targets imply a limitation to a nation’s ability to achieve maximum welfare over time. Even if the commitment corresponds exactly to the optimal level of emissions, it is most unlikely that the same target will be optimal after a couple of years with economic growth, changing industrial structure and perhaps different possibilities of engaging in JI projects.

A second difference between the welfare of emissions approach and the explicit target approach relates to the international control mechanism. With explicit targets, there is clearly a need for international control of the factual abatement of an initiative, since both investor and host have incentives to exaggerate the effect of the abatement. In particular, this highlights the problem of assessing the expected emissions provided that no actions are taken. This is later referred to as the baseline assessment. If the welfare of the investor, on the other hand, depends on the global emissions of greenhouse gases, the countries will carry out the control themselves, and the importance of an international control regime is radically limited: If the investor believes that the investment is beneficial, the international control mechanism has few reasons to diverge from the investors opinion.

These examples show that the issues discussed in this report do not add up to the sum of problems to be met by a JI regime. Some problems occur under some circumstances, others under other circumstances. The reason why they are raised here is that we can not tell what the conditions for JI will be. One can not even take it for granted that JI will be accepted as a means to achieve reductions in the worldwide emissions of GHGs under FCCC.

Because of the problems related to controls, JI initiatives will have to be limted to projects with effects that are relatively easy to identify. Still, a number of problems remain. The global effect of a project is difficult to assess because the assumptions underlying the evaluation of the project may be violated as a consequence of the project itself. In other words, the macro effect may be different from the effect estimated at the micro level. At the micro level, the difficulties in predicting the effects start already when the project is negotiated. The investor has to consider possible effects of asymmetric information and design a contract that limits the possibility for the host to get a better price than it deserves. Furthermore, the investor has to consider the environmental effect of the initiative in the light of the expected cost, both of which are uncertain. The next chapter provides an analysis of these problems and suggests how to handle them.

4. ANALYSES OF JI CONTRACTS, INCENTIVE PROBLEMS AND UNCERTAINTY

4.1 Introduction

In order to make the mechanism of JI operational, a profusion of issues and potential problems need to be considered and solved. The basic hypothesis of this report is that JI is a recommendable mechanism under certain conditions, that is as long as certain prerequisites for JI projects are satisfied. Referring to the FCCC, JI should contribute to reducing global GHG emissions in a cost-effective manner. Thus the important question is: Under what conditions will JI contribute to a cost-effective reduction of global GHG emissions?

Due to the number of issues and potential problems involved in JI, a realistic strategy for the analysis is to focus on the fundamental issues facing all categories of JI projects, even the 'simplest' project types. Subsequently, after finding ways to handle these issues, one can take on more complicated JI project categories and additional problems related to these. With this background the analyses in this report are founded on two principles:

i) divide JI projects into categories based on 'simplicity', and analyze the simplest category first, and

ii) focus on incentive contracts.

The guiding principle for categorizing JI projects is the size of 'transaction costs'. The transaction costs for JI can, in general terms, be defined as the administrative costs for all parties involved in the development, implementation, control and verification process of a JI project. Furthermore, JI projects are organized according to the following two dimensions:

1) The type of countries involved (Annex II countries, or Annex II countries and all other countries),

2) Project types (fossil fuel saving, changing industrial technologies, carbon sink enhancement, or changing agricultural practices).

Based on these dimensions, four main JI project types can be defined, confer Table 4.1. Apart from project Type IV, which concerns a regime of tradeable GHG quotas, the project types are organized according to increasing transaction costs; they are lowest for Type I and highest for Type III. Type I is the simplest project type, whereas there are significant baseline (which in general terms can be defined as the GHG emission time path in the absence of any JI projects) and control problems for Types II and III. There may be additional monitoring problems for Type III projects. Type III are mostly forestation projects. Transaction costs and other characteristics of JI projects will be further analyzed in the following.

Type IV tradeable GHG quotas is a reference situation in which the transaction costs are lower than for the other types. However, Type IV presupposes a regime which is unlikely to be established in the near future. A more detailed specification of the project types is given later in this section.

Table 4.1 JI project types classified according to rising transaction costs[a].

JI project dimensions	FCCC Parties involved	GHGs abatement category
Type I	Annex II countries	- Fossil fuel saving. - Changing industrial technologies.
Type II	All countries	- Fossil fuel saving. - Changing industrial technologies.
Type III	All countries	- Carbon sink enhancement. - Changing agricultural practices.
Type IV	All countries	All categories

[a] Transaction costs are lowest for Type I and highest for Type III.

According to principle ii) above this report focuses on incentive contracts. The background for this principle is the existence of asymmetric information and incentives for parties undertaking JI projects that may lead to inefficiencies, *inter alia* in terms of uncertain national (and global) GHG abatement effects of the projects, and in terms of reducing the cost saving potential of JI projects. These incentive problems would not exist if all parties were only concerned with the global best in terms of reducing climate change. However, a more realistic assumption is that most parties might exploit asymmetric information for their own good (e.g. in terms of reducing their cost share of the global climate measures), to some detriment of the global climate.

Incentives are an essential part of economics, since individuals are assumed to prefer leisure and require some compensation to exert an effort. A standard example from the literature is an employee in a firm who requires wages to forego leisure and work for the firm. The employees' work contract may serve as an incentive contract and induce them to work. For example, the contract may state that payment depends on some measurement of output.[15] Another example of incentive contracts is procurement contracting. For example, the government orders telecommunications equipment from a private enterprise and is concerned that the equipment is produced at the lowest cost

[15] The reader is referred to e.g. Hart and Holmström (1987), Kreps (1990), and Eatwell, Milgate and Newman (1991) for surveys and some applications of incentive contracts.

while meeting the quality standard.[16] Some degree of asymmetric information between the parties of the contract is common, for example limited ability of the firm to control the efforts of an employee. Therefore, the incentive contract must often be contingent on some proxy for effort, such as number of hours worked, and there will be a possibility for the employee to shirk.

From this perspective, and since the report focuses on bilateral JI contracts, an important issue is the potential of incentive contracts designed to reduce such incentive problems. In a bilateral setting both the investor country and host country must accept a JI contract and consequently find that the total benefits are larger than the costs. In this perspective focus on incremental costs in the literature on JI seems less promising, also due to all the methodological problems involved in making the concept operational. The important issue in a bilateral setting is rather how to reduce the incentive problems through JI criteria from the COP, through institutional arrangements, or through formulation of incentive contracts for JI projects. In addition to bilateral contracts we consider other institutional settings, such as Clearinghouse and Credits Bank, since there are some significant differences in the incentive structure.

Closer specification of project types

In this section a closer description of the project types are given. Type I JI projects are the simplest types of projects. Only Annex II countries are involved and the host country must consequently be an OECD country (except Mexico). GHG emissions are abated through fossil fuel saving, either through increasing energy efficiency or fuel switching, or through changing industrial technologies. Several institutional settings are possible in addition to a bilateral arrangement between an investing and a host country.

One option is for all the Annex II countries, or, more realistically, a group of OECD countries (e.g. the European Union) to establish a system of tradeable GHG quotas within the group and report their joint emission abatement to the COP. Then it will be for the COP to approve the emission abatement of the group compared to a baseline established for the same group of OECD countries. As long as such joint reporting of emission abatement and tradeable quotas of a group of countries are accepted within the criteria for JI projects, there is a definite advantage in terms of cost effectiveness.[17] However, since an opening for such tradeable quota regimes within a JI framework is unclear at present, and may be further into the future than a JI regime where Annex II countries negotiate bilateral JI contracts, we will, in the following, focus on a bilateral JI arrangement between two OECD countries.

In general there are few incentive problems and relatively low transaction costs associated with Type I projects. The problem of establishing a baseline is not a serious

[16] Baron and Besanko (1987) analyze asymmetric information, monitoring problems and risk sharing in procurement contracts.

[17] Confer the discussion in Bohm (1994a) and Barrett (1993b).

obstacle for this category of projects since baselines must be established by Annex II countries and reported to the COP. Annex II countries are obliged to report their emission targets and emissions to the COP. A country may then state that the projected GHGs emission time path of the country is its official baseline. To serve as a baseline the emission time path must be binding in the sense that it can only be modified under particular (predetermined) circumstances. Otherwise there will be an incentive to increase the baseline if the emission target turns out to be more expensive than anticipated or planned. Credits from JI investments can then be subtracted from this baseline and contribute to meeting the legally binding emission target of the OECD countries. Another option is to start with the legally binding target (which must be expressed as a emission time path) and subtract JI credits from this target. In such a case JI projects may serve to make the target more ambitious. JI credits would then lead to a national target of lower GHG emissions.

At the project level a simple JI project example would be fuel switching for an existing power plant, e.g. substituting a gas-based technology for a coal-based technology in a electricity-generating thermal power plant. If there is no change in the amount of electricity produced, the GHG abated can be calculated as the difference between the emissions from the coal and gas combusted by the power plant.

The transaction costs depend on the status of the Parties. Since the European Union is a Party to the FCCC, countries within the European Union may undertake policies that meet a GHG emissions target jointly, including the option to make JI investments in other countries. Annex II countries that are single Parties to the FCCC (i.e. countries outside of the European Union) cannot report their joint emissions target and policies to meet the emission target unless their transactions are accepted by the COP through an agreed procedure.

Type II projects have higher transaction costs than Type I projects because all Parties to the FCCC can participate, even those countries that have not established a national emission target. In this case defining the baseline is much more complicated than for Type I projects since developing countries are not obliged to report national emission targets to the COP. They are only obliged to report GHG emissions and inventory. Annex II countries of the FCCC are, in addition to a GHG inventory, obliged to communicate their GHG emission target, which can serve as the basis for a baseline (see section 4.3 for further discussion of baselines). With respect to fossil fuel saving and institutional setting, the situation for Type II projects is similar to Type I projects.

For Type III projects the countries involved and institutional setting are similar to Type II projects, but the abatement mechanism is, instead, carbon sink enhancement or changes in agricultural practices. The prevailing project categories are afforestation (i.e. forestation of an area without previous forest) or reforestation (i.e. replanting of trees in an area that has been logged) projects, in which the biomass of some area is increased through carbon sequestration in trees, but sequestration in soil and other vegetation than trees is also possible.

Type IV projects concern a situation where GHG quotas (in particular carbon quotas) can be traded globally, and a supporting international regime has been established. This is a reference situation since such a regime in theory can achieve cost effectiveness on a global scale[18]. Such a regime can serve as a useful reference situation. One important problem when establishing such a regime is to agree on the initial distribution of GHG quotas, which to a large extent will determine the income distribution effects between nations from such a global climate policy.

Issues and methodology
The analyses of potential problems concerning development, implementation and control of each JI type in the later sections of this chapter are organized around seven issues. These are listed in the first column of Table 4.2. The second column of the table indicates the analysis framework applied, and the JI project types where the specific issue is relevant are shown in the righthand column. Thus issues 1, 2 and 3 are the basic ones in the sense that they are relevant for both Type I, II and III projects, whereas issues 4, 5 and 6 are only relevant for Type II and III (and not Type I) projects. Finally, issue 7 is only relevant for Type III projects.

Table 4.2 Issues relevant to operationalizing JI projects, framework for the analyses, and relevant JI project types.

Issues	Framework for the analyses	Relevant JI project type
1. Incentives for investor and host to overstate potential of project	Incentive contracts	Type I, II and III
2. Asymmetric information and project selection	Principal-agency models with hidden information and hidden actions	Type I, II and III
3. Risk related to Nature's choice	Model to evaluate alternative measures under uncertainty	Type I, II and III
4. Project selection under uncertain transaction costs	Analysis of uncertain project costs and no-regrets options	Type II and III
5. Risk of leakages	Evaluation of bottom-up and top-down models	Type II and III
6. Political 'distortions'	Incentive contracts	Type II and III
7. Control problems for carbon sink enhancement projects	Incentive contracts (to induce host country to choose consistent national policies)	Type III

[18] Bohm (1994a) and Barrett (1993b) discuss and compare regimes of tradeable carbon quotas and JI.

The following section 4.2 discusses potential problems regarding incentives to overstate the GHG abatement effect of a JI project when the parties to a JI contract report to the COP (issue 1 in Table 4.2). Section 4.3 deals with some potential problems in host countries related to 'political distortions' and definition of baseline (issues 6 and 7 in Table 4.2). Political distortions refer to the risk of political decisions that may reduce the national abatement effect of a JI project, and thereby also reduce the appropriate credits for the investor. In section 4.4 the concept of leakage is discussed, and the importance of the level of aggregation of the analysis for the risk of leakages examined (issue 5 in Table 4.2). A general introduction to principal-agent models in section 4.5 is followed by an application to bilateral JI contracts, with a focus on asymmetric information and hidden action associated with JI projects between investor and host firms (issue 2 in Table 4.2). This example and model type is both relevant at the micro level, i.e. between firms, and at the macro level, i.e. between countries. In section 4.6 different uncertainty profiles of JI project types are analyzed, with the aim of finding implications for the selection of project types (issues 3 and 4 in Table 4.2). Finally, a summary of the results from the analyses is presented in 4.7.

4.2 Incentives for investor and host to overstate the potential of JI projects

In a bilateral JI setting investing and host countries will prepare a JI project and report the project and estimated GHG abatement effect to the COP, or some designated body established by the COP. After a JI project is initiated, there will be a monitoring process to determine its actual GHG abatement effect and a later report to the COP, as discussed in Chapter 7. Incentive contracts based on after-the-fact control of the GHG abatement effect may play an important role; they may reduce the incentive to overstate the abatement potential of projects, as discussed in section 4.3.

Since the COP, or some designated body established by the COP, will have less project background data than the participating countries, and since it will be impossible to control all JI projects, both the investor and host will have incentives to overstate the potential of the project. Asymmetric information and less-than-perfect *ex post* control give both the investor and host an interest in exaggerating the GHG abatement effect of the JI project. Investors can gain extra credits if they are not so concerned about global GHG emissions abatement and the danger of climate change. The consequence is lower abatement cost per unit and the host may play along to make the project appear more attractive for the investor. Furthermore, some of the extra gain could be shared between the investor and host. On the other hand the investor has an interest in keeping the estimated GHG emission abatement effect of the project low in bilateral conract negotiations with the host so as to get a better bargaining position and cut down the price the host can charge (i.e. the cost of the project claimed by the host). On the part of the investor such strategic behavior may partially counterbalance the incentive to overstate the potential of the project to the COP. The COP could be able to take advantage of these conflicting incentives for the investor, for instance through inspection of the negotiations and the contract (which would require some additional resources spent by the COP), or through specifying criteria for JI contracts that can extract some additional information from the host, and thus reduce the information

’gap’ between the host (and investor) and the COP. However, the incentive to overstate is not reduced for the host, which is likely to be the best informed part under this type of asymmetric information. Thus there is still a danger that the realized GHG abatement effect of the project is less than the anticipated one. This will make the process of controlling and verifying the global abatement effect more complicated and uncertain.

In a situation of asymmetric information and incentive problems the crucial issue is how to reduce such incentive problems. This may be achieved through special reporting criteria which all JI project candidates must satisfy; established by the COP, or through institutional arrangements for the JI mechanism. Two possible institutional arrangements are Clearinghouse and Credits Bank, confer chapter 2.

Reporting criteria
In a situation with strong incentives to overstate the abatement effect of a JI project, the COP is left with the option of establishing reporting requirements which can be verified by a third party.[19] One relevant type of criteria should demand strict documentation requirements for the GHG abatement effect of a JI project compared to a reasonable baseline, confer Possible Criterion 6, in INC (1994a), and the discussion in chapter 6. The further specification of such criteria will *inter alia* depend on the definition and control of baselines.

Clearinghouse
When moving from bilateral arrangements to a Clearinghouse institutional setting one important feature is the establishment of a ’market’ for JI projects.[20] In this setting a potential host may still exaggerate the GHG abatement potential of a JI project in order to make it appear more attractive to a potential host. However, the market should have a moderating effect on the ability for hosts to exploit asymmetric information, exaggerate the abatement effect or understate project costs because there are other potential hosts that may lower their ’prices’ (i.e. abatement unit cost) as long as there is a net rent to gain.

This reasoning is based on the workings of a perfect competitive market, where one prerequisite is a homogenous good, i.e. that JI projects can be treated as a homogenous good where the single interesting feature is the unit abatement cost. To the extent that there are other features of JI projects that are important and which differ between projects and that are not fully included in the calculations of the unit abatement cost, such as different risk profiles with respect to emission abatement effect, the market situation can be described as monopolistic competition. Under monopolistic competition hosts have some monopoly power through offering a more or less ’unique’ good (i.e. a JI project) that can result in extra rent in the short run, but the extra rent can

[19] Confer the criteria proposed by the Intergovernmental Negotiating Committee in INC (1994a) and the discussion in Jones (1993).

