SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY

Intermediary report - January 2003

CLIMATE CHANGE, INTERNATIONAL NEGOTIATIONS
CLIMNEG II
CP-24

KUL - UCL

SPSD II

PART 1

SUSTAINABLE PRODUCTION AND CONSUMPTION PATTERNS

GENERAL ISSUES

AGRO-FOOD

ENERGY

TRANSPORT

This research project is realised within the framework of the Scientific support plan for a sustainable development policy (SPSD II)

Part I "Sustainable production and consumption patterns"

The appendixes to this report are available at :
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Rue de la Science 8 - Wetenschapsstraat
B-1000 Brussels
Belgium
Tel : 32/2/238.34.11 – Fax 32/2/230.59.12
http://www.belspo.be (FEDRA)

Contact person :
Mrs Aurore Delis (deli@belspo.be)
Tel : 02/238.37.61

1. Administrative Data

Contract number:	
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Project title:	
Climate change, international negotiations CLIMNEG 2	
Coordinator CLIMNEG 2 network:	
Name:	Prof. dr. Stef Proost
Address:	Katholieke Universiteit Leuven Centrum voor Economische Studiën Research group Energy, Transport and Environment Naamsestraat 69 B - 3000 Leuven Belgium
Telephone	+ 32 16 32.68.01
Fax	+ 32 16 32.69.10
E-mail	stef.proost@econ.kuleuven.ac.be

2. Introduction

2.0. Preamble

During the first year of the CLIMNEG 2 project, an important change has occurred in the composition of the research network. In September 2002, Jutta Roosen (UcL-ECRU) has left the Université catholique de Louvain to take up a position at the university of Kiel in Germany.

Given that there was no other specialist in the field of agricultural economics in the UcL-ECRU department to take over the part of the CLIMNEG 2 project, we had to look, in close consultation with OSTC officials (in particular Mrs. Anne Fierens), for another solution. This solution consists in a substantial modification of the research plan and the association of a new partner, Université catholique de Louvain, Center for Operations Research and Econometrics (UcL-CORE). The promotor of this new part of CLIMNEG 2 is Prof. Thierry Bréchet (UcL-CORE, Chaire Lhoist Berghmans).

In the original CLIMNEG 2 research plan the UcL-ECRU team was responsible for two major tasks. The first task (*3-B-2a: Construction non-CO_2 emission data and emission abatement cost functions for the agricultural sector internationally and in Belgium*) bears on the collection of data which is of crucial importance to other CLIMNEG 2 teams, in particular the K.U.Leuven-CES team who has to incorporate this information in the simulation models. The second task (*2-D The incentive structure of emission reduction policies)* consists of a more theoretical analysis of non-point source pollution problems in the context of climate change.

Concerning Task 3-B-2a (data collection) it should be mentioned that the UcL-ECRU team has made a big effort to deliver, earlier than required by the CLIMNEG 2 research planning, a set of useful data on non-CO_2 GHG emissions and emission abatement costs. However, this data set is not 100% complete (in particular the regional differentiation of non-CO_2 GHG emission abatement cost functions) and cannot be used as such in the CLIMNEG simulation models. It was agreed that K.U.Leuven-CES will take over this task since they are also the main users of this information in the rest of the CLIMNEG 2 research network. Because of legal reasons, this task will be performed by KULeuven-CES in a subcontracting format for UcL-CORE (T. Bréchet).

Concerning *Task 2-D Incentive structure emission reduction policies*, all remaining CLIMNEG 2 partners and the OSTC officials have agreed to re-orientate the available resources towards extensions of some existing tasks and to the development of a completely new task. In particular, an important new *Task 1-C: Environmental Taxation, Public Finance And Intergenerational Distribution* has been created aiming at developing an overlapping generations version of the existing CLIMNEG World Simulation model. This model will be used to analyse issues of intergenerational equity and efficiency in the context of climate change and will contribute to a better and more profound analysis of the intergenerational equity questions in the original task 1-A of the CLIMNEG 2 research plan.

In addition, new tasks *2-A-3 Including non-CO_2 GHG emissions from agriculture in MacGEM model* and *2-A-4 Analysis of the participation of USA and non-Annex B countries* have been added to the CLIMNEG 2 research agenda. These tasks aim at extending the existing MacGEM simulation model with non-CO_2 GHG emissions and abatement cost functions and using the intertemporal MacBank model for analysing the prospects of participation of the USA and non-Annex B countries in future commitment periods of the UNFCCC. These new tasks will make the MacGEM simulation model more realistic by adding a more sophisticated intertemporal emission trading mechanism. This will allow for studying the formation of subsequent climate coalitions in a dynamic setting.

A detailed description and time table of these new tasks can be found in the new technical annexes to the CLIMNEG 2 contract.

2.1. Context and summary of CLIMNEG 2 project

The CLIMNEG 2 research project is devoted to the analysis of international and Belgian climate change policy questions in the post-Kyoto era. The research project is an exercise in integrated assessment analysis, i.e. it looks at the problem of climate change from a broad perspective in order to fully appreciate the numerous and complex interactions between the many economic actors (consumers, producers, national governments, supranational organisations) and the complex physical environment they are operating in. This broad perspective is reflected in the extensive geographical coverage (international, European and Belgian perspective), the extensive time horizons considered (several centuries for integrated assessment modelling, several decades for analysis of EU and Belgian climate change policies for the first commitment period 2008-2012 of the Kyoto Protocol), and the variety of policy questions it considers (integrated assessment of both climate change and acidification for the emissions of sulphate aerosols, the interaction of policy instruments like carbon taxes and emission permit trading and so forth).

The CLIMNEG 2 project is organised around three major research themes. In the first major research theme of the proposal, *criteria for sustainable development*, we want to operationalize the concept of sustainable development in the context of climate change. The analysis will identify minimal requirements a sustainable economic development should satisfy. These conditions will be derived from a theoretical welfare economic analysis of the trade off between the fundamental concepts of (1) economic efficiency, (2) environmental sustainability, (3) intragenerational and intergenerational equity, and (4) implementation and strategic stability of post-Kyoto climate agreements.

The second major research theme will focus on *climate policy instruments* and in particular on the combination of tax instruments and emission trading, the microstructure, initial allocation and trading rules of GHG emission permit markets. For the purpose of this research theme, a portable simulation tool will be developed for analysis of GHG emission trading under different institutional regimes (number of participants, trading ceilings, banking, market power etc.).

Thirdly, the CLIMNEG 2 project contains an important *integrated assessment modelling* effort. The project will refine and update several models that are currently available in the network (the integrated assessment model CLIMNEG World Simulation CWS model, the general equilibrium model GEM-WORLD, the Belgian MARKAL energy system model). The project will create “soft links” between the models in order to achieve consistency between the different levels of analysis. For the integrated assessment aspect of the project, an important interdisciplinary contribution from climatology is called upon in order to refine the carbon cycle and regional temperature change module of the existing CWS model by allowing for a multi-gas approach and by adding a sea-level module. The climate team will also contribute to the identification of criteria for sustainable will analyse the Brazilian proposal concerning industrialised countries’ historic responsibility.

2.2. Objectives

The aim of the CLIMNEG 2 project is to characterise theoretically and to simulate numerically the economic and climate change consequences of different GHG emission reduction policies on the global, European and Belgian level. This characterisation and simulation exercise requires a coupling of a long term economic model with a simplified but reliable representation of the climate system. The purpose of this multidisciplinary research is to build a consistent interaction between the economic variables and climate change consequences. Emission trajectories are translated into regional temperature change which feed back into the economic model through climate change damage functions. These damages affect negatively production and consumption possibilities in the long term. The results of this long term analysis will be used as input for recommendations for short term climate change policies. The results and conclusions of this multidisciplinary research can serve as input and background information for the Belgian team participating in international climate negotiations.

2.3. Expected outcomes

Numerical simulation models are the main ingredients of the CLIMNEG 2 project. These models provide flexible tools that can be used to analyse many different policy questions. The models used in the CLIMNEG 2 project are the following.

1. **CLIMNEG World Simulation CWS model**. The CLIMNEG 2 research project will update and extend the existing integrated assessment CWS model in the following way: increasing the number of regions from 6 to 18, constructing new BAU scenarios, abatement cost and climate change damage estimates and so forth. CWS model is particularly suited for analysing long term (several centuries) climate change policy issues like post-Kyoto burden sharing, GHG concentration stabilisation policies and game theoretic stability analysis of international climate agreements.
2. **GEM-E3-WORLD** is a computable general equilibrium model of the world economy. It describes in much more detail than CWS the economic production process (18 sectors) and trade flows between 18 world regions. However, it is not coupled to a carbon cycle/temperature model and it considers a time horizon of only a few decades. The CLIMNEG 2 project will extend the GEM-E3-WORLD model with non-CO_2 GHG emissions originating from agricultural production.

3. **Mac-GEM and MacBank**. The CLIMNEG 2 project will develop a new, simple and portable simulation tool for GHG emission trading markets and flexible mechanisms. It is based upon GHG marginal abatement cost functions that are estimated on simulations results by GEM-E3-WORLD.

4. **MARKAL** is a partial equilibrium model of the energy system for Belgium. It is able to identify cost efficient GHG reduction policies in Belgium for a time horizon of a few decades. The CLIMNEG 2 project foresees adding an agricultural non-CO_2 GHG emissions module to MARKAL.

5. Finally, the possibility of **coupling** of **medium-sized climate model** (MoBidiC, Gallée et al., 1991, Crucifix et al., 2000 and 2001) and an applied general equilibrium **model of the world economy**, for example GEM-E3-WORLD, will be investigated. This effort will build on UcL-ASTR experience of coupling very different models with coupler interfaces.

3. Detailed description of scientific methodology

THEME 1: CRITERIA FOR SUSTAINABLE DEVELOPMENT

1-A. Intergenerational Equity And Climate Change

Philosophical arguments w.r.t. responsibility for historical emissions

The argumentation is based on a survey text on intergenerational justice in which the moral relationship between current and future generations is central. In addition, the issue of to what extent future generations can claim current generations' resources is addressed. This text is based on the work of Lukas Meyer (Intergenerational Justice, contribution to be published in the Stanford Encyclopaedia of Philosophy. This author will be the central speaker on a workshop in 2003), Axel Gosseries (2002, Historical Emissions and Free-riding, CLIMNEG Working Paper 52) concept of "intergenerational free riders" and Schokkaert and Eyckmans (1999), Greenhouse negotiations and the mirage of partial justice, in: Dore, M.H.I., and Mount, T.D. (eds.) Global environmental economics: equity and the limits to markets (Blackwell Publishers, Malden (Mass.) USA and Oxford UK), 193-217

1-B. Sustainable Forms Of Cooperation In International Environmental Agreements

An effective solution for the problem of global climate change requires an international agreement with four characteristics: efficiency, equity, ecological sustainability and voluntary participation constraints. We focus in this task on two issues. First we try to incorporate most recent advances in game theory (in particular the theory on *endogenous coalition formation*) to model voluntary participation constraints. Secondly, we develop a framework to study the trade off between these four dimensions in an integrated way. We will do this using a standard *welfare economics framework* and focusing on one particular instrument: internationally tradable emission permits. More details on the methodology (and references to the literature) for this task can be found in section 4 of this report.