[20] Confer Hanisch et al. (1993) for a further discussion of Clearinghouse.

disappear due to the entry of new hosts. Under perfect competition JI projects will be offered at minimum costs, and thereby lead to efficiency. Under monopolistic competition, however, JI projects are not offered at minimum cost, so there will be some inefficiency and an additional cost involved in financing some specific abatement effect compared to perfect competition.

The Credits Bank
In the case of the Credits Bank the overstating incentive problem is also likely to be reduced. A unit abatement price will develop as an average return to JI projects compared to costs, and consequently the JI project risk in terms of uncertain costs and abatement effect is shared between the investors. In this setting a potential host may still exploit asymmetric information and exaggerate the GHG abatement potential of a JI project in order to make it more attractive for the Credits Bank, but there is less room for an alliance with an investor compared to a bilateral setting. In addition, the resources of the Credits Bank should mean improved capacity to participate in the reporting to the COP and thus discourage exaggerations of the abatement potential. The Credits Bank can arrange auctions, where potential hosts offer their JI projects at a price, and the bank buys the cheapest projects (in terms of unit abatement cost) up to the preferred total abatement effect. Furthermore, the Credits Bank may act as a monopsonist (i.e. single buyer) of JI projects, in which case the 'market' power of the Credits Bank makes it able to reduce the 'prices' charged by potential hosts. All these possibilities imply relatively more 'market' power to the Credits Bank compared to the hosts, and may, under some circumstances, reduce the ability for hosts to extract extra rent due to asymmetric information.

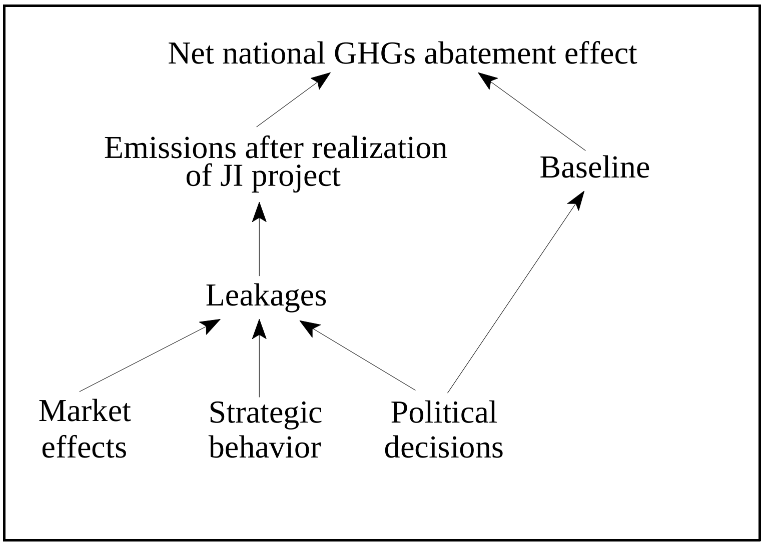
4.3 'Political distortions', baseline problems, and the potential of incentive contracts

Some issues associated with planning and political decisions are more pronounced at the national level than at the firm level. In Figure 4.1 the determinants of the net national GHGs abatement effect of a JI project are shown in principal terms, where the net national abatement effect is defined as baseline emissions subtracted from emissions after realization of a JI project. Emissions after realization of a JI project can be higher than anticipated due to leakages. Leakages can be defined as a lower-than-planned or calculated GHGs emission abatement effect at the national or global level. In the literature leakages are commonly discussed only in terms of market effects (e.g. effect on relative prices and consumer reactions and changes in 'terms of trade'),[21] but this report also includes strategic behavior and political decisions as determinants of leakages in Figure 4.1. In general terms the baseline may be affected by political decisions and the possible existence of JI financing of no-regrets projects, which are projects that are profitable under ordinary market conditions. In the following we consider a baseline that is determined *ex ante*, that is before any JI activities are

[21] For a general discussion of leakages and baseline definitions the reader is referred to e.g. Barrett (1993a), Bohm (1994a) and (1994b), Kuik, Peters and Schrijver (1994), and Selrod and Torvanger (1994).

undertaken. The baseline can only be modified later in particular circumstances. However, the discussion of leakages concerns an *ex post* situation, where JI projects have been or are being implemented.

Figure 4.1 Determinants behind net JI abatement effect



This section deals with political decisions at the national level which may reduce the abatement effect through leakages. A government in a host country may let its planning, economic policy (e.g. politically motivated market interventions) and political decisions be influenced by external funding and implementation of JI projects, or the anticipation of such funding (cf. the discussion in section 4.2.2 on contracts between two firms). Since JI projects will *inter alia* have local economic and labor market effects, and, depending on the size of the project, may have some national effects, it can be rational for the government to let its policies be influenced by such external funding. Such influence is more likely the larger the total JI funding is. These effects will make the calculation of the emission abatement more complicated and uncertain, in particular for developing countries or countries with an economy in transition to a market economy which does not have a national emission target as a foundation for a baseline.

There is also room for strategic behavior by the host government in a game of baseline calculations with investing countries or enterprises in that anticipated future external JI funding may be influenced and increased. One example of this can be to exaggerate project costs and 'turn' no-regrets projects into projects that need external funding to be realized, thus earning extra profits.

The potential of incentive contracts
Policy changes that affect the net abatement effect of JI projects are difficult to monitor and control. By assumption these policy changes are a rational response to incentives that make them profitable and are due to limited monitoring and control abilities by the investor (and COP). In such a situation an important issue is the potential of incentive

contracts to induce a host country to refrain from political decisions that reduce the net national abatement effect of one or more JI projects. Incentive contracts can contain bonus payments and/or fees,[22] and must be based on some after-the-fact (i.e. after realization of the JI project) verification possibilities. All JI projects need not meet an after-the-fact verification process of the net GHG abatement effect, but at least some fraction of the projects must be chosen for spot checks, see chapter 7. The final fee or bonus payments might depend on the results of an after-the-fact report by the project participants, but some projects should also be subject to a closer verification process. Finally, the host must find that the expected benefit from a JI project, given the exposure to the output risk of the project, is high enough to be willing to offer the project and participate in it.

Some options for incentive contracts are:

1. A simple type of incentive contract could include contingencies on the success of the JI project in the form of a bonus to be paid to the host upon after-the-fact control of the abatement effect of the JI project. The host will receive the bonus if the project satisfies the planned abatement effect; eventually one could accept some smaller deviation from the plan.

2. A variant of a 'deposit-refund' system, in which the host presents the JI project and pays a fee at the beginning of the project which is repaid if the after-the-fact control process shows that the abatement effect coincides with the planned effect (cf. Swierzbinski (1994)). Under such contracts the host has an incentive to have the project controlled if it is successful. The incentive-correcting feature of the contract can be adjusted through the initial fee, the amount paid back if the project is successful (which may be higher or lower than the initial fee), or the probability of control.

3. A more demanding and politically less feasible solution would be to focus on the additional baseline and control problems of non-Annex II countries and require that the host country must establish a national emission target in order to participate in JI contracts. This target could be stated in every JI contract. Alternatively, a statement on this could be issued to the COP.

No such contracts can be expected to remove the initial incentive problem of 'political distortions'. However, contracts might be able to reduce the problem. The feasibility of all contracts depend on the after-the-fact monitoring and verification possibilities for measuring the GHG abatement effect of a project at the national level. Furthermore, some incentive contracts may be less acceptable to host countries (cf. option 3 above), and there may be distribution effects between investor and host that limit their potential.

---

[22] One option is to give the host country some share of the emission credits. Credits are interesting to Annex II host countries, but could also be of interest as 'political credits' to other countries.

A note on carbon sequestration projects

Let us now turn to carbon sequestration projects, which potentially have larger baseline, control and verification problems than most other JI project categories. The main feature of these projects is carbon sink enhancement, mainly in the form of afforestation or reforestation. The monitoring and control problems of carbon sequestration projects are similar to problems facing other project categories. But in some respects control might be more complicated, for example long-term monitoring of forest areas, which can be necessary to verify the long-term net sequestration of carbon. The carbon dioxide will be released to the atmosphere if the forest is later logged or exposed to other human interference that destroys the forest. A longer time horizon than for other JI project categories may thus be required. With this background, carbon sequestration projects are included in Type III together with projects intended to change agricultural practices. The earlier mentioned incentive contracts should be applicable for Type III projects, but some adjustments are necessary due to the mechanism now being carbon sequestration instead of carbon abatement. The purpose of incentive contracts would in this case be to induce the host country to avoid forest and national policies inconsistent with the planned sequestration under the JI project, for instance making plans to increase logging in other forest areas that may reduce the forest cover and long-term carbon fixation in those areas.

4.4 Leakage and the level of aggregation

Leakage is usually discussed in relation to unilateral actions to mitigate climate change and has two main explanations.[23] First, measures taken in cooperation within a number of countries may cause changes in the terms of trade between cooperating and non-cooperating countries. A carbon tax on fossil fuels within a group of countries, for instance, implies an increase in their costs relative to the costs in non-cooperating countries. This improves the competitiveness of non-cooperating countries and makes them produce more traded goods and increase emissions. Second, a reduction in the demand for fossil fuels following a carbon tax will lower the world market price for fossil fuels and thereby stimulate demand in countries without carbon taxes.

In general, therefore, leakage means that the estimated effect on emissions of a given climate measure may be different from what it turns out to be because of market effects not considered when the effect on emissions was estimated. There are many indications that these macro-effects tend to moderate the effect of climate measures. Therefore the term ’leakage’. Its importance is, however, uncertain. The global reduction in the emissions of CO_2 from a unilateral carbon tax within the OECD has been estimated to be between 94 percent (Oliveira-Martins, Burniaux and Martins(1992)) and 20 percent (Pezzey (1992)) of the reduction in OECD. Strictly sppeaking, the problem is of a methodological nature. It occurs because one cannot evaluate all kinds of possible measures properly within the frames of global models.

---

[23] See Barrett (1994) for a survey.

The leakage problem is of particular relevance for the evaluation of JI initiatives, since emission reductions from these initiatives will have to be documented to the COP in order to be accepted as ’emission-credits’. Credits need to be estimated, and COP will be concerned with the global effect of the initiative. However, it is most unlikely that evaluations made by macroeconomic models can be used, partly because they are not relevant for an evaluation of all possible measures, and partly because it will be difficult to agree on a baseline. As a consequence, acceptable measures to be carried out through JI will be rather restricted, probably to micro-oriented projects. Then, the baseline problem may be avoided, but the leakage problem remains. Bohm (1994b) discusses possible implications of this dilemma. He expresses a rather pessimistic view on the potential of JI as a means to attain substantial reductions in global emissions of greenhouse gases.

Measures under JI, therefore, will usually have to be evaluated ’project by project’ by so-called ’bottom-up’ analysis. As pointed out by several economists such projects may have macroeconomic effects of significance,[24] e.g., to the ranking of measures. Such effects are excluded in the ’bottom-up’ approach, which has to be based on exogenous prices. Fuel switching from coal for instance may cause excess capacity in coal mining and thereby a reduction in the price of coal, which results in a higher demand for coal. Such effects might be estimated for more general classes of topical projects and added to the effects in the ’bottom-up’ analysis. However, further methodological development is required in order to merge micro and macro analysis. As for JI it means that one would prefer projects with low or foreseeable leakage effects. This has to be considered from case to case. The leakage of a fuel switch from coal to petroleum, for instance, would depend on whether the country possessed coal mines or not.

It should be added in this context that ’leakages’ of JI projects often will originate from a stimulation of the economy in the country where the project is carried out. As Jones (1994) points out, it is not clear how this is to be interpreted in relation to the FCCC. The Convention emphasizes the need for a stimulation of the economy in developing countries, because it may expedite the date at which these countries will be able to impose a climate policy. Thus, the leakage may actually fulfill some of the intentions of the Convention.

The possible terms of trade effects between investing countries and host countries have been analyzed in Aaheim (1994a). Compared to a situation without JI, lower costs of abatement will make committed countries able to increase consumption and investments, which stimulates imports from host countries. To meet the increase in the demand for export products, they will have to increase production which again stimulates foreign trade. Therefore, investing countries will also meet increased demand for their own traded goods. However, the restricted supply of resources will affect the

[24] Håkonsen and Mathiesen (1993) make a comparison between a 'bottom-up' and a 'top-down' estimate of the costs of measures to reduce emissions of methane and nitrous oxide. They show that measures with marginal net benefit in a 'bottom-up' approach may be highly beneficial in a 'top-down'-context.

price of traded goods. In what direction the terms of trade will move is an open question. In general, the countries with the best ability to substitute between input factors will end up as 'winners'. There are many indications that this applies for the 'rich' countries which initially imposed the target. To the 'poor' countries, an extra cost may have to be imposed to account for the effect of the terms of trade.

Recall, finally, that JI may have an intertemporal leakage effect, as discussed in chapter 3. This effect occurs because lower abatement costs may stimulate economic growth and in the long run increases emissions.

4.5 Principal-Agency models

4.5.1 Introduction

A branch of the incentive contract literature is the principal-agency literature.[25] In the standard example a firm can be the principal and one employee the agent. The situation could be classified as moral hazard[26] with hidden action (i.e. the employee's effort is hidden for the principal).[27] This literature deals with how to design a compensation scheme that motivates the agent to act in the interest of the principal, given asymmetric information that leads to unverifiable efforts. The contract cannot be made contingent on efforts since efforts are unverifiable. Even if the output can be exactly measured, the effort cannot be measured if output also depends on some variable that cannot be observed (with certainty). Due to uncertainty and incomplete contracts agents do not bear the full consequences of their actions. The agent may have some degree of risk aversion, which is a common assumption in the literature. Risk aversion can be defined as reluctance to accept risk, for instance measured as the extra compensation required to accept a risky option of the same expected value as an option of certain value.[28] Thus a risk averse agent requires extra compensation, i.e. insurance, to accept risk in terms of payment that depends on the uncertain output resulting from effort and some variable that cannot be observed. On the other hand, the principal would prefer that the agent bears the full consequences of the effort to give incentives to work hard (and exert an optimal effort). Thus there will be a tradeoff between incentives and insurance, and the incentive contract has to strike a balance between these considerations.

Let us now relate the principal-agent literature to the analysis of JI contracts between

[25] Surveys of this literature can be found in, for example, Hart and Holmström (1987), Kreps (1990) and Rasmusen (1989).

[26] The term moral hazard refers to situations where agent act in their own interest, but to the detriment of others (i.e. the principal).

[27] Confer the classification of asymmetric information models in Rasmusen (1989).

[28] Moreover a risk neutral agent requires no compensation to take on risk as long as the expected outcome is equal to the certain outcome.

an investor and a host (where both the investor and host may be countries or firms). In such a setting the investor and host negotiate a contract on a JI project, after which the host exerts some effort to implement the project. Afterwards, the investor (and COP or any designated body) is assumed to be able to observe the output of the project (i.e. the GHG abatement effect), but, due to monitoring problems, the exact effort of the host cannot be determined. The project output is uncertain since it depends both on effort and some variable that cannot be directly observed, or that is excessively expensive to monitor and verify. Thus it is not possible to let the payment to the hosts depend on their efforts and there will be an incentive for the host to exert too low an effort, and thereby gain an 'informational rent'. The informational rent increases the project cost for the investor and makes cost minimization unobtainable. Consequently, the potential cost saving of JI projects for the investor is reduced.

If the host is risk neutral it is possible for the investor to offer the host a choice of different contracts in such a way that the host will prefer a contract that makes him exert a high effort.[29] Through such an arrangement the host is induced to bear all the risk, which is optimal since the effect of the effort choice is internalizec. However, if the host is risk averse, there will be a tradeoff between giving incentives to exert enough effort and protecting him from too large a variation in compensation for the effort. Thus the earlier result of a reduced potential cost saving for the investor is obtained.

Given a risk averse host and imperfect effort control possibilities the inefficiency in terms of a non-minimized project cost can to some extent be reduced through formulation of incentive contracts. Even if perfect control is not possible there is an option to reward the host for outcomes that are relatively more likely if he exerts a high effort, eventually in combination with some fee (or reduced bonus) if the outcome is less likely if he had exerted a high effort.