1-C. Overlapping generations modelling

The research in CORE has started to study a new framework for the analysis of the interaction between economy and climate change: the overlapping generations framework. Both for the issues of international cooperation in climate policy and intergenerational equity, it is relevant to take into account finite lives and to distinguish the chain of generations instead of relying on the infinitely lived agents.

In integrated assessment models, pollution results from production and consumption activities. Models differ in the assumptions made on human demographics and institutional forces. A common device is the infinitely lived agent whose life spans from the present to the indefinite future. This fiction is widely used for its simplicity and its mathematical tractability. What is studied within this framework is generally optimal resource allocation, i.e. decision like "How much do I consume now? Should I eat all the cake now and starve tomorrow? Or rather postpone consumption to the future and refrain from consuming now?"

This is an efficiency problem rather than an intergenerational equity problem. This is no surprise since infinitely lived agent (ILA) models are actually single generation models. Extending this framework to a multiple overlapping generations (OLG) one is the task we started to tackle.

The OLG structure has a number of consequences. First, the size of the "cake" (i.e. the product to be consumed) at any given date depends on decisions made by previous generations at a time where present generations were still to be born. Since pollution is a by-product of these decisions, it also comes from decisions on which present generations have no responsibility but which will affect their welfare. In this sense, the size of the "cake" and the level of pollution are inherited. Second, a given generation can only trade with co-existing generations. In such a framework, one is able to disentangle efficiency and equity issues.

Within this framework, we study two issues : international cooperation in climate policy and intergenerational equity related to climate change. What is the value added with respect to the previous programs (CLIMNEG 1 and Climbel)? We now actually face a three-externality setting: (a) an environmental externality, (b) an international externality and, specifically of CLIMNEG 2, (c) an intergenerational externality.

THEME 2: CLIMATE POLICY INSTRUMENTS

2-A. Functioning of GHG emission permit markets

MacGem and MacBank (Task 2.A.1)

The MacGEM model is used here in order to quantify the repercussions of the US withdrawal from the Kyoto Protocol and of the Bonn and Marrakesh agreements. MacGEM consists of a set of marginal abatement cost functions for carbon emissions originating from fossil fuel use. The model aims at evaluating compliance costs and permit trading equilibria for the first commitment period of the UN Framework Convention on Climate Change UNFCCC. The approach is similar to Ellerman and Decaux (1998) and Criqui et al. (1999). Emission trading equilibria are computed by seeking a price for which total market excess permit supply is zero. Excess supply of every of the 15 world regions/countries in the model depends upon its marginal abatement cost function and assigned amount of emissions. The marginal abatement cost functions are estimated on data generated with the GEM-E3-World general equilibrium model (for detailed descriptions of GEM-E3-World, see Capros et al. (1997 and 1999). MacGEM also allows for the introduction of trading restrictions like for instance a Commitment Period Reserve (CPR, see further), transaction costs and limited accessibility of the Kyoto flexible mechanisms like Joint Implementation (JI) and Clean Development Mechanism.

However, the MacGEM model does not explicitly take into account the possibility to bank emission permits from one commitment period to the other. This important limitation must be addressed in conjunction with the issues of future commitments and participation of USA and non-Annex B countries. The purpose here is to explore these questions by setting up a simple dynamic partial equilibrium model based on a set of marginal abatement cost curves for CO_2 fossil fuel energy, called MacBank. The simplicity of the model is motivated by the requirement of flexible participation structures and by the willingness to model all the main characteristics of the permits market like, for instance, the use the Clean Development Mechanism, possible restrictions on permits' trades and inclusion of carbon sinks. One can also use the permits allocation rules the most often referred to in the literature. The robustness of our results is tested by sensitivity analyses.

2-B. Initial allocation of GHG emission quota and trading rules

Equitable and coalitionally acceptable allocations of GHG emission quotas

The purpose is to analyze the welfare implications of different rules to allocate tradable CO_2 emissions quotas among the regions of the world by using a long term dynamic (closed loop) model. The total amount of quotas to be distributed at a each period of time corresponds to the world optimal amount of emissions to be realized during that period. Since coalitional rationality is a necessary condition for the stability of an agreement, we develop a method consisting in finding an allocation of quotas which guarantees coalitional rationality for every country along the entire time path and which is as close as possible to any given equitable allocation rule. Hence, the priority is given to satisfying participation constraints and the degree of freedom that is left is devoted to satisfying equity in the allocation of the quotas. The members of any coalition of countries for which an equitable allocation-based rule is not acceptable, receive more quotas in order to compensate the coalition so as to make it indifferent between signing and not signing the global agreement. The countries belonging to unconstrained coalitions receive then fewer quotas than the others. However, the equitable rule is preserved among them.

THEME 3: INTEGRATED ASSESSMENT MODELLING

3-A. Climate Modelling

Regarding task 3A-1, we proposed to extend the CLIMNEG 1 CWS model by adding multiple gases and aerosols, updating the regional temperature predictions, and adding a sea-level rise module. The interactive Java Climate Model (JCM) developed by Dr Ben Matthews which is being adapted for use in CLIMNEG 2 already contains all of these elements, implementing the latest models from IPCC-TAR. JCM is based on an efficient java implementation of the same simple models and formulae which were used for the core predictions of IPCC-TAR. Using the IPCC-TAR models strengthens credibility and comparability with other projects. Moreover using the existing sets of well-known model parameters, already tuned to a set of more complex models, will help us to investigate uncertainties within new integrated assessment applications for CLIMNEG 2.

JCM also has an interactive graphical interface enabling anybody to explore many mitigation policy options and scientific uncertainties simply by adjusting parameter controls with a mouse in a web browser. The code was designed to work very efficiently, in order to show an instant response to adjustment of any parameter, thereby demonstrating cause-effect relationships, and the sensitivity to various assumptions, risk and value judgements. Therefore, although the scientific calculations are much more complex than those of the

CLIMNEG 1 CWS model, they are sufficiently fast that time should not be an issue for integrated assessment applications, even when looping thousands of times to solve an optimisation problem. We should also remember that the ultimate "integrated assessment model" will remain the global network of human heads, and so the interface of JCM may eventually help to provide a quantitative framework for the global dialogue and to communicate the conclusions of CLIMNEG 2 back from computer code to people.

JCM can be found online at www.chooseclimate.org/jcm

3-B. Economic Modelling

The CLIMNEG World Simulation (CWS) model was developed under the first CLIMNEG contract, see Eyckmans and Tulkens (1999). It is a long term, dynamic multiregion optimal growth model that includes an endogenous climate change externality. It is based upon the seminal RICE model by Nordhaus and Yang (1996).

4. Detailed description of the preliminary results, preliminary conclusions and recommendations

THEME 1: CRITERIA FOR SUSTAINABLE DEVELOPMENT

1-A. Intergenerational Equity And Climate Change

Philosophical arguments w.r.t. responsibility for historical emissions
During the year 2002, this research part has faced some delay due to the limited availability of researcher Luc Van Liedekerke (K.U.Leuven-CES-ETE). A schedule has been drawn up in order to eliminate the backlog during the year 2003. The schedule is listed in Section 5 of this report.

Overlapping generations modelling
The first step has been to make a literature review. Models in the literature can be classified according to the following criteria:

(a) Pollution results from production: from a polluting input: **PI**

(b) Pollution is a joint product of total output: **PJ**

(c) Pollution results from consumption: **PC**

(d) Consumers are not affected by pollution: **A0**

(e) Consumers are negatively affected by pollution: **A(-)**

(f) Consumers are positively affected by environmental amenities: **A(+)**

(g) Selfish OLG agents: **S-OLG**

(h) Altruistic OLG agents: **A-OLG**

(i) Infinitely-lived agents: **ILA**

A list of references, sorted according to the categories above can be found in appendix to this report.

1-B. Sustainable Forms Of Cooperation In International Environmental Agreements

Endogenous coalition formation
The research on endogenous coalition formation in international environmental agreements has focused on recent coalition formation equilibrium concepts (see among others Ray and Vohra (1997) and Chwe (1994). An algorithm has been developed to calculate farsighted stable coalition structures, see Eyckmans (1999, revised 2003). An important part of this work is done in close collaboration with Michael Finus (Fernuniversität Hagen, Germany) en Laszlo Koczy (K.U.Leuven-CES, Mathematical Economics and Econometrics).

Framework to trade off equity, efficiency and participation constraints

Within the scope of the master paper of Greta Coenen (KULeuven-CES-ETE), a theoretical model has been set up to study the trade off between equity and efficiency for a specific policy instrument, i.e. tradable emission permits, as foreseen in the Kyoto Protocol. The international tradability of greenhouse gases ensures that the marginal cost of emission reduction of the last ton of greenhouse gases is equalized across all countries such that the final allocation of emission reduction efforts is cost efficient. In addition, the initial allocation of rights can be used to pursue equity considerations without reducing the efficiency of the allocation. When no constraints are imposed on the initial allocation of emission rights (i.e. when negative permit endowments and hot air are allowed) the first best solution can be implemented. If on the other hand "hot air" or negative permit endowments are politically infeasible, it can occur that the first best allocation will not be achieved

THEME 2: CLIMATE POLICY INSTRUMENTS

2-A. Functioning of GHG emission permit markets

MacGem and MacBank

The analysis carried out using the **MacGEM** model has led to the following results (see Eyckmans, Van Regemorter and van Steenberghe, 2001):

- While in the absence of an agreement on CO_2 emission reductions, world carbon emissions would increase by about 30.1% compared to 1990, the 'original' 1997 Kyoto Protocol would have limited this increase to 15.5%. However, non participation by the USA causes world emissions to increase by 25.5% in 2010. The equilibrium carbon permit price and Annex-B* (EU15, OEU, AUZ, JAP and CAN) total costs fall by 50%.
- The introduction of activities enhancing carbon sinks leads to a further decrease of carbon emission abatement efforts. Given the non-participation of the US, our results show that accounting for carbon sinks enhancement activities will lead to a further decrease of Annex-B* total costs by more than 45% (55% and 60% for CAN and AUZ respectively).
- Another element of the Bonn and Marrakesh agreements, the commitment period reserve (CPR), plays in an opposite direction. On the one hand, our analysis suggests that the CPR has been well designed in the sense that it limits as much as possible the risk of overselling while not imposing further costs to CEU. On the other hand, it also emphasises the central role played by CEU, particularly when the accessibility to emission reductions in non-Annex B countries via CDM projects is low.