4.5.2 Asymmetric information and selection of projects

The problems discussed in this section are how informational constraints affect the potential cost-savings of JI and the distribution of welfare between hosts and investors, and how strategic behavior among the potential hosts could lead to an increase in global emissions.

The motivation for an investor to participate in the JI project is to receive abatement credits less costly than through domestic measures. If the investor had complete knowledge about the abatement achieved and the investment cost of different JI

[29] Let us assume that the agent can exert a high effort or a low effort. If he exerts a high effort a high output is more likely then if he exerts low effort, and vice versa for the low output case. Since the agent is risk neutral he requires no extra compensation to take on risk. To induce him to choose the high effort it is then sufficient to offer him a bonus in the high output case that makes his expected benefit higher if he exerts high effort rather than low effort.

options, the project with the lowest cost per unit abatement would have been implemented first. However, due to incomplete information about the different JI projects, the investor is not able to tell in advance the final impact on abatement of the different JI options.

Consider a JI project where the investor finances less energy consuming technology. The investment project implies that the host can produce the same quantity of goods with less use of energy. The production function, which describes the technology, has changed. However, complete information about the production function ex post of the investment may not be available to the investor at the date of contracting with a host.

Some relevant information about the impact on the abatement or the cost of an investment may be private information held by the host. The host may have more accurate information about the impact on the production function of an investment. Furthermore, the abatement achieved by an investment could also depend on the actions taken by the host during the project period. For instance actions to maintain the machinery and training of employees to operate new machinery could have a significant impact on the abatement achieved by the investment. These actions could, however, be difficult for the investor to observe. The investor could therefore face two types of asymmetric information: The host has private information about the impact on the production function of the JI investment and private information about its own actions during the project period.

Private information held by the host has an impact on the design of JI contracts. The investor has two goals for a JI contract that will be in conflict under asymmetric information. The investor wants the host to take the correct actions during the project period. Furthermore, the investor seeks to minimize the cost of the project and hence keep the financial transfer to the host at the minimum level necessary to persuade the host to accept the contract. We will use a simple model to illustrate how these two goals are in conflict.[30] We relate the analysis to the micro level, where an investor firm makes a contract with a host firm.

The basic model

Consider an investor that wishes to enter into a JI contract with a firm in another country. The investor can choose among different firms. These firms are equal prior to the JI project but differ with respect to energy efficiency after the investment has taken place. The use of energy is also affected by the firms different actions, henceforth referred to by the generic term effort.

The use of fossil fuel ex post of the investment is assumed to be equal to the efficiency parameter less the effort. The abatement (*A*) achieved by the investor is equal to the

[30] This study is based on Hagem (1994) where the design of JI contracts is studied in the framework of a model presented in Laffont and Tirole (1993).

reduction in use of fossil fuels (measured in CO_2 - units);

$$A = E^0 - \beta + e \qquad \textbf{(4.1)}$$

where E^0 is the use of fossil fuels measured in CO_2 - units before the investment takes place, β is the ex post energy efficiency parameter and e is effort exerted by the host firm.

Assume that the efficiency parameter can take one of the two values $\{\beta_1,\beta_2\}$, where $\beta_1 < \beta_2$. A firm with β_1 is henceforth referred to as an efficient firm and the firm with β_2 is referred to as an inefficient firm. Before the investment takes place the firms have private information about their ex post efficiency parameter. It is, however, assumed that the value of the two different efficiency parameters is common knowledge, but the investor is incapable of identifying which β to attach to a specific firm ex ante.

A higher level of effort, *e*, will increase the abatement effect of the project. However, effort incurs a disutility to the firm. Maintenance of the machinery and monitoring the work done by the employees could be time consuming and costly for the firm. Consequently, the host firm seeks to minimize the effort put into the project. To accept to carry out the JI project the host firm has to be compensated by a net monetary transfer *T* in addition to the reimbursement of the observable cost of the project. The observable cost of the project is assumed to be equal to the investment cost less the reduction in energy expenditure. The firm is willing to participate in the JI project if the utility from participating is at least as large as the utility it can get if it turns down the contract. We refer to this level of utility as the host firms' 'reservation utility.' The reservation utility is normalized to zero. Let the utility of participating, *U*, be equal to the financial transfer less the disutility of effort exerted. Hence the firm will only accept the contract if

$$U = T - w(e) \geq 0 \qquad \textbf{(4.2)}$$

where *w(e)* is the disutility of effort. The disutility of effort is assumed to increase with effort at an increasing rate.

The investor's benefit from the project is the value of the abatement credits less the observable cost of the project and the financial transfer to the firm. The value of the abatement credits equals the cost of carrying out the abatement nationally. Each investor chooses one host without knowing whether the firm is efficient or inefficient and offers the firm a JI contract. It is assumed that it is beneficial for the investor to carry out the project with both types. Equation (4.2) has to be satisfied for both type of firms. The investor selects the JI contract that maximizes the expected benefit given the belief about the probabilities of β_1 and β_2.

General results
In order to discuss the impact of asymmetric information it is useful first to study the characteristics of the JI contracts under complete information about the efficiency parameter (β). The investor specifies the abatement required, *A*, and the financial transfer, *T*, in the JI contract offered to the host. Let the abatement-transfer pair $\{A_1^*,T_1^*\}$ characterize the JI contract designed for the efficient firm and the abatement-transfer pair $\{A_2^*,T_2^*\}$ characterize the JI contract designed for the inefficient firm. Due to the specification of the abatement function (4.1), the contracts designed for the two types differ only on the specification of the level of abatement required. The contract offered to an efficient firm specifies a higher abatement level than the contract offered to an inefficient firm. The contracts ensure that the firm that carries out the project exerts the first-best effort level, which in the model is identical for both firms. A first-best level of effort ensures that the marginal disutility of effort for the host firm is equal to the marginal benefit of effort for the investor. The first-best effort level is hereafter denoted e^*. The financial transfer specified in the two different contracts is identical. Since financial transfers are costly for the investor, the firms are left with no rent, that is, $U = 0$. The financial transfer covers exactly the firm's disutility of the effort exerted: $T_1^* = T_2^* = w(e^*)$.

Under asymmetric information the investor does not know whether the chosen host firm is an efficient firm or an inefficient firm. It can be shown that under asymmetric information, it is optimal to offer the chosen firm a menu of two contracts, one designed for the efficient firm $\{A_1,T_1\}$ and one designed for the inefficient firm $\{A_2,T_2\}$. The contracts differ from the contracts designed under complete information. The contract designed for the efficient firm requires the same abatement as the contract designed under complete information. Since $A_1 = A_1^*$ it follows from (4.1) that the efficient firm exerts the first-best effort level e^*. The financial transfer, however, exceeds the disutility of effort, $T_1 > w(e^*)$. Hence, private information held by the firm provides the firm with a positive rent. The contract designed for the inefficient firm requires lower abatement than under complete information, or $A_2 < A_2^*$, which induces the inefficient firm to exert less effort than the first-best level e^*. The financial transfer T_2 leaves the inefficient firm with no rent.

The ability for the efficient firm to mimic the inefficient firm forces the investor to give the efficient firm a positive rent. When the type of firm is unknown to the investor, the efficient firm can always mimic the inefficient firm and choose the contract designed for the latter. Note from (4.1) that $e = A - E^0 + \beta$. From the fact that $\beta_1 < \beta_2$, an efficient firm exerts less effort than an inefficient firm to obtain the same abatement level. Choosing the contract designed for the inefficient firm therefore leaves the efficient firm with a positive rent, since T_2 has to satisfy (4.2). The investor therefore has to give the efficient firm a positive rent larger than the rent it can receive by mimicking the inefficient firm to make it beneficial for the firm to choose the contract designed for it. If the contract designed for the efficient firm is the preferred contract it has to satisfy the following condition:

$$T_1 - w(A_1 + \beta_1 - E^0) \geq T_2 - w(A_2 + \beta_1 - E^0) \qquad \textbf{(4.3)}$$

The higher the abatement level required by the inefficient firm, the larger the rent that must be given to the efficient firm in order to prevent it from choosing the contract designed for inefficient firms. The investor could design a menu of two contracts which induced both types of firm to exert the first-best level of effort. However, that contract would result in a high rent for the efficient firm. To reduce the rent to the efficient firm the investor lowers the effort level requested from the inefficient firm.

The probability distribution has a crucial role in the determination of the optimal contract. The efficient firm enjoys a higher rent when the investor's probability of the efficient type is lower. The effort of the inefficient firm is lower when the probability of the efficient type is higher.

No-regret options and strategic behavior
A main conclusion from asymmetric information is that the firm that carries out the JI project may receive a positive rent. This section discusses the possible adverse effect on global emissions of leaving positive rent to the firm. The possibility of being chosen as a host for a JI project, and hence receiving a positive rent in the future, may reduce the incentive to invest in less polluting technology today. Strategic behavior of the potential host firm may therefore have an adverse effect on global emissions.[31]

We will analyze the impact on global emissions of strategic behavior in a two-period model. Consider a situation where firms in a country without a legally binding emissions target know that there is a possibility of being chosen as a host for a JI project in the future (the second period). Assume that there are two alternatives for investment. The less costly investment alternative induces lower emission abatement than the most costly investment alternative. The most costly investment alternative is preferred by the investor, while the less costly investment is profitable for the efficient firm (a no-regrets investment option). The potential host firm makes its investment decision in the first period contingent on the expected JI contracts in the second period. If an efficient firm invests in the no-regrets project in the first period, it will gain a profit from the investment. However, it has revealed the private information about its efficiency parameter to the investor. We will restrict the analyses to the situation where the investors will choose a host among those firms that have not implemented the investment in the first period. The reason for this assumption is that the investors

[31] Aaheim (1994a) discusses conditions for abstaining from implementing no regret options in a more general context.

receive abatement credits only for actual abatement, i.e. abatement in excess of no-regrets abatement. The efficient firm knows in period one that if it invests in the no-regrets project it loses the opportunity of earning a rent in period two. If the profit of the no-regrets project in the first period exceeds the expected utility of refraining from implementing the no-regret project, the firm invests in period one. The investment decision for the efficient firm in period one will hence depend on the profit obtained from the no-regret investment project in period one, the rent from the JI project in period two, the discount factor, and the probability of being chosen as a host. The probability of being chosen as a host is equal to the ratio of investors to potential host firms.

If all of the efficient firms find it optimal to abstain from no-regrets investments in period one, global emissions in that period will be higher than they would have been in the absence of a JI regime. The global emissions increase equals the abatement following from the no-regrets project multiplied by the number of efficient firms. Another possible outcome is that some of the efficient firms invest in period one. To see why this could be an outcome, consider a situation where the profit of the no-regret option exceeds the expected utility of not implementing the projects. Some firms will carry out the no-regrets investment. The more efficient firms that carry out the no-regrets investment in period one, the smaller will be the number of potential hosts and the lower the probability for the investor to pick an efficient firm in period two. The expected utility of abstaining from no-regrets investment increases in the number of efficient firm that carry out the no-regrets project for two reasons. First, the rent is a decreasing function of the investor's probability of choosing an efficient firm. Secondly, the number of investors compared to host firms has increased and therefore also the probability for the efficient firm to be chosen as a host. This situation leads to two different equilibrium outcomes. Either all efficient firms invest or some of the efficient firms invest in the no-regret project. If the latter situation is the outcome, the number of efficient firms investing will be determined by the following condition for equilibrium: the expected utility of abstaining from no-regrets projects equals the profit of carrying out the no-regrets. The increase in global emissions is higher the smaller the number of efficient potential host firms that carry out the no-regrets project.

Main effects of asymmetric information and implications for the design of criteria for JIs

According to the basic model presented above, asymmetric information causes an inefficient allocation of abatement, which at a global level may imply reduced potential cost saving from JI. First, because JI projects are not carried out exclusively by efficient firms, the investor is not able to separate the efficient firm from the inefficient firm and hence the less costly projects from the more costly projects. Second, if the host firm chosen is an inefficient firm, the project is carried out with too low effort.

Asymmetric information induces a reallocation of income from the investors to the efficient hosts. Asymmetric information is hence beneficial for the hosts but costly for the investors. An increase in the investors' expected cost of abatement could have an impact on the choice of abatement targets. Barrett (1993b) discusses the impact of abatement cost on the choice of unilateral emission targets when countries act strategically. He concludes that lower costs of achieving global abatement give parties to the FCCC an incentive to undertake more abatement unilaterally than they otherwise would.

Asymmetric information is not just costly for the investor, but also generates uncertainty related to the abatement cost per unit and the total abatement achieved by the project. The uncertainty could be reduced by establishing a Credits Bank that receives funds from the investors and implements several JI projects. By taking the average over many projects the risk in terms of uncertain abatement effect is shared among the investors. Furthermore, a single investor in the form of a Credits Bank could reduce the informational rent and consequently incentives to abstain from no-regrets investments (confer section 4.2).

A main conclusion from the model presented is that private information held by the firms may be beneficial for the firms if they are chosen to be a host for a JI project. The potential host firms may act strategically to take advantage of their private information. One type of strategic behavior is to abstain from investing in less polluting technology so as to avoid revealing their private information. Strategic behavior of the potential host firm may therefore have an adverse effect on global emissions.

The increase in global emissions due to strategic behavior is dependent on the number of potential hosts relative to investors. More potential hosts reduces each firm's probability of being chosen as a host for a JI project in the future, and hence makes it less profitable to abstain from investing in less polluting technology today. The more countries that accept to be hosts, and hence the more potential host firms, the smaller is the possible adverse effect on global emissions due to strategic behavior.

4.6 Evaluation of alternative measures under uncertainty

In this section we discuss how to adapt to uncertainty about the future cost of alternative measures and point to some possibilities to reduce the uncertainty.
It is evident that climate measures in some developing countries can be carried out at lower costs than the least cost of such measures in industrialized countries. However, it is difficult to assess the exact amount to be paid for a given abatement project. Apart from the difficulties in predicting the outcome of negotiations, there are uncertainties that are the same to all Parties. These relate to the problem of predicting the future. To be able to compare alternatives, it is vital that the uncertainty is explicitly taken into account.

4.6.1 Classification of uncertainties by their impact on project evaluation

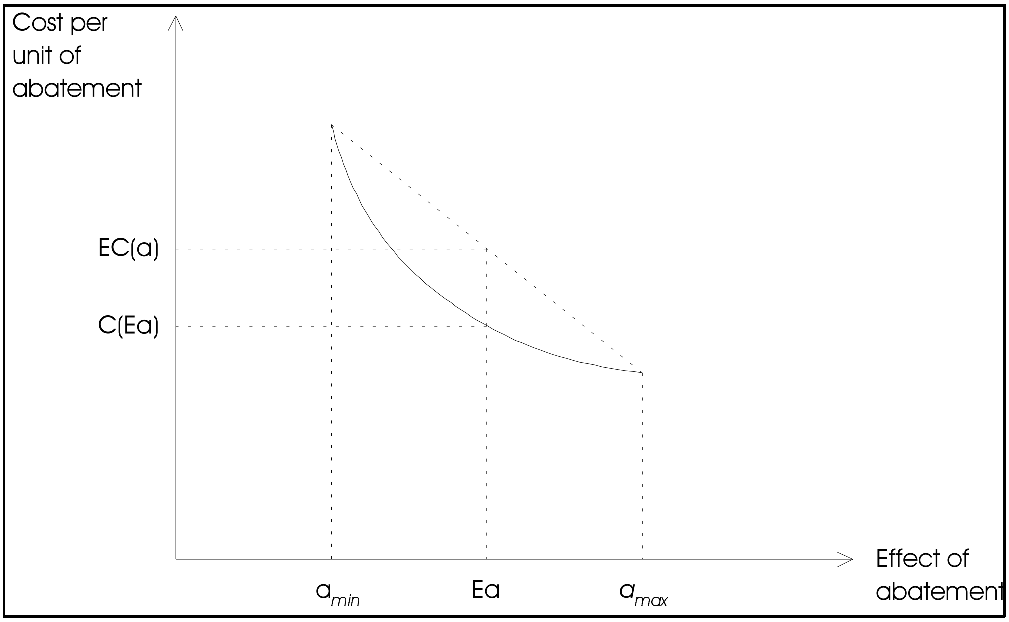
An evaluation of the future cost of an emissions target requires information about the amount of necessary investments, future operating costs, the factual amount of GHG emissions abated by the different measures, and the necessary amount to abate in order to attain the target. All of these components will usually be uncertain. The uncertainty should therefore be made explicit for all of them in order to make a practical assessment and comparison between alternatives. How the uncertainty should be expressed, however, depends on its impact on the evaluation. Rather than attaching a probability distribution to each of the uncertain components one has to identify factors that affect fixed costs, factors that affect costs subject to continuous adjustment, and factors that affect the necessary amount to abate, i.e. the baseline assumption.

Uncertain fixed costs
Fixed costs are costs that accrue for a given future period after they have been initiated. The decision to initiate them is to some extent irreversible. The most typical is an investment with no alternative applications. It has no second hand value and the investor will therefore be stuck with the capital cost as long as the capital equipment lasts ('sunk cost'). Operating costs are fixed costs if they are attached to an irreversible decision, such as maintenance of capital equipment or the operation of a project that cannot be stopped.

The uncertainty of fixed costs should be expressed in terms of the present valued cost in different possible states. 'States' refers to conditions upon which the uncertain variables, for instance price of oil, depend. Rather than basing the cost estimate on the cost in the expected state, one should find the expected cost of all states, i.e. the weighted average of all possible states. Figure 4.2 displays the difference between these two concepts. Assume that it is uncertain whether or not the investment yields the expected amount of abatement *Ea*. If it is successful the necessary abatement to achieve the emission target is a_{min}. If the investment fails, the necessary amount to abate will be a_{max}. Both possibilities have the same probability to occur. Thus, we find the expected abatement, *Ea*, in the middle of these two. The abatement cost curve *C(a)* is decreasing: If the investment fails, one have to initiate additional measures in order to achieve the given target. The marginal cost of additional abatement is increasing, which means that the curve is convex. If the project turns out more effective than expected, one may gain either because other measures may be relaxed or, in the context of JI, credits may be 'sold' to other countries. Because there is more to lose if the project fails than there is to gain if it succeeds, the expected cost is higher than the cost of expected abatement.

Although uncertainty about the technical performance of the equipment requires quite different kinds of information, the method to use in order to take the uncertainty into account is the same: Calculate the expected cost per unit of abatement as illustrated in Figure 4.2.

Figure 4.2 The expected cost of abatement



Uncertain adjustment costs
Adjustment costs relate to measures that are flexible in the sense that the decision maker may switch to an alternative at any time. An example would be a measure that requires no investments, only operating costs. The uncertainty of such measures relates both to the prices of intermediate inputs and to the effectiveness or quantity of the abatement. Also in the case of adjustment costs, the uncertainties about price and quantity can be treated similarly. Different from fixed costs, however, it is not relevant to measure uncertainty in terms of the total amount of future (discounted) operating costs for a given alternative. The uncertain variable should rather be expressed in terms of a stochastic process. This means that the uncertainty relates to the change in the variable, e.g. the price of input, from one point in time to another.

Stochastic processes are often intractable for analytical purposes. An exception is the so-called Brownian motion, which can be represented by the expression

$$dq_t = q_t(r\ dt + \sigma\ dz) \qquad \textbf{(4.4)}$$

where q_t is the stochastic variable representing a price or a quantity, r is its expected rate of change, dz is a random variable with normal distribution, and σ is an expression for the standard deviation. It is important to note that the history of the development of q_t does not affect the 'future' path. All historic information of relevance is embedded in the level of q_t at t. The expression simply says that q is expected to increase by rate r per t, but it may deviate from this expected path, described by the stochastic term, $q_t \sigma dz$.

Uncertain baseline
For a country that commits itself to an emissions target, the necessary amount to abate in some future year may be uncertain for reasons such as the level of future economic activity, technological improvements and future composition of economic sectors. Since the same source of uncertainty is attached to all kinds of future abatement costs, the process related to the adjustment cost has to be expressed in terms of the uncertainty of the 'state' variable, here equal to the fixed costs. This implies huge difficulties of a technical character, which will not be dealt with in this report.[32] However, one problem related to this kind of uncertainty has been discussed frequently in relation to JI, the so-called 'cream skimming problem' (Jones (1994)). Cream skimming means that rich countries use up the low cost alternatives when they are alone on the scene, and that poor countries have to pay more for abatement when they face targets some time in the future. This problem will be dealt with briefly in section 4.6.3.

4.6.2 The value of a flexible strategy

Whether the uncertainties are related to fixed costs or adjustment costs have large impacts on the evaluation of projects. The conventional cost-benefit criteria states that the project with the highest net present value (or if the emission target is fixed, least net present value of costs) should be chosen. To achieve an optimal solution by this criteria, one has to assume either that the choice cannot be postponed, or that there is full certainty about future operating costs and that operating costs are constant in the future.[33]

If it is possible to postpone the investment, and operating costs increase with full certainty, a combination of the two alternatives may prove better than deciding at once. Consider two extreme alternatives, one with only investment costs (fixed cost alternative) and one with only operating costs (adjustment alternative). Let the cost of the investment be 100 million USD and the present operating cost of the other alternative 5 million USD. The operating cost is expected to increase by 1 percent annually. Both alternatives are expected to last into infinity. The present value of the operating cost alternative is 111 million USD if a 5.5 percent rate of return is required. According to the cost benefit criteria, therefore, the recommendation is to invest.

However, the cost of the operating cost alternative is presently lower that the capital cost of the investment at 5.5 million USD. With a 1 percent increase in the cost of the

---

[32] A procedure for merging stochastic processes with certainty equivalent aggregates is suggested in Johansen (1980).

[33] See e.g. Dixit and Pindyck (1993).

operating cost alternative, it will take approximately 9 years before it reaches 5.5 million. Thus, by postponing the investment one could reduce total costs, and the minimum cost would be attained by postponing it about 9 years. The present value of this strategy is about 98 million USD. This implies that, rather than the cost-benefit criteria, a critical level for the operating cost would be a more appropriate criteria. In this case, the critical level is equal to the required return on the investment. If the operating cost is below, one should continue the operating cost alternative. If it is above, one should invest.

If we introduce uncertainty and assume that the decision maker is risk neutral, the investment cost can be replaced by the expected investment cost. A seminal paper by McDonald and Siegel (1986) shows, however, that when comparing the two alternatives, a new aspect occurs: At a given t, we do not know whether the future operating cost will increase more or less than expected. If at some time the operating cost equals the required return on the investment cost there is a chance that the operating cost will fall in the next period. Thus, if the criteria given under certainty is followed, and the investment is made, one may regret this decision with a significant probability. The investment is irreversible and its cost will accrue with certainty. Therefore, it may be rational to wait and see how the operating costs develop.

The difference in flexibility between the operating cost alternative and the investment alternative results in a *higher* critical value for the operating costs under uncertainty than under certainty. It is possible to assess this critical value if the investment will last into infinity and is regarded as sunk costs, and the operating costs follow the Brownian motion commented on above.[34] Here, we briefly discuss some properties related to JI projects and extend the example given above.

Due to the rather strong assumptions underlying the analysis above, it may be hard do find direct practical application of these results. However, some topical categories of abatement measures can be regarded close to either the investment alternative or the operating cost alternative. Especially since JI projects must be compared with potential measures taken 'at home', one has to consider also general abatement measures as alternatives.

Table 4.3 displays some categories of measures to mitigate climate change which may be considered either as a fixed cost project or an adjustment program. In practice, all projects will of course have some of both, but there is clearly a 'bulk' of costs in either of them for the categories listed in the table, at least if we allow for a wide interpretation of the term negligible. In category (5), fuel-switching, investments may of course be significant.

[34] For further details, see Aaheim (1994b).

Table 4.3 Topical categories of abatement alternatives

Description	Abatement (*a*)	Fixed cost (*A*)	Adjustment cost (*q*)
(1) Energy efficiency improvement	Lower emissions due to energy consumption	Cost of equipment	Negligible
(2) Forestation programs	Enhanced sinks from trees	Cost of planting	Negligible
(3) Investment in hydro or solar power plants	Emissions from the alternative	Difference in the investment costs	Negligible
(4) Investment in infrastructure	Lower emission from higher energy efficiency	Investment costs	Negligible
(5) Fuel switching, e.g. from coal	Difference in emission coefficients	Negligible	Price difference between fuel types
(6) General measures	Macro effect on emissions	Negligible	Macroeconomic cost (e.g. reduction in GDP)

However, the relevant investment cost would be the necessary amount of investments required to make the switch possible. This implies that (5) applies as an adjustment alternative mainly when replacement of old coal-based facilities is considered. Recall that if the future operating costs of a fixed cost alternative can be considered as certain and constant, they can be included in the investment cost and regarded as such. This may apply for the operating costs of a forestation program.

The first four categories can be regarded as fixed cost alternatives while the two latter consists of costs of adjusting to a given emission target. Except for (6), all categories may apply both as an alternative to be carried out in the committed country and in the host country. Apparently, however, most of the measures to be considered as potential JI projects will probably fall into the fixed cost alternatives.

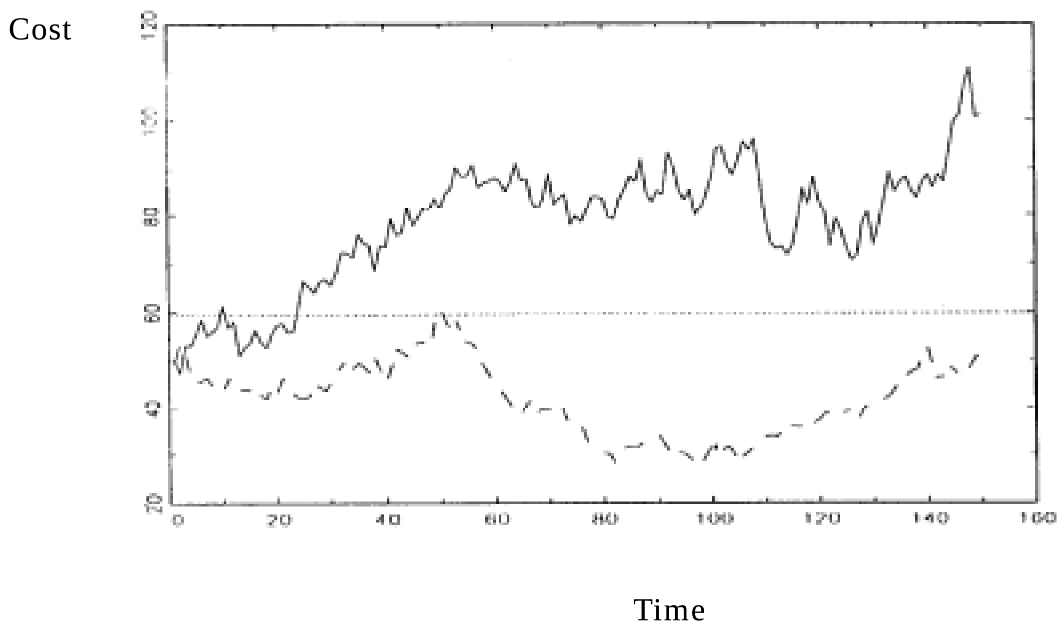
In some cases the assumption of an infinite time horizon for the fixed cost alternative may be problematic. Strictly speaking, investments with infinite time horizon do not exist, but for practical purposes it is sufficient to assume that the present value of the abatement cost is negligible at the terminal period. Therefore, projects which aim to enhance sinks by forestation (category 2) will normally have a time horizon limited to the main growth period for the trees, and may not fit as an example after all.

To provide an illustration of the importance of these results, compare energy saving (1) and fuel switching (5). Assume that a country considers investing in energy savings that will lead to an annual reduction at 100,000 tons of CO_2. The cost of the investment is 100 million USD. To abate a similar amount with fuel switching, one has to pay 50,000 USD per 1,000 tons the first year (i.e. 5 million USD for 100,000 tons). This 'price' is expected to increase by 1 percent per year, but there is a considerable uncertainty related to this increase. Assume that historic data shows that it deviates annually by 5 percent from its expected path. We set the alternative return on capital to 5.5 percent.

The example is similar to the one discussed above. When the uncertainty is taken into account, however, the expected time of postponement increases substantially. The critical cost for the fuel switching alternative increases from 55,000 USD to about 60,000 USD, implying a 'certainty equivalent' return on capital at 6 percent. The expected switching time from fuel switching to energy saving is now 18 years.

In practice, however, we do not know when this switch is going to take place. Figure 4.3 displays two examples of paths for q_t that follows the same Brownian motion. The two paths vary significantly. While the upper path reaches the critical q_t -value after 10 years, it takes 50 years before this level is reached in the second example.

Figure 4.3 Switch time under alternative paths for q_t



According to the optimal strategy, it would be correct to invest at *t = 50* in the latter case. Moreover, if one looked back at, e.g., *t = 100*, hindsight would perhaps result in regrets for this decision, as the cost of the fuel-switching alternative reaches its peak exactly at this point in time. Compared with the cost-benefit criteria, however, which resulted in a clear recommendation in favor of the investment, the optimal strategy is now to postpone the investment for up to 50 years.

JI implies a significant increase of the range of possible measures to mitigate climate change from those measures available in one country, thereby extending the ability to follow flexible strategies. Financing fuel switching in other countries is one example of topical projects for JI. Perhaps equally important, investments in JI will be less attractive than a present value calculation of a project would indicate, if the committed country has a flexible alternative available at home. A number of economic policy measures to restrict emissions constitute such flexible alternatives.

4.6.3 The ’cream skimming’ problem

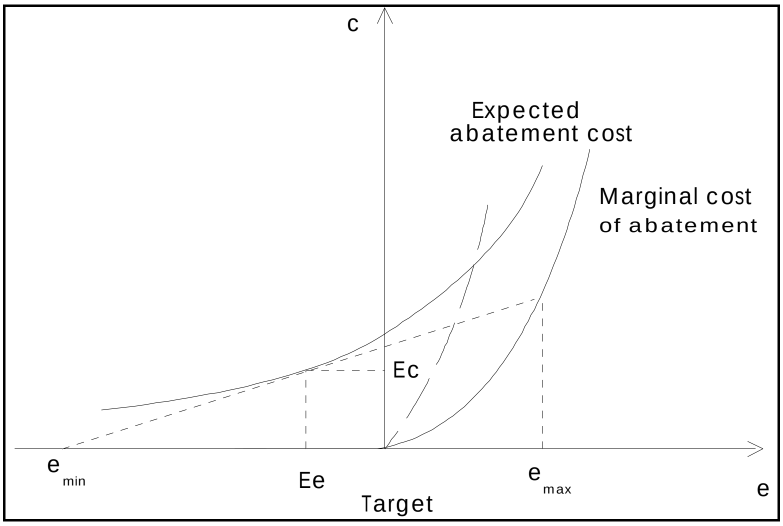
JI implies that the least cost abatement alternatives on a world scale are initiated first. Most of these low cost alternatives are expected to take place in poor countries. Thus, when developing countries commit themselves to abate emissions of GHGs, they will face higher costs than necessary today under JI. This is called the ’cream skimming’ problem.

This is a problem first only for countries without present commitments that anticipate targets in the foreseeable future. This would be the situation for European countries in transition toward market economy in phase III. Second, if these countries are certain about how much to abate in the future and what the cost will be, they will be able to account for a premium which compensates the future extra cost that accrues because the ’best’ projects are not available anymore. Thirdly, new and attractive abatement alternatives may occur in the future due to *inter alia* technical progress. In other words, the cream skimming problem occurs as a consequence of uncertainty for a limited number of countries.

However, the uncertainty about the future cost of abatement is substantial for the countries that anticipate future targets. To get a picture of the importance of this uncertainty, consider Figure 4.4 taken from Aaheim (1994a). The curve to the right expresses the marginal cost of abatement from a given target in some future year. If the emissions exceed this target, the country will need to introduce abatement at the cost indicated by this curve. There is uncertainty about the level of future emissions. They may be low (e_{min}) or high (e_{max}) with expected emissions *(Ee)* below the target.

The first uncertainty refers to the steepness of this curve, i.e. uncertainty about the future abatement cost. JI adds to this uncertainty by the fact that every new project accepted by this country before *t* represents a shift downward of the cost curve (e.g. to the dotted curve). Since the curve is convex, the cost of the ’first abatement’ increases the more JI projects that has been accepted previous to this future year.

Figure 4.4 The expected cost of a future emission target



The second uncertainty refers to the emissions. If the emissions turn out as expected (*Ee)*, there will be no need for abatement. However, the figure shows that this does not mean that the expected cost (*Ec*) is zero because the expected cost is the average cost of low emissions (e_{min}) and high emissions (e_{max}). The expected abatement cost curve refers to increasing expected emissions with equal distribution. Thus, as long as there is some possibility that emissions may exceed the target, the target will have an expected cost. These two factors may give rise to a substantial 'risk premium' in assessing a price for a JI project.