From the **MacBank** model, six important results emerge (see van Steenberghe, 2002):

1. In 2008-2012, permits prices are likely to be much higher than predicted by most recent studies and the amount of banked permits might largely exceed the amount of hot air.

2. The banking provision significantly reduces world total costs but increases total costs of all Annex B countries except countries of eastern Europe, via a rise in the permits price in the first two periods.
3. The issue of market power on hot air is not a relevant one, at least according to our base case scenarios. The reason is that the banking provision enlarges the market by making it intertemporal and therefore prevents countries of eastern Europe to act as dominant players.
4. Total costs are not huge and the permits allocation rule strongly influences the distribution of the costs among countries and may lead some of them to enjoy considerable net gains.
5. The participation structure affects the evolution of banking.
6. Most parameters, especially reference emissions, have a crucial impact on the level of the permits price and the abatement costs.

2-B. Initial allocation of GHG emission quota and trading rules

In the context of the discussions taking place on post-Kyoto commitments, two results of this analysis deserve particular attention. Firstly, equitable allocation rules need to be very much modified for the agreement to be coalitionally rational. For instance, constraining the Egalitarian rule (same amount of quotas per capita) by coalitional rationality leads the USA to receive about 3 times the amount of quotas it would get under the unconstrained egalitarian rule. Such a departure from the Egalitarian rule is necessary in order to provide the USA - and the coalitions to which USA could belong to - incentives to join the global agreement. Under the coalitionally constrained Grandfathering rule (quotas are allocated in proportion to emissions in 1990), the picture changes. Developing countries must be compensated and receive more quotas than under the unconstrained rule, while USA receives only half of the quotas it would get under this unconstrained rule. More detailed description of these results can be found in Germain and van Steenberghe (2001).

Secondly, taking coalitional rationality constraints into account does not mean that there is no more room for satisfying equity principles. Indeed, once they are constrained by coalitional rationality, the allocation rules based on various principles of equity still lead to quite different amount quotas in each country. For instance, USA, JPN and CHI receive respectively 20% more, 45% more and 12% fewer quotas under the constrained Grandfathering rule than under the constrained Egalitarian one in 2090-2100.

THEME 3: INTEGRATED ASSESSMENT MODELLING

3-A. Climate Modelling

Developing the climate model

Global average temperature predictions may be scaled using climate change maps from complex Global Climate Models (GCMs), to generate patterns of regional climate changes. Recently (November-December 2002) the regional climate map of JCM was substantially developed to incorporate the latest GCM datasets provided by the IPCC data-distribution centre (DDC), based on the SRES scenarios. Up to nine climatic variables (temperature, precipitation, cloudiness etc.) are available per dataset, and the predicted changes may be added to the 1961-1990 baseline climatology, for each of twelve months.

However climate change impacts depend on socioeconomic factors ("vulnerability") as well as physical climatic changes. GCMs work with gridcells (typically a few degrees square) whilst socioeconomic data/predictions are usually made for countries or administrative regions. Moreover we need aggregated regional impacts for integrated assessment applications. Therefore polygons defining country boundaries (including subregions of large countries) were added to JCM , and a routine was developed to calculate the average of any climatic variable for any polygon. This flexible approach will use the same region codes as the new socioeconomic datasets currently being incorporated within the economic models of CLIMNEG 2, anticipating eventual integration.

Another problem is that the greatest impacts are caused by extreme climatic events. Therefore it is important to consider, for each region, changes in climate variability and periodic cycles (e.g. El Niño, NAO) as well as the trends in the long-term average climate. This requires very large GCM datasets, therefore the essence of this variability would have to be captured in some simpler way for application in integrated assessment applications. We are beginning to contemplate various methods for doing this.

During January 2002, a flexible interactive plot was developed for JCM to aid exploration of this regional data, and the range of options for the regional distribution of CO_2 emissions under mitigation/stabilisation scenarios (see below) was extended. The old regional abatement cost and damage cost functions of CLIMNEG 1 were also added to JCM (the "costs plot" shows the effects, for any scenario combination). These must be replaced by more sophisticated functions of the regional climate impacts (see above).

The CWS socioeconomic model of CLIMNEG is written in GAMS, a language for efficient solution of optimisation problems defined by relatively few equations. The more complex models, large datasets and feedbacks of the climate science calculations of JCM could not simply be rewritten in GAMS.

There are therefore three possible approaches to future integration, all of which remain open at present:

(a) Create a GAMS-Java interface for directly coupling the models. Java can connect easily with any other system (even across the web), however it is not clear whether GAMS is able to pipe data to and from an external module within its optimisation loop.

(b) Implement the optimisation routines and economic models within JCM. The core loops and scripting code of JCM are being restructured to make a framework for batch calculations, which will soon be tested using a simple optimisation algorithm developed for this purpose by KULeuven-CES-Leuven. Implementing the economic models in JCM would also make the whole system explorable by anybody via the interactive graphical interface. However, java code might not be so convenient for the initial development of these models.

(c) Use JCM to derive simpler approximations of emissions-concentrations-climate relationships (as in CWS), for incorporation into the GAMS code. However we would have to derive and translate new parameterisations for each change in the climate models, making it difficult to investigate the effect of uncertainties (very important as climate change is essentially a "risk" problem).

Stabilisation scenarios

Work has also begun on task 3A-2, to investigate pathways leading to stabilisation of greenhouse gas concentrations or climate impacts. JCM already includes a module which generates scenarios to stabilise either CO_2 concentration or global temperature at any level and in any year (easily adjustable by the user). A target curve is defined by a simple mathematical formula, based on the original scenarios of IPCC 1994 (of which the WRE scenarios are a variant with steeper initial growth, also an option in JCM). An iterative method is then applied to find the emissions required to attain this target in each year. There are also several options to define the relationship between emissions of CO_2 and those of the other gases.

Experimenting with these scenarios, in combination with the range of climate model parameters (or sets of parameters tuned to GCMs), it becomes clear that, inter alia:

- Choosing a target to stabilise temperature rather than CO_2 concentration (at equivalent levels) would shift the burden of risk caused by large uncertainty in the climate models away from those who will suffer from climate impacts, and towards those who plan emissions reductions.
- To stabilise the global temperature at 2°C (above preindustrial level) -the original maximum proposed by EU - requires CO_2 concentrations between 450 and 500 ppm. The 550 ppm figure often quoted by policymakers is only credible for CO_2 equivalents, including the other greenhouse gases.

The options to stabilise temperature, and to stabilise including all the gases, are new in JCM. It is anticipated to write a paper describing these methods (and some further variants to be developed) and observations, and encouraging the definition of up-to-date multi-gas stabilisation scenarios by IPCC.

JCM was also used by a course of 50 students in UCL in a role-play game to negotiate a quantitative interpretation of UNFCCC Article 2. This process helped us as scientists to anticipate the types of issues that might arise during real negotiations on this topic, for example: coping with uncertainty in models and scenarios, confusion regarding the meaning of "CO_2 equivalent", preferences for indicators for the target.

Brazilian Proposal ("contributions to climate change")

The Brazilian Proposal concerns the attribution of responsibility for contributions to climate change. This summer the UNFCCC-SBSTA initiated a model intercomparison exercise to consolidate and compare research on scientific and methodological aspects of this topic, followed by a workshop in September. JCM was adapted to take part in this exercise (stage 1 of this work was done in Bern, stage 2 in Louvain-la-Neuve), and Ben Matthews attended the workshop as a Belgian delegate. The results are available on the website: http://www.cru.uea.ac.uk/unfccc_assessment and a report was also sent to OSTC.

Work on this topic was not specified in the CLIMNEG 2 workplan. However the scope of this UNFCCC process has become considerably broader than the original Brazilian proposal, as shown by its title “Contributions to Climate Change”. Moreover this is the only official intercomparison of relatively simple climate models, and its recommendations help to define the state of the art specification for future development of such models in a policy-relevant context. Participation thus helps to boost the scientific credibility of JCM and future work with CLIMNEG 2.

These calculations also raise questions of intergenerational and interregional equity (relating to CLIMNEG 2 task 1A), particularly regarding attribution of non-linear/mixed-cause effects. These issues were discussed informally within CLIMNEG 2 group.

This work also combined several sources of historical data, each using a different set of world regions, which highlighted the importance of developing a flexible approach to region definition in future model development.

3-B. Economic Modelling

During 2002, the update of the CWS model has been initiated:

- A new base set of 16 world regions has been made and the necessary data have been collected (CO_2 emission data and socio-economic basic data from the World Development Indicators from the Worldbank).
- The programming of the CWS model has been adapted in order to work with a completely flexible geographical aggregation. In addition, the used time interval (10 years in the old version of CWS) is now fully flexible.
- A new calibration routine has been developed, that allows the CWS to reproduce any SRES scenario (see IPCC, 2000) as a business as usual scenario. At the same time, the calculation speed has been optimized through a better choice of initial values for endogenous variables of the CWS model.
- The first tests have been carried out in order to check the reference scenarios. Alternative scenarios (Nash, Pareto efficiency and coalitional equilibria) will be tested in 2003.
- The inclusion of non-CO_2 greenhouse gases has faced a considerable delay, see below.

Due to the leaving of Prof. Dr. Jutta Roosen (UcL-ECRU) during the summer of 2002, this part of the project has faced a considerable delay. The data collected by the UcL-ECRU team are not sufficient in order to be able to complete task 3-B-2. Therefore, the CLIMNEG 2 research contract has been adapted such that K.U.Leuven-CES can take over this task (working on a subcontract for UcL-CORE) and will collect emission data and marginal emission reduction cost curves for non-CO_2 greenhouse gases during 2003.

5. Future prospects and future planning

THEME 1: CRITERIA FOR SUSTAINABLE DEVELOPMENT

1-A. Intergenerational Equity And Climate Change

Philosophical arguments w.r.t. responsibility for historical emissions

Research schedule for 2003 and beyond:

- Trying to interpret the Shapley value in an intertemporal context (i.e. players have to contribute towards the costs in proportion to their "marginal" contribution to the problem; each player pays a part of the future damage they cause and transfers this into a "climate fund" intended to relieve damages from climate change for future generations).
- An application of the working paper by Ambec and Sprumont (2000), "Sharing a river" (Université de Montreal) to the climate problem.
- Simulations with the CLIMNEG World Simulation model to estimate the magnitude of transfers/climate fund.