4.6.4 Means to reduce uncertainty

In general, uncertainty implies extra costs and should be limited as much as possible. The fact that continuation of projects with mainly operating costs should be prolonged under uncertainty compared with certainty does not imply that uncertainty is attractive. On the contrary, the expected present value of a strategy is of course higher the lower the uncertainty is. Therefore, it is important to discuss whether JI may contribute to reduce uncertainties about climate measures.

One way that has already been mentioned is that JI widens the available climate measures, thus extending the possibilities for flexible strategies. To what extent remains to be seen, however. According to Table 4.3 it seems that flexible alternatives mainly will exist within countries that commit themselves to targets. This is not because flexible alternatives are unavailable in, e.g., developing countries, but rather that the type of measures that allow for flexible strategies, such as general economic measures, will not be appropriate for JI. Fuel switching represents, however, one possible exception.

A second possibility to reduce the impact of uncertainty through JI relates to a standard result in economic theory, namely the importance of diversification. A country that initiates a number of abatement measures with uncertain costs should aim at making the uncertainty of its total portfolio of measures as small as possible.[35] Therefore, the uncertainty of a particular measure may be irrelevant for its evaluation if in constitutes a part of a portfolio of measures. Then, it is the correlation between this particular measure and all the other measures that counts. In other words, the uncertainty of a given measure may be attractive if it counterbalances the uncertainty of other measures, because it thereby reduces the total uncertainty of all the measures.

Introduction of JI may contribute to stabilizing the uncertainty of climate measures by extending the availability of alternative measures. Moreover, attention to this aspect may provide guidance to how an efficient JI regime should be designed, namely to diversify all measures on a world scale in order to minimize the total uncertainty. From this point of view, the perfect JI regime would be the establishment of a Credits Bank that 'traded' abatement projects subject to JI. Other properties of such a bank are dealt with in section 4.2 and chapter 7.

4.6.5 Project selection under uncertain transaction costs

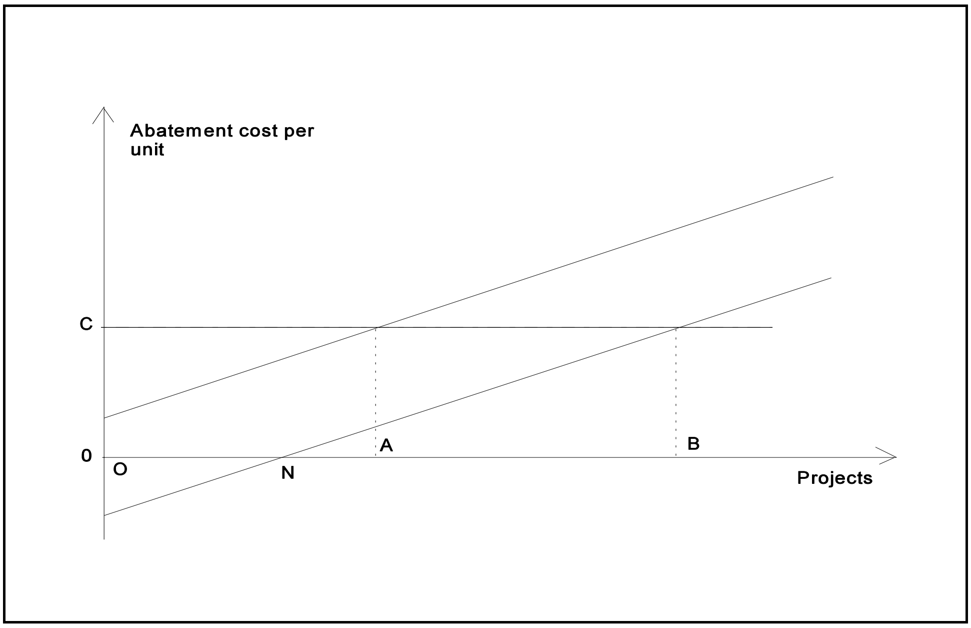
In the process of planning, developing, implementing, monitoring and controlling JI projects there are transaction costs (cf. Barrett (1993b)). Transaction costs can be defined as the total administrative costs of undertaking the JI project, that is total project costs subtracted economic expenses in strict terms, such as project investment costs and operation and maintenance costs for some time horizon. In principle, transaction costs should be included in the total JI project costs to find the abatement cost per unit of emissions for the JI project, which is a main criteria for the acceptance of the project and selection of the project in a portfolio of possible JI projects. Some degree of 'economics of scale' is likely to exist for transaction costs associated with JI projects. Thus the transaction cost share of total costs is probably larger for small-scale JI projects than larger JI projects. This means a relatively disadvantage to small projects compared to larger projects (cf. the discussion in Bohm (1994b)). In general transaction costs may significantly reduce the number and types of interesting and acceptable JI projects. Due to 'economics of scale' effects (i.e. information gathering, human skills, experience, etc.) and smaller incentive problems in a Credits Bank setting, transaction costs may be reduced and more potential JI projects be acceptable.

---

[35] Wilson (1984) provides a framework for a practical application of this result.

Transaction costs (and other project-related costs) cannot be known with certainty when planning and developing JI projects. The abatement cost per unit might also be uncertain due to baseline uncertainty and / or uncertain emission abatement effects from a JI project. This type of uncertainty will have implications for the comparison of projects with different profiles and the optimal choice between them. This situation is illustrated in the diagram in Figure 4.5. In the figure the vertical axis represents abatement cost per unit of emission, which is increasing upwards in the diagram. The horizonal axis represents the accumulated size of JI projects in terms of anticipated emission abatement, which is increasing to the right. The projects are ranked according to increasing abatement cost per unit, and represented by the lower upward-sloping line. The first part of the line, from *O* to *N* is below zero, which represents no-regrets projects. These are projects that can be undertaken for a negative cost, meaning that they are profitable under normal market conditions even if global climate benefits are not included in the calculations.[36] Let us assume that an investor country has an upper abatement unit cost limit represented by *C*. Then the JI investor will be interested in financing projects from *N* to *B*, since projects from *O* to *N* are profitable on their own (i.e. no-regrets) and should be undertaken by the host without any external funding.

Figure 4.5 JI project selection under transaction cost uncertainty



The project cost is zero in *N* and increases to the right to reach *C* for the last project.

Now consider the situation where the abatement cost per unit, which includes

[36] Confer Selrod and Torvanger (1994) for further discussion of no-regrets options.

transaction costs, is uncertain. This uncertainty is represented by a potential upwards shift in the project curve. This is shown as the upper upwards-sloping line. Thus there is some probability that the true cost curve is the upper one instead of the lower one, which means higher abatement costs. The earlier no-regrets projects now turn out to have a positive cost, and the investor would finance projects from *O* to *A*. The total cost is higher and fewer investments undertaken.

When comparing the two situations and project cost lines we find that the optimal project selection, where the cheapest projects are realized first, is particularly sensitive to uncertainty of the cheapest and most attractive projects. If the cheapest projects are no-regrets they should not be made applicable for credits under JI arrangements. On the other hand there is some probability that they are not no-regrets projects, in which case they could be the most attractive projects. The upper cost end for JI projects is also sensitive to uncertain cost data, confer the change from *B* to *A*. However, since the investor would prefer to start with the cheapest projects, the sensitivity of the lower cost end would be more important for finding the least cost project portfolio. The analysis of conditions under which projects are no-regrets or not would be of particular interest. This uncertainty may lead to inefficiency due to a biased selection of projects since the cheapest projects may be turned down out of concern that these projects are no-regrets. Consequently investors may be left with only JI projects in the medium cost range being attractive. However, in a Credits Bank setting the experience, human skills, and information gathering capacity of such an institution could reduce the potential inefficiencies related to transaction cost and abatement effect uncertainty.

4.7 Conclusions

The transaction costs involved in planning and implementing JI projects are smallest for Type I JI projects, where only Annex II countries are involved, and GHG emissions are abated through fossil fuel saving or changing industrial technologies. There are additional problems and higher transaction costs if non-Annex II countries are involved (Type II projects), or if carbon dioxide is sequestrated through forestation, or GHG emissions reduced through changing agricultural practices (Type III projects). This is an argument for developing JI criteria for Type I projects first, since some basic problems must be solved to take on any type of JI project. Thus we recommend that JI projects that are likely to contribute to solving these basic issues are given some priority as pilot projects in the present FCCC phase I.

The incentives for parties to a JI contract to overstate the abatement effect to the COP can be reduced through institutional arrangements like Clearinghouse or Credits Bank. This is partly due to establishing some type of market that may reduce the importance of asymmetric information, and partly due to the resources and know-how of such institutions.

Leakages can be caused by market effects, strategic behavior, or political decisions. There is potential for incentive contracts between parties to a JI project that reduce the risk of leakages based on after-the-fact control, such as a bonus to be paid to the host country if the project is successful. The success in terms of national GHG abatement effects will also depend on the host country's political decisions in the implementation period. Due to the risk of leakages JI projects should be evaluated 'project-by-project' (i.e. 'bottom-up'), if possible supplemented by macroeconomic effects based on model analysis.

Asymmetric information between parties to a JI contract can reduce the potential global cost saving from JI, since the most cost-effective projects are not carried out first. Furthermore, asymmetric information leads to inefficient implementation of some of the chosen projects. Thus the cost per unit GHG abatement for the investor would not be minimized. Furthermore, strategic behavior of the host could lead to uncertain abatement outcomes for the investor (and at the global level). The risk of such effects can be reduced through a Credits Bank institution, and shared among all investors.

Due to uncertainty related to future prices and other conditions there is an extra value associated with a flexible GHG abatement strategy, i.e. to have the opportunity to regret a measure that is taken. This may affect the ranking of different JI project categories. Thus uncertainty can favor, e.g., fuel switching JI projects, since the operating cost of these is relatively more important than the investment cost, as compared to, e.g., energy efficiency improvement projects, where investment cost is relatively more important than operating cost. It may also favor general domestic measures compared with inflexible agreements with host countries. Uncertainty can be reduced through project diversification, where the aim is to reduce the uncertainty of the total portfolio of JI projects as much as possible. There is also uncertainty related to the size of transaction costs and the existence of no-regrets projects. 'Economics of scale' related to transaction costs can imply a relative disadvantage for small JI projects. If there is some risk that the cheapest JI projects are no-regrets and do not qualify for credits based on after-the-fact control, there may be a biased selection of projects where the most cost-effective projects are not attractive to investors. Such inefficiencies could be reduced in a Credits Bank regime, due to larger information gathering capacity and more know-how compared to single investors.

5. GREENHOUSE GASES AND PROJECT CATEGORIES

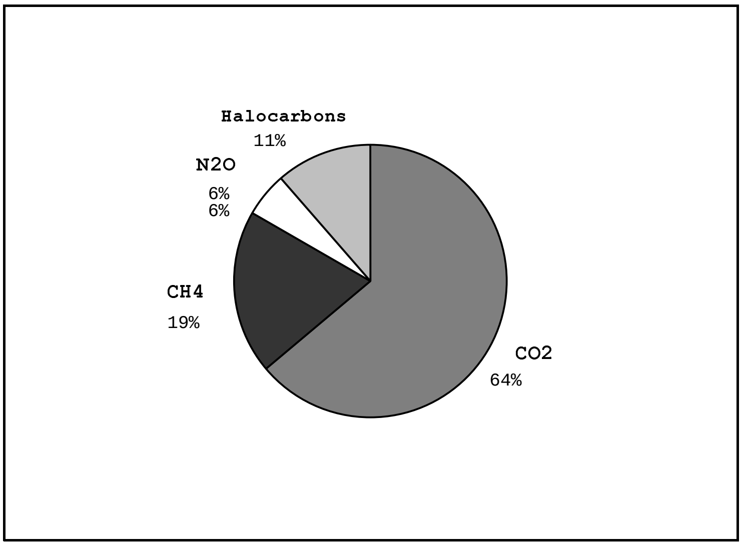
5.1 Introduction

The FCCC states in Article 3.3 that measures and policies to mitigate climate change should cover all relevant sources, sinks and reservoirs of GHGs. Thus, as a point of departure, all GHGs except those gases covered by the Montreal Protocol on Substances that Deplete the Ozone Layer should ideally be included in the JI mechanism. However, the knowledge about the sources and sinks and the climatic impact varies with regard to the different gases. Thus, the selection of gases that should be considered in JI projects needs careful attention.

5.2 Geographical location of emissions

The globally most important GHGs for the direct radiative forcing of climate is carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and halocarbons (mainly chlorofluorocarbons (CFCs)). Figure 5.1 shows the radiative forcing[37] from the changes

Figure 5.1 The contribution from various gases to the direct radiative forcing of climate since pre-industrial times (IPCC (1994)).



[37] 'A change in average net radiation at the top of the troposphere (known as the tropopause), because of a change in either solar or infrared radiation, is defined (...) as a radiative forcing. A radiative forcing perturbs the balance between incoming and outgoing radiation. Over time, climate

in these gases since pre-industrial times.[38] These gases have atmospheric lifetimes that allow the gases to be well mixed in the atmosphere, and their climatic impacts are therefore not dependent on the geographical location of emissions. The climatic effect of measures to reduce emissions or increase the strength of the sinks will also be independent of location. With this background joint efforts and cooperation on the implementation of measures between countries should be considered.

5.3 Climate impact mechanisms of gases

There are large variations in the scientific knowledge about the climate impacts of the various gases emitted to the atmosphere (hereafter named source gases). Several gases have, in addition to their direct radiative effect on climate, also indirect effects on climate through chemical and physical interactions in the atmosphere.[39] The source gases that affect the radiative balance of the Earth / atmosphere and thereby climate, may thus be divided into three groups:

i) GHGs that have a direct effect on climate due to their radiative properties. Source gases such as carbon dioxide (CO_2) and perfluoromethane (CF_4) belong to this group (see discussion about the gases and their sources in section 5.5).

ii) Gases which have no or negligible direct greenhouse effect, but which indirectly affect climate through impacting on chemical and physical processes in the atmosphere. Greenhouse gases (GHGs) and compounds interacting with solar radiation may thus be affected. Nitrogen oxides (NOx), carbon monoxide (CO) and non-methane hydrocarbons (NMHC) are examples of such source gases.

iii) Source gases that possess the ability to affect climate both directly and indirectly. Methane (CH_4), chlorofluorocarbons (CFCs) and hydrochloro-fluorocarbons (HCFCs) belong to this third group.

The climate gases that will be affected by the indirect GHGs through atmospheric chemistry are mainly ozone (O_3) and methane (CH_4), but HCFCs and hydrofluorocarbons (HFCs) will also be affected. Indirect effects are recognized as potentially important, but for several gases the scientific knowledge is still

---

responds to the perturbation to reestablish the radiative balance. A positive radiative forcing tends, on average, to warm the surface; a negative radiative forcing, on average, tends to cool the surface' (IPCC (1994)).

[38] In IPCC (1994) the pre-industrial period is defined as earlier than 1750.

[39] Isaksen et al. (1992a), IPCC (1992), Lelieveld and Crutzen (1992), Hauglustaine et al. (1994a), Fuglestvedt et al. (1994ab).

unsatisfactory.[40] Extensive research is going on to reduce the uncertainties with regard to our understanding of indirect effects.

5.4 Global Warming Potentials

The Global Warming Potential (GWP) index was introduced as a tool for policymakers to compare the potential of the various well-mixed source gases to affect climate. It is a relative measure since it expresses the climate effect compared to the effect of a reference gas. It is derived from the globally-averaged net radiative fluxes at the tropopause. Thus, it is a global measure that describes the effects on the whole surface-troposphere system. It expresses the cumulative warming effects of the gases over a chosen time horizon. In IPCC (1990) this was defined as the time integrated commitment to climate forcing from the instantaneous release of 1 kg of a trace gas expressed relative to that from 1 kg of CO_2:

$$GWP = \frac{\int_0^n a_i \cdot c_i \, dt}{\int_0^n a_{CO_2} \cdot c_{CO_2} \, dt} \qquad \textbf{(5.1)}$$

where a_i is the instantaneous radiative forcing due to a unit increase in the concentration of the GHG i, c_i is the concentration at time t, and n is the time horizon. The corresponding values for the reference gas CO_2 are given in the denominator.

The INC recommends that all relevant gases in the context of climate change should be included in measures to mitigate climate change. INC also recommends that the climatic effect of the various source gases relative to CO_2 given as GWPs should be used in estimates of contribution to the enhanced greenhouse effect from the individual source gases. But due to the nature of the atmospheric effects, and insufficient knowledge of such effects, the GWP concept cannot be used for all sources gases that enhance the greenhouse effect.