Planned initiatives for 2003:
On Wednesday May 28, there will be a research day on the issue of historical responsibility in cooperation with the Centre for Economics and Ethics. The provisional speakers are Lukas Meyer (University Bremen), Axel Gosseries (Louvain-La-Neuve), Luc Van Liedekerke (K.U.Leuven) en Alexia Leseur (Ecole Polytechnique, Paris). The purpose is to get a better insight in the moral arguments that can play a role in the problem of historical responsibility for global warming. Furthermore, the texts of this conference will be collected in a special issue of *Ethical Perspectives*.

Global warming will be the theme of the general meeting on February 6 of the Deliberation Centre for Christian Ethics of the K.U.Leuven (in which mainly academics of the KUL take seat). The speakers will be Jean-Pascal van Ypersele and Johan Eyckmans. The idea is to gather people from the K.U.Leuven that work on this issue, in order to initiate a moral debate on this topic. Luc Van Liedekerke will be responsible for the organisation of this meeting.

1-B. Sustainable Forms Of Cooperation In International Environmental Agreements

Endogenous coalition formation
Several new papers will be written on this subject, some of which are already available in a first draft. An important initiative in the area of international environmental agreements and coalition formation is that we plan a CLIMNEG Workshop on International Environmental Agreements on March 14, 2003. Several leading scholars (for instance Charles Kolstad, University of California at Santa Barbara, Michael Finus, Fernuniversität Hagen, Santiago Rubio, University of Valencia and Ekko van Ierland, University of Wageningen) in this area have been invited for a one-day intensive academic workshop in order to detect most recent

developments in this field. The preliminary program is already available on the website http://www.climneg.be (Agenda).

Framework to trade off equity, efficiency and participation constraints
Currently, the theoretical model has been formulated and the broad outlines of the theoretical results are finished. During the next months, a simple (static) simulation model will be developed to test these results and to illustrate them for the problem of global climate change. This will result in research papers during the spring of 2003.

1-C. Overlapping generations modelling

As far as international cooperation in climate policy is concerned, the OLG model we want to develop has to in line with the CWS (Climneg World Simulation) model elaborated in previous programs. This implies that our OLG model must include additive abatement and damage costs functions. Moreover, production and consumption must be kept as simple as possible because the focus of the model is interaction between countries within or ouside coalition using game theory and simulations. As a result, pollution, i.e. CO2 emissions will be modeled as a joint product of the output and the consumers preferences will not depend on the stock of greenhouse gases.

Since no results have been obtained at this preliminary stage, one can only formulate conjectures. We expect to find less room for cooperation in this model than in the ILA model because of the intergenerational externality dimension.

As far as intergenerational equity, we prefer to let preferences depend on the stock of pollutant and model individual choice as a trade off between bequeathing physical capital or bequeathing a clean environment to the young generations. The latter, also called environmental maintenance, is assumed to be managed by the government in order to avoid the classical free-riding problem of contributing individually to a public good. We are interested in studying concepts of equal treatment between generations.

THEME 2: CLIMATE POLICY INSTRUMENTS

2-B. Initial allocation of GHG emission quota and trading rules
The MacBank model will be further developed in order to include non-CO_2 gases. We expect the abatement to fall significantly from those observed under the single pollutant. Moreover, it will be of interest to look if the amount of permits banked from one period to the other (see results above) is sensitive to the inclusion of the non-CO_2 gases.

THEME 3: INTEGRATED ASSESSMENT MODELLING

3-A. Climate Modelling
JCM does not yet include any socioeconomic model, which will be a focus of future development. JCM does already include data from RIVM Image model for emissions, population, GDP, and energy use, for the six IPCC-SRES scenarios and 12 regions. The options described above (section 4, theme 3-A) for the potential integration of CWS and JCM will be further explored, and a paper will be written about the stabilisation issue.

3-B. Economic Modelling

- For the updated version of the CLMNEG World Simulation model, alternative scenarios (Nash, Pareto efficiency and coalitional equilibria) will be tested in 2003.
- The inclusion of non-CO_2 greenhouse gases and emission abatement cost functions will be carried out.

APPENDIX 1: References

Detailed References for Task 1-A: Intergenerational Equity and Climate Change

PI_A0_S-OLG papers

Howarth, R.B. and R.B. Norgaard, (1992). "Environmental valuation under sustainable development", *American Economic Review* **82** (2) (Papers and proceeding), p.473-477.

Howarth, R.B. and R.B. Norgaard, (1995). "Intergenerational choices under global environmental change", in D.W. Bromley (ed.), *Handbook of environmental economics*.

Howarth, R.B. (1996). "Climate change and overlapping generations"", *Contemporary Economic Policy* **14** (4), 100-111.

Howarth, R.B. (1998). "An overlapping generations model of climate-economy interaction", *Scandinavian Journal Of Economics* **100** (3), 575-591. (with simulations)

PI_A0_S-OLG/ILA papers

Stephan G., G. Müller-Fürstenberger and P. Previdoli, (1997). "Overlapping generations or infinitely-lived agents. Intergenerational altruism and the economics of global warming", *Environmental And Resource Economics* **10**: 27-40.(with simulations)

PI_A(+)_S-OLG papers

Gerlagh, R. and B. van der Zwaan, (2001): "The effects of ageing and an environmental trust fund in an overlapping generations model on carbon emission reductions", *Ecological Economics* **36**, p311-326

PJ_A(-)_A-OLG papers

Jouvet, P.-A., Ph. Michel and J.-P. Vidal (1997). "Intergenerational altruism and the environment", XXX **102** (1), p. 135-150.

PC_A(+)_S-OLG papers

John, A., R. Pecchenino, D. Schimmelpfennig and S. Schreft (1995). "Short-lived agents and the long-lived environment", *Journal Of Public Economics* **58**.

John, A. and R. Pecchenino (1994). "An overlapping generations model of growth and the environment", *The Economic Journal* **104**, p.1393-1410.

Other References

Capros, P., Georgakopoulos, P., Van Regemorter, D., Proost, S., Schmidt, T. and Conrad, C. (1997), The GEM-E3 General Equilibrium model for the European Union, *Economic and Financial Modelling*, Summer/Autumn, 51-160

Chwe, M. S.-Y. (1994), Farsighted coalitional stability, *Journal of Economic Theory* **63**, 299-325

Criqui, P., Mima, S. and Viguier, L. (1999), Marginal abatement costs of CO_2 emission reductions, geographical flexibility and ceoncrete ceilings: an assessment using the POLES model, *Energy Policy* **27**, 585-602

Ellerman, A.D. and A. Decaux (1998), Analysis of post-Kyoto emission trading using marginal abatement cost curves, MIT Joint Progam on the Science and Policy of Global Change Report Series n°40

Eyckmans J., and Tulkens, H. (1999), Simulating with RICE Coalitionaly Stable Burden Sharing Agreements for the Climate Change Problem,.CORE Discussion Paper n° 9926 (UcL-CORE, Louvain-la-Neuve)

Eyckmans, J. (2001), On the Farsighted Stability of the Kyoto Protocol, CLIMNEG/CLIMBEL Working Paper 40 (UcL-CORE, Louvain-la-Neuve)

Eyckmans, J., Van Regemorter, D., and van Steenberghe, V. (2001), Is Kyoto fatally flawed? An analysis with, ETE WP 2001-18 (K.U.Leuven, CES)

Germain, M. and van Steenberghe, V. (2001), Constraining Equitable Allocations of Tradable Greenhouse Gases Emission Quotas by Acceptability, CLIMNEG Working Paper 39

Gosseries, A. (2002), Historical Emissions and Free-riding, CLIMNEG Working Paper 52

IPCC (Intergovernmental Panel on Climate Change), (2001) Climate Change 2001 – The Scientific Basis, Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change, edited by J.P. Houghton, et al. (Cambridge University Press, UK and New York), 448pp.

IPCC (Intergovernmental Panel on Climate Change)(2000), Special Report on Emissions Scenarios, ed. by Nakicenovic, N., J. Alcamo, G. Davis, B. de Vries,. Fenhann, S. Gaffin, K. Gregory, A. Grtibler, T. Y. Jung, T. Kram, E. L. La Rovere, L. Michaelis, S. Mori, T. Morita, W. Pepper, H. Pitcher, L. Price, K. Raihi, A. Roehrl, H-H. Rogner; A. Sankovski, M. Schlesinger, P. Shukla, S. Smith, R. Swart, S. van Rooijen, N. Victor, Z. Dadi (Cambridge University Press, UK and New York, 599pp.

Joos, F., Prentice, I.C., Sitch, S., Meyer, R., Hooss, G., Plattner, G.K., Gerber, S. and Hasselmann, K. (2001), Global Warming Feedbacks on Terrestrial Carbon Uptake under the IPCC emissions scenarios, *Global Biogeochemical Cycles* **15**(4), 891-907

Meyer, L. (forthcoming), Intergenerational Justice, contribution to be published in the *Stanford Encyclopaedia of Philosophy*

Nordhaus, W.D., and Yang, Z. (1996), A regional dynamic general equilibrium model of alternative climate change strategies, *The American Economic Review* **86**, 741-756

Raper, S.C.B., Gregory, J.M. and Osborn, T.J. (2001), Use of a upwelling-diffusion energy balance model to simulate and diagnose A/OGCM results, *Climate Dynamics* **17**, 601-613

Ray, D., en Vohra, R. (1997), Equilibrium binding agreements, *Journal of Economic Theory* **73**, 30-78

Schokkaert and Eyckmans (1999), Greenhouse negotiations and the mirage of partial justice, in: Dore, M.H.I., and Mount, T.D. (eds.) *Global environmental economics: equity and the limits to markets* (Blackwell Publishers, Malden (Mass.) USA and Oxford UK), 193-217

van Steenberghe, V. (2002), CO_2 abatement costs and permits' price: exploring the impact of banking and the role of future commitments, CLIMNEG Working Paper 51

APPENDIX 2: CLIMNEG activities

See attached listing “CLIMNEG 2 Agenda”.

The agenda can be consulted at our website http://www.climneg.be.

APPENDIX 3: CLIMNEG WORKING PAPERS

See attached listing “CLIMNEG Working Papers”.

All CLIMNEG 2 working papers can be downloaded in PDF format from our website http://www.climneg.be.