The atmospheric lifetimes of the various GHGs considered in IPCC (1994) vary from about 1/2 year to 50 000 years. The GWP values will therefore depend on which time horizon that is chosen. The GWPs are often given for the horizons 20, 50, 100, 200 and 500 years. When GWPs are used in order to compare emissions on a common scale, attention should therefore be given to the choice of horizon, and whether several

[40] IPCC (1992), (1994).

horizons should be used. If only one time horizon will be used, a horizon of 100 years should be chosen in accordance with the recommendation of INC (1994b).

INC also recommends that both emissions and uptake of gases should be incorporated into the greenhouse inventories for the countries. Increased capacity of the sinks is only possible for CO_2. Absorption of CO_2 from the atmosphere will increase as long as the biomass stock is increasing.

5.5 Choice of gases

Many gases can potentially be reduced through JI projects. Based on the status of the current knowledge it seems prudent to include the following gases in JI projects:

* Carbon dioxide (CO_2)
* Methane (CH_4)
* Nitrous oxide (N_2O)
* Perfluorocarbons (PFCs)
* Sulphur hexafluoride (SF_6)
* Hydrofluorocarbons (HFCs)

5.5.1 Carbon dioxide

Carbon dioxide is the most important gas for the anthropogenic enhancement of the greenhouse effect. The dominating anthropogenic source is combustion of fossil fuels (coal, oil and gas), and the CO_2 emissions can be estimated from statistics on fossil fuel production and use, together with information on the carbon content. Deforestation and changes in land use also make significant contributions to the increased levels of atmospheric CO_2, but significant uncertainties are related to the numbers for the net emissions from these sources. Table 5.1 gives the most recent emissions and uptake numbers published by the IPCC (1994).

The table shows that the emissions from production and use of fossil fuels, and cement production, (a), together with net emissions from changes in tropical land use, (b), adds 7.1 ± 1.1 gigatons carbon per year (GtC / yr) to the atmosphere as CO_2. Of this amount, 3.2 ± 0.2 GtC remains in the atmosphere, (d), while uptake in the ocean, (e), re-growth of forests in the Northern Hemisphere, (f), and other terrestrial sinks, (g), remove the remaining part of the annual anthropogenic input of CO_2 to the atmosphere.

Table 5.1 Annual average anthropogenic carbon budget for the period 1980-1989 (IPCC (1994)).

CO_2 sources	GtC / yr [a]
(a) Emissions from fossil fuel and cement production	5.5 ± 0.5
(b) Net emissions from changes in tropical land use	1.6 ± 1.0
(c) Total anthropogenic emissions (a + b)	7.1 ± 1.1
Partitioning among reservoirs:	
(d) Storage in the atmosphere	3.2 ± 0.2
(e) Ocean uptake	2.0 ± 0.8
(f) Uptake by Northern Hemisphere forest regrowth	0.5 ± 0.5
(g) Additional terrestrial sinks (CO_2 fertilization, nitrogen fertilization, climatic effects) {(a + b) - (d + e + f)}	1.4 ± 1.5

[a]The numbers are given in gigatonnes of carbon per year (1 GtC = 3.7 Gt CO_2).

5.5.2 Methane

Next to CO_2, methane is probably the most important gas for the anthropogenic enhancement of the greenhouse effect. Methane is emitted to the atmosphere from both natural and anthropogenic sources. In IPCC (1994) the anthropogenic fraction of the total sources is estimated to be 60-80%. The most important natural source is wetlands, while the dominating anthropogenic sources are production and use of fossil fuels, rice paddies and enteric fermentation mainly in cattle, sheep and buffalo. Production and use of fossil fuels is estimated to contribute about 20% of the total emissions. Other significant anthropogenic sources are landfills, biomass burning, animal waste and domestic sewage.

In addition to the direct radiative effect of methane on climate, several indirect effects through atmospheric chemistry interactions are related to emissions of this gas. Numerous studies have focused on these effects and the studies give results that are in good agreement.[41] The climatic implications of these indirect effects are therefore considered to be relatively well known. In the 1994 report from IPCC Working Group I, methane is the only gas for which the indirect effects are included in the GWP estimates. The indirect effects are comparable in magnitude to the direct effect.[42] The

[41] i.e. Isaksen and Hov (1987), Isaksen (1988), Berntsen et al. (1992), Lelieveld and Crutzen (1992), Fuglestvedt et al. (1994b), Hauglustaine et al. (1994b).

[42] IPCC (1992), Lelieveld and Crutzen (1992), Fuglestvedt et al. (1994b), Hauglustaine et al. (1994b).

scientific knowledge about the effects of emissions of this gas is considered sufficient to permit inclusion of this gas in the greenhouse gas accounting needed in JI projects.

5.5.3 Nitrous oxide

There are large uncertainties connected to the emissions estimates for N_2O. The emissions are probably distributed among several small sources and it is difficult to quantify their contribution. According to IPCC (1994) the natural sources are larger than the anthropogenic. Important natural sources of N_2O are oceans and tropical forest soils, while cultivated soils are probably the most important anthropogenic source. Other contributing sources are industrial processes, biomass burning, degassing of ground water used for irrigation and cattle and feed lots.

The effect of increased levels of N_2O on the radiative forcing of climate is small but significant. In addition to its direct climate impact, N_2O also reduces the levels of stratospheric ozone, thereby indirectly affecting climate. In the IPCC assessments, however, this indirect effect is not included among the mechanisms judged to be significant for climate change. It is therefore recommended that this gas may be included in JI projects.

5.5.4 Perfluorocarbons and sulphur hexafluoride

The perfluorocarbons (PFCs) that will be considered here are perfluoromethane, perfluoroethane, perfluorocyclobutane and perfluorohexane. These gases, as well as sulphur hexafluoride, are present in very low concentrations in the atmosphere, but the levels are rapidly increasing. They are considered important for the radiative balance and climate due to their strong absorbing properties as well as their extremely long lifetimes. The lifetimes are 50 000 years for perfluoromethane, 10 000 years for perfluoroethane and 3 200 years for sulphur hexafluoride. This leads to very high GWP values for these gases.

Natural sources of PFCs are not known, and the most important source is probably the aluminum industry. SF_6 is emitted from the production of magnesium and aluminum as well as from secondary foundries and electrical equipment. Although the contribution from the perfluorocarbons and sulphur hexafluoride to the global enhancement of the greenhouse effect is small, these gases may be important for the contribution on country levels.[43]

5.5.5 Hydrofluorocarbons (HFCs)

Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are groups of

[43] Isaksen et al. (1992b).

gases that exert significant direct radiative effects on climate. In addition, these gases destroy ozone in the stratosphere. Ozone is an important climate gas and model studies indicate that depletion of stratospheric ozone has significant effects on climate due to absorption of solar radiation and absorption and emission of longwave radiation.[44] These are factors that complicate calculations of the total effect of CFCs and HCFCs on climate. Since these gases are covered by the Montreal protocol, which has its own mechanisms for control, the CFCs and HCFCs need not be covered by the FCCC.

Hydrofluorocarbons (HFCs) were introduced as substitutes for the CFCs and HCFCs. They do not destroy stratospheric ozone since they do not contain chlorine. However, some of the HCFs have strong direct effects on the radiative balance, but, since they do not affect stratospheric ozone and thus have no known significant indirect effects on climate, the GWPs may be calculated with reasonable degree of confidence. These gases may thus be included in JI projects.

5.6 Knowledge of emission sources

The knowledge of the emission sources varies among the different gases. Most sources of methane are relatively well known, while there are significant limitations to our understanding of the sources of N_2O. The emissions of HCFs, on the other hand, are well known. The status of the knowledge of the emissions must be taken into account when JI projects are designed. Furthermore, the accuracy in monitoring or estimating the amount of gas emitted or taken up, and the possibilities of detecting any effects of measures, must be considered (see the discussion at the end of this chapter). This lack of knowledge about the sources may make it difficult to establish the baseline emissions, which is a prerequisite for JI projects. Thus the effects of measures implemented to reduce emissions may be difficult to estimate. Since there are large uncertainties related to the emission numbers of nitrous oxide (N_2O) special attention should be given to this gas. The ranges given by IPCC (1994) for the global emissions from cultivated soils and biomass burning are 1.8-5.3 and 0.2-1.0 MtN / yr, respectively, illustrating the uncertainties connected to these sources.[45] The ranges for industrial sources and cattle / feed lots are 0.7-1.8 and 0.2-0.5, respectively. For methane there are large uncertainties related to emissions from the petroleum industry (5-30 Mt CH_4 / yr), coal combustion (1-30 Mt CH_4 / yr), rice paddies (20-100 Mt CH_4 / yr), biomass burning (20-80 Mt CH_4 / yr), and domestic sewage (15-80 Mt CH_4 / yr).

5.7 Short lived gases that have indirect effects on climate

Extensive research is presently being conducted in order to understand the climatic impacts of emissions of the short lived gases NOx, NMHC and CO. Emissions of these

---

[44] IPCC (1992), and references therein.

[45] MtN : Megatons of nitrogen (equal to teragrams of nitrogen (TgN)).

gases may affect the radiative balance and climate through chemical processes in the atmosphere. This occurs mainly by affecting tropospheric ozone and the cleansing capacity of the atmosphere and thereby also the levels of the greenhouse gases CH_4, HCF and HCFC. Furthermore, these gases cause local and regional damages such as effects on health, corrosion and acid deposition. The uncertainties related to the climatic impacts of NOx, CO and NMHC are so large that these gases should not be included in JI projects under the FCCC. The atmospheric lifetimes of these gases are relatively short (from hours to days for NOx and from days to a few months for CO and NMHC). Their effects on climate through changes in tropospheric ozone will therefore be regional.

5.8 Reporting

In the preparation and reporting of inventories of sources and sinks the IPCC Guidelines for National Greenhouse Gas Inventories should be used. The documentation should be transparent and thorough to allow reproduction of the estimates. This means that essential assumptions, emission factors, activity data and other relevant information must be given explicitly. If other methods than the IPCC method are used such documentation is of particular importance to ensure or assess the comparability of various estimates. The reduction in emission or increase in uptake that is obtained from the implementation of a project should be given in metric tons on a full molecular basis for each gas. An assessment of the uncertainty in the emission numbers would be useful for the evaluation of the projects.

The emissions may be given in a common unit (CO_2 equivalents) by the use of GWPs. These estimates may be improved in the future and it is important that all parties use the most recent GWP values. The values given by the IPCC should be used. Table 5.2 lists the GWP values published by IPCC (1994) for the gases that are prudent to include in JI projects.

Table 5.2 Global Warming Potentials (GWPs) for the gases recommended for JI projects.

Gas	Chemical formula	Lifetime (years)	Global Warming Potential (Time horizons)		
			20 years	100 years	500 years
Methane[a]	CH_4	14.5±2.5[b]	62	245	75
Nitrous oxide	N_2O	120	290	320	180
HFC-23	CHF_3	250	9200	12100	9900
HFC-32	CH_2F_2	6	1800	580	180
HFC-43-10mee	$C_4H_2F_{10}$	208	3300	1600	520
HFC-125	C_2HF_5	36	4800	3200	1100
HFC-134	CHF_2CHF_2	119	3100	1200	370
HFC-134a	CH_2FCF_3	14	3300	1300	420
HFC-152a	$C_2H_4F_2$	15	460	140	44
HFC-143	CHF_2CH_2F	35	950	290	90
HFC-143a	CF_3CH_3	55	5200	4400	1600
HFC-227ea	C_3HF_7	41	4500	3300	1100
HFC-236fa	$C_3H_2F_6$	250	6100	8000	6600
HFC-245ca	$C_3H_3F_5$	7	1900	610	190
Sulphur hexafluoride	SF_6	3200	16500	24900	36500
Perfluoromethane	CF_4	50 000	4100	6300	9800
Perfluoroethane	C_2F_6	10 000	8200	12500	19100
Perfluorocyclobutane	$c\text{-}C_4F_8$	3200	6000	9100	13300
Perfluorohexane	C_6F_{14}	3200	4500	6800	9900

[a] The GWP for methane includes both direct and indirect effects.
[b] The lengthening of the chemical lifetime due to the CH_4 / OH feedback is taken into account.
Source: IPCC (1994)

5.9 The main project categories, emissions of various GHGs, and monitoring possibilities

The most important scheme for reducing GHGs emissions is to reduce combustion of fossil fuels asociated with production and consumption of goods and services. The major GHG released from fossil fuel production, transport, distribution and combustion is carbon dioxide, but also some methane and nitrous oxide are also released. The principal ways of reducing fossil fuel combustion are:

i) fuel switching,
ii) energy efficiency improvements,
iii) changing the economic structure,
iv) output reduction.

Category iii) refers to changes in the production (and consumption) structure from more GHG-intensive to less GHG-intensive activities, whereas category iv) refers to the relation between the level of production in an economy and the release of GHGs. In relation to JI projects, categories iii) and iv) are less relevant as long as JI projects are assumed to be of limited size compared to the national economy. Another category is sink enhancement, where net anthropogenic release of carbon dioxide is reduced through carbon fixation in biomass or changes in land use and management practices. The most common sub-categories are reforestation and afforestation. The distinction between these sub-categories can be of importance since, according to some definitions of baseline, reforestation may not be considered an increase in carbon sequestration.[46] As earlier discussed in section 4.3, there are further potential problems related to baseline definition and calculations for carbon sequestration projects. Next, there are possibilities to change agricultural practices and reduce emissions of carbon dioxide, methane and nitrous oxide. Finally there is a potential for GHG emissions abatement through changing industrial technologies. Some abatement options and examples for this and the other categories are given in Table 5.3.

The four JI project categories of greatest interest are listed in the table. It should be noted that project categories 1) and 2) are listed under Type I and II projects in Table 4.1, whereas categories 3) and 4) are listed under project Type III in the same table. We will mostly be concerned with fossil fuel saving and carbon sinks enhancement projects, which have the largest potential in terms of anthropogenic emissions to the atmosphere, and probably also in terms of cost per unit of emissions abatement.

The most practical way to estimate reduction in carbon dioxide emissions from reduced fossil fuel combustion in category 1) is to employ consumption data from the relevant generators, heaters, vehicles or other machinery. The carbon content of various fossil fuels is well known. Thus the monitoring possibilities will depend on the availability and quality of consumption data for each fuel type. Estimation of nitrous oxide and methane emissions is more complicated since the emissions are more technology-

[46] If reforestation projects should be applicable for credits as JI projects would *inter alia* depend on the number of years since the earlier forest disappeared due to logging or other intervention in the area and the type of intervention.

Table 5.3 JI project categories

JI Project category	Abatement options	Examples	Greenhouse gases	Monitoring possibilities
1) Fossil fuel saving: - Fuel switching. - Energy efficiency improvements.	- Develop renewables. - DSM.[a] - Reduce losses in energy supply sector.[b]	- Substitute gas for coal in a thermal power plant. - Replace traditional light bulbs with high-efficiency CFLs.[c]	- Carbon dioxide - Nitrous oxide - Methane	- Consumption data. - Site observations.
2) Changing industrial technologies.	- Replace process technologies. - Modify products and related technologies.	- Replace older aluminum production technologies.	- Perfluorocarbons - Sulphur hexafluoride - Hydrofluorocarbons	- Site observations.
3) Carbon sinks enhancement.	- Afforestation or reforestation. - Changes in land use and management practices.	- Reforestate degraded grasslands. - Increase carbon sequestration in soils.[d]	- Carbon dioxide	- Remote sensing. - Field observations.
4) Changing agricultural practices.	- Develop new crop variants. - Collect and combust methane emissions.	- Develop rice variants that generate less methane emissions. - Employ methane from dung and wastes as energy source.	- Carbon dioxide - Methane - Nitrous oxide	- Field observations. - Remote sensing.

[a]Demand Side Management.
[b]Losses in conversion, transportation, and distribution.
[c]Compact Fluorescent Lamps.
[d]One option is application of phosphorus.

specific, and varies with, among other things, the combustion conditions. Controlling and verifying emissions will have to rely on measurements and site inspections. Employing the relevant emission coefficients for each fuel type and greenhouse gas (e.g. coal, oil and gas), the total reduction in emissions can be estimated.

The change in GHG emissions from modifying and replacing industrial technologies in category 2) can be estimated from technology data and field observations. Emission reduction is technology-specific and must be controlled from site observations, engineering data and emission measurements for each technology. The quality of the verification process will be very much dependent on how attainable site inspections are and their frequency.

The increase in the relevant type of biomass in category 3) can be calculated based on species and local ecological conditions. Total carbon fixation can then be estimated from the carbon content of the specific biomass type. Trees are most important for carbon sequestration.[47] Afforestation and changes in land use can be inspected by remote sensing (airplanes or satellites) in combination with field observations. From such observations the change in carbon dioxide fixation can be estimated with the help of models, although with some inaccuracy. Compared to the earlier project categories monitoring seems to be more complicated for category 3).

GHG emissions abatement in category 4) can be estimated from model calculations calibrated on field observations. With respect to changes in agricultural practices and effect on emissions of carbon dioxide, methane and nitrous oxide, remote sensing is also an option, but it is likely that site observations and estimates will be more important since emission sources and the relations between agricultural activities and emissions are more complicated and ambiguous than for project categories 1) and 2). Consequently, monitoring possibilities are also relatively smaller for project category 4) as compared to categories 1) and 2).

5.10 Conclusions

Based on the discussion in this chapter on the state of knowledge of sources and sinks of various GHGs, as well as the knowledge of their climate impact, carbon dioxide, methane, nitrous oxide, perfluorocarbons, sulphur hexafluoride and hydrofluorocarbons can be included in JI projects and made applicable for credits. Based on present knowledge and monitoring possibilities, project categories 1) and 2) listed in Table 5.3 (fossil fuel saving and changing industrial technologies) are less complicated to include in JI arrangements than project categories 3) and 4) (carbon sinks enhancement and changing agricultural practices). Thus project categories 1) and 2) are considered as Type I or II JI projects, as defined in Table 4.1, which, according to the project categories from Table 5.3, involve relatively few potential problems in implementation and abatement effect control. However, project categories 3) and 4) are considered as Type III JI projects, involving further potential implementation, monitoring and control problems. With this background it is recommended that JI projects involving project categories 1) and 2) should be given some priority as pilot projects in the present FCCC phase I (where no countries have legally binding commitments).

[47] Fischer et al. (1994), however, show that there can also be a significant carbon sequestration potential through introduction of deep-rooted grasses in savanna areas.

6. INVOLVING PRIVATE ENTERPRISES

This chapter considers what type of national framework would best stimulate the involvement of private enterprises in initiating and financing JI projects.

Similar to other environmental regimes, the rules of FCCC apply, in the first instance, to the actions of states. However, it is the responsibility of the states to ensure that Parties under their jurisdiction, frequently private enterprises, comply with the rules of the regime, also with respect to a future global JI regime. Assuming that a JI mechanism is operational under the FCCC, an investor government will receive credits for JI investments undertaken by a private enterprise in a host country. Then the investor's government must determine criteria for approval of such investment schemes undertaken by the enterprises, and settle on an 'exchange rate' between such credits and a change in national regulations affecting the private enterprise.[48]

In the present phase I, where no Parties to the FCCC have legally-binding commitments, some private enterprises have already engaged in offsetting investments, denoted as *OI* in Table 6.1. These are investments to reduce GHG emissions in another country undertaken by a private enterprise at its own cost. The motivation for such investments can be an expectation of future restrictions on GHGs emissions and establishment of a credits mechanism. Enterprises in the vanguard of such investments could make extra profits in future markets and, as discussed below, might earn public relations benefits related to 'a green image'. The investment in *OI* can be compared to other investments undertaken by companies under uncertainty, where an expected profit must be anticipated.

In phase II with an operational JI mechanism, governments, international organizations and private enterprises can be involved in various ways in the financing of JI projects. One option for JI projects is for a government, as part of a bilateral arrangement, to invest in a JI project which is carried out by the host country's government or one of its state institutions. In Table 6.1 such JI project settings are named JI^{State}. The investor government can instead contract a private enterprise in the host country, or private enterprises in both the investing and host countries, to operate the JI project, denoted as $JI^{Contract}$ in the table. Depending on the documented GHGs' abatement effect from the JI project, the investing country should receive emission abatement credits.

[48] An example of this would be a Norwegian company employing oil-based heaters in the production process. The company is facing new restrictions on emissions of air pollutants. Then the company makes JI investments in Poland if this is a much cheaper way of reducing emissions than in its own production process. The government is credited the reduced GHG emissions in Poland, and transfers some of this benefit to the company by allowing reduced GHG emissions in Poland to count as fulfilling (part of) its obligations to reduce emissions of air pollutants in Norway.

Table 6.1 Different settings for Joint Implementation projects with respect to financing and operation.

		OPERATING AGENT IN HOST COUNTRY	
		The state	Private enterprises[a]
FINANCING AGENT IN INVESTOR COUNTRY	The state	JI^{State}	$JI^{Contract}$
	Private enterprises	-	$JI^{Enterp.}$ OI

[a]This may also be private enterprises in the investor country.

The most promising and interesting JI option for private enterprises is $JI^{Enterp.}$ in which private enterprises are induced to finance and carry out JI projects. In this case, private enterprises finance and operate JI projects in a host country, given incentives established by the government in the investing country. The private enterprises may face, or anticipate that they will face, restrictions on emission of pollutants in terms of taxes or quotas of GHGs. In principle, as long as a linkage between the regulations and JI investments is established, any other type of government regulation that is costly to the enterprises can be employed to give private enterprises incentives to undertake JI projects. The enterprises will have incentives to invest in JI projects as long as the investment cost is lower than the possible gain of modifying national regulations, for example through lobbying. The incentives can be in terms of tax credits or increased domestic quotas of GHGs (or eventually less reduction in domestic emissions required from the private enterprises).

Anticipation of future regulation is a significant reason why private enterprises might be interested in investing in JI projects, and there are a number of reasons why enterprises anticipating regulation might want to be involved in JI projects. Moreover, private enterprises may even choose to do so before regulation under the FCCC becomes mandatory. One alternative is for private enterprises to engage in OI. Private enterprises might want to be involved in JI projects to acquire, maintain, or improve their image as environmentally responsible companies. Private enterprises are interested in getting ’eco-labelled’ by the government as this improves their ’green image’ and might have a positive impact on consumer behavior and consequently improve their market position.

Private enterprises may also consider that other aspects are important when making decisions about financing JI projects. During an initial phase of voluntary measures and regulations, private enterprises may acquire useful experiences which they could draw on when regulation later becomes mandatory. In a situation with no mandatory rules and regulations, they may gain useful experiences that can help them identifying and exploring the most effective ways for JI. In a more regulated business environment later, it might be costly to make mandatory investments in JI. Furthermore, by pointing to their experiences with JI, enterprises might attempt to influence the way a government designs rules and regulations for JI. Finally, the private companies with the best JI performances will probably be the strongest candidates for government investments in JI.

There are indications that private enterprises may finance JI projects even before binding rules are agreed to within FCCC, that is in Phase I as discussed in chapter 1. The Clinton Climate Change plan does not rely on any compulsive measures but, if it seems justified later, binding regulations will in all likelihood be introduced by the Clinton administration.[49] At present, the private sector in the United States seems to be anticipating future binding domestic climate change regulations. It should also be noted that the Clinton administration has established 'groundrules' for JI projects, commonly known as the United States' initiative on JI (USIJI), and has initiated bilateral arrangements with developing countries.[50] In line with this domestic development, the United States may at some future point have a considerable interest in getting binding rules and commitments within the FCCC that can harmonize the costs of regulation across countries, at least within the group of OECD countries.[51]

---

[49] William J. Clinton and Albert Gore, Jr., *The Climate Change Action Plan* (Washington, D.C.: October 1993).

[50] Department of State, 'Availability of Groundrules for U.S. Initiatives on Joint Implementation', *Federal Register*, December 17 1994, vol. 58, no. 241, pp. 66057-66059; Department of State, 'Final Groundrules', *Federal Register*, June 1 1994, vol. 59, no. 104, pp. 28442-28446; Costa Rican Office for Sustainable Development, 'From Rio to Reality: First-of-Its Kind Bilateral Climate Change and Sustainable Development Accord Signed by U.S. and Costa Rica' (Arlington, VA: September 30, 1994).

[51] Such a chain of events facilitated the establishment of the global ocean dumping regime. See Ringius (1992), Radwaste Disposal and the Global Ocean Dumping Convention: The Politics of International Environmental Regimes', Ph.D. diss., the European University Institute, Florence, Italy, 1992.

7. REPORTING AND VERIFICATION

7.1 Introduction

Most environmental treaties have a poor record of effective implementation control. The inclusion of effective mechanisms for compliance and implementation control is often hampered by the reluctance of states to cooperate. Their arguments essentially reflect opposition to what they perceive as foreign influence over management of their national resources.

Relevant experiences from the environmental field show that an international regime's built-in procedures are important in order to create an efficient implementation control system. Similar to some other agreements where national measures have transboundary effects, emphasis should be put on establishing prior notification and consultation arrangements. Attention should in addition be given to the development of reporting and fact-finding procedures. At present there are no rules or regulations developed for implementation control under the FCCC.[52] However, the COP will in all likelihood address this issue in March / April 1995.

States have recently used various types of non-compliance control procedures in environmental treaties. Such non-compliance procedures are intended to increase the implementation of treaty obligations. The most recent example is the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer, one of the most effective environmental treaties with regard to verification and control. The implementation control regime under the Montreal Protocol has a quasi-judicial form and serves as a party-steered verification and control regime. The Montreal Protocol consists of strong legally binding substantive and technical standards and an effective verification and control system supported by a fund. This three-pillar system makes the Montreal Protocol unique compared to other international environmental regimes. As discussed in chapter 4, implementation effectiveness might in addition be enhanced through use of incentive contracts between Parties wishing to engage in JI projects.

7.2 An institutional arrangement

In order to meet some minimum requirements for the COP's authorization of JI arrangement under the FCCC, it will be essential to keep records of reported JI projects, to perform some control and verification functions, and to prepare information needed for the COP to award credits according to agreed criteria. The COP should therefore create a mechanism assisting it in performing such functions. In this respect, several organizational alternatives are possible, even if the COP may prefer to be the only

[52] Article 13 in the Convention reads: 'The Conference of the Parties shall, at its first session, consider the establishment of a multilateral consultative process, available to Parties on their request, for the resolution of questions regarding the implementation of the Convention.'

authoritative body. The experiences with the Montreal Protocol indicate that the Parties to the FCCC may choose the COP as the authoritative body, while the preparatory work needed for its decision-making will be entrusted to a specialized organization, perhaps created for that particular purpose.

The experiences from relevant international environmental agreements, as well as the complexity of many JI-relevant issues, underscore the need for a specialized JI secretariat. Such a JI secretariat should be financed by a group of the most committed countries. This secretariat might report to a special Committee on implementation under the COP if so decided. Such a Committee, consisting of a limited number of country Parties elected for a limited time period by the COP, might be of significant assistance in performing control and verification activities. Depending on the nature of the institutional arrangement for JI that finally will be created by the COP (see chapter 2 for the possible alternatives) the Committee / JI secretariat might:

- provide information on reported JI activity to all interested parties as well as the public;
- coordinate development of a common reporting format;
- examine the validity of the baseline established in JI projects that is reported by the participating countries;
- coordinate control and verification activities as decided, and report to the COP; and
- prepare and recommend credits to be awarded by the COP.

Until legally binding commitments have been agreed upon by the Parties, the Committee / JI secretariat might be entrusted to initiate pilot projects conducted through a pilot phase. Such a pilot phase will make it possible to experiment with various ways in which JI might serve the objective of the FCCC once legal commitments are introduced.

If given a broader mandate, the Committee / JI secretariat might collect information on the externalities of JI projects, the local economic and environmental benefits as well as the costs of projects, their positive or negative impact on the development priorities of the host country, how projects have affected the local population, and other important aspects. However, this would imply a larger budget and seems like an unfeasible option for the near future.
Yet another alternative might be to establish an independent institution to act as a Clearinghouse or a Credits Bank for JI projects. Should an extensive use of JI projects develop under the FCCC, a need for a permanent institution with strong capabilities and capacity would be needed. This institution could also be entrusted with the management of a credit system controlling the amount of claimed credits with respect to countries Parties' implementation obligations and possible GHG emissions reductions due to JI projects.

7.3 A reporting and verification regime

It is a reasonable assumption that JI projects will require extensive examination of their GHG abatement effect and perhaps also their externalities. There will most likely be a need for control and verification arrangements that are more extensive than is usual for implementation of Parties' treaty obligations. This requirement must at the same time be weighed against the need to respect the choice of countries as to how they want to inform on the management of their natural resources and pursuance of their national development objectives. A system which takes such concerns into account should be built on a foundation of mutual trust and concern for cost effectiveness. This could imply that the implementation control system for JI projects should consist of two main parts:

- a reporting system by the Parties cooperating in a JI project; and
- a verification system based on a random choice of projects for evaluation.

Reporting

It seems preferable to organize reporting as a three-step process. The first step could be a 'note of information'. Such a note of information should be made by the Parties planning a JI project, and be forwarded to the designated JI organization under the FCCC. It should be publicly available, and might be limited to information on key elements such as who the participants are, the kind of project planning, the expected results, where the project is located, and the time schedule.

A second communication could be an official report by the participants to the COP made in accordance with an established reporting format. The participating Parties could, if they so wish, invite any NGO, research institutions or others to participate in the reporting. To gain sufficient credibility for the mechanism it is necessary that the reporting requirements are carefully considered. As discussed in chapter 4, reporting requirements should include inter alia:

a) Provisions for transparency, meaning that any third party should be able to reconstruct and verify the information given;
b) Information on the baseline, sufficient to reconstruct and evaluate its validity;
c) Information on arrangements between the participating Parties if an incentive contract or other agreements have been made;
d) Information on the projected emission savings, how these are calculated and will be monitored over the lifetime of the project;
e) Information on the externalities of the project; alternatively the benefits / drawbacks of the project might be left to the participating parties to decide; and
f) Broader environmental impact assessments and evaluations of how the projects fit in with national development priorities.

Because JI projects might perform better or worse than expected, a third and final report could be made on the basis of the completed project where actual emission reductions are established. The report will give the possibility to award credits only on the basis of after-the-fact emission reductions. Alternatively, the final report might adjust the quantity of earlier awarded credits.

Verification
Accurate and relevant information reported by the Parties themselves should be the primary tool for verification of the GHG abatement effect from JI projects. The main report must meet some agreed technical standards established by the COP. Adherence to this reporting format should be a prerequisite for receiving emission credits. A Committee on implementation should also have the authority to request further information or clarification from the reporting Parties. Based on an acceptable report, the Committee / JI secretariat could prepare a recommendation for awarding credits to the COP. If such procedures are followed, verification practice would normally not be overly complicated or expensive.

Reporting on JI projects and its GHG abatement effect may be a complicated and difficult task. The JI mechanism should therefore also have a system for reassessment of reports, control of data and on-site inspections. Such an extraordinary verification procedure should be a responsibility entrusted with the Committee, with a representative number of seats for the different groups of countries.

These extraordinary verification processes should include making on spot checks, and different categories of JI projects may be randomly chosen at irregular intervals. Such control or fact-finding missions intended to resolve uncertainty regarding the effects of JI projects might for example be modelled after the OECD environmental performance reviews, where experts representing three member countries, the secretariat and independent experts make a report on another member country.

7.4 Conclusions

* JI projects will require examination and control that is more extensive compared to what usually is the case in relation to implementation of Parties' treaty obligations.

* These requirements must be balanced against the need to respect how countries wish to inform on their management of natural resources as well as how they pursue their national development objectives.

* Such a system might be found in a combined reporting and verification system based on mutual confidence.

* In order to achieve a credible system that is acceptable to the Parties, carefully designed reporting obligations should be developed and agreed upon by the COP.

* Apart from the reporting of the Parties participating in a JI project, an implementation control should allow for independent reassessment of reports by a designated body under the COP. This activity should be conducted as randomly chosen spot checks.

* This designated body should be a Committee on Implementation under the COP. A JI secretariat should also be established to serve as an information center on JI activity and assist the Implementation Committee and the COP in the tasks discussed in this chapter.

* The first COP should make decisions as to the establishment of these bodies. They may initiate a constructive phase I period during which pilot projects and further discussions on JI may help all Parties evaluate the possible benefits from JI and the question of how JI may best serve the objective of the FCCC.

8. CONCLUSIONS

The motivation for countries participating in JI arrangements is important for the global effect of the abatement. Our point of departure is that most countries will give first priority to what they perceive as being their own national interest and less priority to that of the global benefit. There is a need, therefore, to develop the mechanism of JI to attend to these national interests. The need for control depends, however, on each country's motivation for their climate policy. Many of the problems discussed in the report would be reduced if countries choose their climate policy on the basis of the climate situation being important for their own welfare.

It seems likely that the Climate Convention will develop through four phases in the future. The first phase is the present situation, in which no countries have legally binding commitments. In the second phase Annex II countries have legally binding commitments, whereas Annex I countries have legally binding commitments in the third phase. In the fourth phase all countries have legally binding commitments.

Different institutional settings are possible for JI projects. The least complex setting includes bilateral contracts between an investor country and a host country. Other options are a Clearinghouse institution and a Credits Bank institution.

The transaction costs involved in planning and implementing JI projects are smallest for projects in which only Annex II countries are involved and GHG emissions are abated through fossil fuel saving or changing industrial technologies. There are additional problems and higher transaction costs when non-Annex II countries are involved, or if carbon dioxide is sequestrated through forestation, or GHG emissions reduced through changing agricultural practices.

The Parties' incentives to overstate the abatement effect of a JI project in reports to the COP can be reduced through institutional arrangements such as Clearinghouse or Credits Bank. This is partly due to establishing some type of market that may reduce the importance of asymmetric information, and partly due to the resources and know-how of such institutions.

Leakages, defined as a lower GHG abatement effect from a JI project than anticipated, can be caused by market effects, strategic behavior, or political decisions. There is a potential for incentive contracts between parties to a JI project that reduce the risk of leakages based on after-the-fact control, such as a bonus to be paid to the host country if the project is successfully completed. The success in terms of national GHG abatement effect will also depend on the host country's political decisions in the implementation period. Due to the risk of leakages, JI projects should be evaluated 'project-by-project' (i.e. 'bottom-up'), if possible supplemented by macroeconomic effects based on model analysis.

Asymmetric information between parties to a JI contract can reduce the potential global cost saving from JI, since the most cost-effective projects may not be carried out first. Furthermore, asymmetric information leads to inefficient implementation of some of the chosen projects. Thus the cost per unit GHG abatement for the investor would not be minimized. Furthermore, strategic behavior of the host could lead to uncertain abatement outcome for the investor (and at the global level). The risk of such effects can be reduced through a Credits Bank institution, and shared among all investors.

Due to uncertainty related to future prices, as well as other conditions, there is an extra value associated with a flexible GHG abatement strategy, i.e. to have the opportunity to regret a measure that is taken. This may affect the ranking of different JI project categories. Thus uncertainty can favor, e.g., fuel switching JI projects, since the operating cost of these is relatively more important than the investment cost, as compared to, e.g., energy efficiency improvement projects. It may also favor general domestic measures compared with inflexible agreements with host countries. Uncertainty can be reduced through project diversification, where the main idea is to make the uncertainty of the total portfolio of JI projects as small as possible. There is also uncertainty related to the size of transaction costs and the existence of no-regrets projects. If there is some risk that the cheapest JI projects are no-regrets and do not qualify for credits based on after-the-fact control, there may be a biased selection of projects where the most cost-effective projects are left out.

Based on the present knowledge of sources and sinks as well as the knowledge of climatic impact of different greenhouse gases the following gases should be considered in JI projects: carbon dioxide, methane, nitrous oxide, perfluorocarbons, sulphur hexafluoride, and hydrofluorocarbons. Inventories of sources and sinks and documentation should be transparent and based on the IPCC Guidelines and INC recommendations.

To involve private enterprises in the financing of joint implementation projects the government must establish a transfer mechanism for credits from the government to the private enterprises. Furthermore they must meet national regulations that makes it profitable to undertake JI projects. The incentives can for example be in terms of tax credits.

In order to achieve a credible system that is acceptable to the Parties, carefully designed reporting obligations should be developed and agreed upon by the COP. Apart from the reporting of the Parties participating in a JI project, an implementation control should allow for independent assessment of reports by a designated body under the COP. This activity should be conducted as randomly chosen spot checks. The COP should therefore establish a Committee on Implementation under the COP. A JI secretariat should also be established to serve as an information center on JI activity and assist the Committee on Implementation and the COP.

REFERENCES

Baron, D. P. and D. Besanko (1987), 'Monitoring, moral hazard, asymmetric information, and risk sharing in procurement contracting', *RAND Journal of Economics*, Vol. 18 No. 4, pp. 509-32.

Barrett, S. (1993a), 'Joint Implementation for Achieving National Abatement Commitments in the Framework Convention on Climate Change', OECD, Group on Economic and Environment Policy Integration, mimeo, Paris.

Barrett, S. (1993b), 'A Strategic Analysis of "Joint Implementation" Mechanisms in the Framework convention on Climate change', paper to the United Nations Conference on Trade and Development in Geneva, London Business School and Centre for Social and Economic Research on the global Environment, London.

Barrett, S. (1994), 'Climate Policy and International Trade', *Proceedings from IPCC Working Group III Workshop*, Tsukuba 1994.

Berntsen, T., J. S. Fuglestvedt and I. S. A. Isaksen (1992), 'Chemical-dynamical modelling of the atmosphere with emphasis on the methane oxidation', *Ber. Bunsenges. Phys. Chem.* 96, 3, 241-251.

Bohm, P. (1994a), 'Making Carbon-Emissions Quota Agreements More Efficient: Joint Implementation vs Quota Tradeability', *Research Papers in Economics* No. 1, University of Stockholm, Stockholm.

Bohm, P. (1994b), 'On the Feasibility of Joint Implementation of Carbon Emissions Reductions', *Research Papers in Economics* No. 2, University of Stockholm, Stockholm.

Clinton, W. and A. Gore, Jr.(1193), *The Climate Change Action Plan* , October, Washington, D.C.

Costa Rican Office for Sustainable Development (1994), 'From Rio to Reality: First-of-Its Kind Bilateral Climate Change and Sustainable Development Accord Signed by U.S. and Costa Rica', Arlington, VA.

Department of State (1994), 'Availability of Ground rules for U.S. Initiatives on Joint Implementation', *Federal Register*, December 17 , vol. 58, no. 241, pp. 66057-66059.

Department of State (1994), 'Final Ground rules', *Federal Register*, June 1 vol. 59, no. 104, pp. 28442-28446.

Dixit, A. and R. Pindyck: *Investment under Uncertainty*, Princeton University Press, Princeton.

Eatwell, J., M. Milgate and P. Newman (eds.) (1989), *The New Palgrave - Allocation, Information, and Markets*, W. W. Norton, New York and London.

Fisher, M. J., I. M. Rao, M. A. Ayarza, C. E. Lascano, J. I. Sanz, R. J. Thomas and R. R. Vera (1994), 'Carbon storage by introduced deep-rooted grasses in the South American savannas', *Nature*, Vol. 371, pp. 236-8.

'Focus Report: Whither Joint Implementation?', *Global Environmental Change Report* 6, 18, pp.1-3.

Fuglestvedt, J. S., J. E. Jonson and I. S. A. Isaksen (1994a), 'Effects of reductions in stratospheric ozone on tropospheric chemistry through changes in photolysis rates', *Tellus*, 46B, 172-192.

Fuglestvedt, J. S., I. S. A. Isaksen and W.-C. Wang (1994b), 'Direct and indirect global warming potentials of source gases' *CICERO Report 1994:1*. Report to the Norwegian State Pollution Control Authority.

Hagem, C. (1994), 'Joint Implementation under Asymmetric Information and Strategic Behavior '. *CICERO Working Paper* 1994:12, Oslo, forthcoming.

Hanisch, T. (1991), 'Joint Implementation of Commitments to Curb Climate Change', CICERO *Policy Note* No. 2, Oslo.

Hanisch, T., R.K. Pachauri, D. Schmitt and P. Vellinga (1992), 'The Climate Convention: Criteria and Guidelines for Joint Implementation', CICERO *Policy Note* No. 2, Oslo.

Hanisch, T., R. Selrod, A. Torvanger and A. Aaheim (1993), 'Study to Develop Practical Guidelines for "Joint Implementation" under the UN Framework Convention on Climate Change', *CICERO Report* No. 2, and OECD, Group on Economic and Environment Policy Integration, mimeo, Paris.

Hart, O. and B. Holmström (1987), 'The theory of contracts', in Truman F. Bewley, (ed.), *Advances in Economic Theory - Fifth World Congress*, Cambridge University Press, Cambridge and New York.

Hauglustaine, D. A., C. Granier, G. P. Brasseur and G. Mégie (1994a), 'The importance of atmospheric chemistry in the calculation of radiative forcing of the climate system', *J. Geophys. Res.* 99, 1173-1186.

Hauglustaine, D. A., C. Granier and G. P. Brasseur (1994b), 'Impact of increased methane emissions on the atmospheric composition and related radiative forcing on the climate system'. To appear in *Environmental Monitoring Assessment.*

Håkonsen, L. and L. Mathiesen (1993), 'Implementering av rensetiltak i SNF's utslippsmodell', *Arbeidsnotat* nr. 109/93. SNF, Bergen.

IEA (1994), *World Energy Outlook*, Paris.

Intergovernmental Negotiating Committee for a Framework Convention on Climate Change, INC (1994a), 'Matters Relating to Commitments Criteria for Joint Implementation', note by the interim secretariat, for the ninth session of INC in Geneva, 7-18 February.

Intergovernmental negotiating committee for a framework convention on climate change, INC (1994b), 'Guidelines for the preparation of first communications by annex 1 parties', Decision 9/2, INC/FCCC, Ninth Session, Geneva, 7-18 February.

IPCC (1990), Climate change: The Scientific Assessment. Houghton, J. T., G. J. Jenkins, and J. J. Ephraums (eds.), Cambridge University Press, Cambridge, U.K.

IPCC (1992), Climate change: The Supplementary Report to The IPCC Scientific Assessment. Houghton, J. T., B. A. Callander, and S. K. Varney (eds.), Cambridge University Press, Cambridge, U.K.

IPCC (1994), Radiative forcing of climate change. Report to IPCC from the Scientific Assessment Group (WGI).

Isaksen, I. S. A. (1988), 'Is the Oxidizing capacity of the atmosphere changing?', in Rowland, F. S. and Isaksen, I. S. A. (eds.), *The Changing Atmosphere*, Wiley-Interscience, 141-157.

Isaksen, I. S. A. and Ø. Hov (1987), 'Calculations of trends in the tropospheric concentrations of O_3, OH, CO, CH_4 and NO_x', *Tellus* 39B, 271- 283.

Isaksen, I. S. A., Y.-P. Lee, R. Atkinson, H. Sidebottom, J. S. Fuglestvedt, C. Johnson, J. Lelieveld and A. Thompson (1992a), Chapter 5: Tropospheric processes: Observations and interpretation. In: *Scientific Assessment of Ozone Depletion: 1991*, World Meteorological Organization, Global Ozone Research and Monitoring Project, Report No. 25, 1992.

Isaksen, I. S. A., C. Brühl, M. Molina, H. Schiff, K. Shine and F. Stordal (1992b), 'An Assessment of the Role of CF_4 and C_2F_6 as Greenhouse Gases', *CICERO Policy Note 1992:6.*

'JI-Survey' (1994), *Climate Change Bulletin*, No. 4, 3rd Quarter.

Johansen, L. (1980), 'Parametric Certainty Equivalent Procedures in Decision Making Under Uncertainty', *Zeitschrift für Nationalîkonomie*, Vol. 40, pp. 257-279.

Jones, T. (1993), ’Operational Criteria for Joint Implementation’, mimeo, OECD, Paris.

Jones, T. (1994), ’"Joint implementation" as a Policy Instrument for Responding to Climate Change’, *Proceedings from IPCC Working Group III Workshop*, Tsukuba 1994.

Kreps, D. M. (1990), *A Course in Microeconomic Theory*, Harvester Wheatsheaf, New York and London.

Kuik, O., P. Peters and N. Schrijver (eds.) (1994), *Joint Implementation to Curb Climate Change - Legal and Economic Aspects*, Kluwer Academic Publishers, Dordrecht and Boston.

Laffont, J-J. and J. Tirole (1993), *A Theory of Incentives in Procurement and Regulation*, The MIT Press, Cambridge and London.

Lelieveld, J. and P. J. Crutzen (1992), ’Indirect chemical effects of methane on climate warming’, *Nature* 355, 339-342.

McDonald and Siegel (1986), ’The Value of Waiting to Invest’, *Quarterly Journal of Economics*, Vol 101.

Mintzer I. (1994), ’Institutional Options and Operational Challenges in the Management of a Joint Implementation Regime’, in K. Ramakrishna.

Oliveira-Martins, J., J.-M. Burniaux and J. P. Martins (1992),'Trade and the Effectiveness of Unilateral CO_2 Abatement Policies: Evidence from GREEN', *OECD Economic Studies,* No. 19, pp 123 - 140.

Parikh, J. K.(1994), 'Role of Markets, Governments and International Bodies in Joint Implementation with the South', in K. Ramakrishna (ed.) (1994), Ramakrishna K., *Criteria for Joint Implementation under the Framework Convention on Climate Change* , Woods Hole, Mass.: Woods Hole Research Center.

Pezzey, J. (1992), 'Analysis of Unilateral CO_2 Control in the European Community and OECD', *The Energy Journal*, Vol. 13. pp 159-171.

Rasmusen, E. (1989), *Games and Information - An Introduction to Game Theory*, Basil Blackwell, Oxford and Cambridge.

Ringius L. (1992), *Raw Waste Disposal and the Global Ocean Dumping Convention: The Politics of International Environmental Regimes*. Ph.D. Diss., the European University Institute, Florence, Italy.

Selrod, R., and A. Torvanger (1994), 'What Might be Minimum Requirements for Making the Mechanism of Joint Implementation under the Climate Convention Credible and Operational', in Prodipto Ghosh and Jyotsna Puri (eds.), *Joint Implementation of Climate Change Commitments - Opportunities and Apprehensions*, Tata Energy Research Institute, New Delhi, and *CICERO Report* No.4, Oslo.

Swierzbinski, J. E. (1994), 'Guilty until Proven Innocent - Regulation with Costly and Limited Enforcement', *Journal of Environmental Economics and Managemen*t, Vol. 27, pp.127-46.

'US Officials Discuss Details of Joint Implementation Initiative' (1994),*Energy, Economics, and Climate Change* June , vol. 4, no. 6, pp.1-5.

Vellinga, P. and R. Heintz (1993), 'Joint Implementation: A Phased Approach', mimeo, Institute for Environmental Studies, Free University, Amsterdam.

Wexler P., et. al. (1994), 'Joint Implementation: Institutional Options and Implications', College Park, MD: Center for Global Change.

Wilson, R. (1984), 'Risk Management of Public Projects' in R. Lind (ed.): *Discounting for Time in Energy Policy*, Johns Hopkins University Press for Resources for the Future. Baltimore.

World Commission on Environment and Development (1987), *Our Common Future*, Oxford University Press, Oxford and New York.

Young O. R (1989), *International Cooperation: Building Regimes for Natural Resources and the Environment* Ithaca: Cornell University Press.

Aaheim, H. A. (1994a), 'Benefits and Costs of Climate Measures Under Joint Implementation' in N. Nakicienovic, W. Nordhaus, R. Richels and F. Toth: *Integrative Assessment of Mitigation. Impacts, and Adaptation to Climate Change,* IIASA, Laxenburg.

Aaheim, H. A. (1994b), 'Evaluation of Uncertain Projects Under Joint Implementation', *CICERO Working Paper* 1994:11. Oslo.

ANNEX 1

LISTING OF ANNEX I AND ANNEX II COUNTRIES IN THE CLIMATE CONVENTION

Annex I
Australia
Austria
Belarus[a)]
Belgium
Bulgaria[a)]
Canada
Czechoslovakia[a)]
Denmark
European Economic Community
Estonia[a)]
Finland
France
Germany
Greece
Hungary[a)]
Iceland
Ireland
Italy
Japan
Latvia[a)]
Lithuania[a)]
Luxembourg
Netherlands
New Zealand
Norway
Poland[a)]
Portugal
Romania[a)]
Russian Federation[a)]
Spain
Sweden
Switzerland
Turkey
Ukraine[a)]
United Kingdom of Great Britain and Northern Ireland
United States of America

a) Countries that are undergoing the process of transition to a market economy.

Annex II
Australia
Austria
Belgium
Canada
Denmark
European Economic Community
Finland
France
Germany
Greece
Iceland
Ireland
Italy
Japan
Luxembourg
Netherlands
New Zealand
Norway
Portugal
Spain
Sweden
Switzerland
Turkey
United Kingdom of Great Britain and Northern Ireland
United States of America