



Economic Commission for Latin America and the Caribbean
Subregional Headquarters for the Caribbean

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AN ASSESSMENT OF GLOBAL ECONOMIC MODELS FOR CLIMATE CHANGE

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CONTENTS

INTRODUCTION	1
A. Objectives of the project	1
B. Scope of work	1
C. Deliverables.....	1
D. Duration	2
I. FEASIBILITY OF THE PROJECT	2
II. MODELS	5
III. AN ASSESSMENT FOR THE CARIBBEAN REGION USING IAM.....	6
IV. MODELS AND SOFTWARES TO BE USED ON THE PROJECT	12
V. PROJECT ACTIVITIES AND TERMS OF REFERENCE.....	13
Annex I	20
Annex II.....	22

INTRODUCTION

A. OBJECTIVES OF THE PROJECT

The project comprises three phases of which Phase I would be implemented over the period September to December 2008. The major objectives of Phase I are, firstly, to establish the scope and feasibility of carrying out a study on the costs/benefits of taking action on climate change adaptation and cost effectiveness of mitigation in the Caribbean compared to a “business as usual” scenario, and secondly, to support initial actions to alert policymakers and key influencing constituencies to the urgency of this challenge.

B. SCOPE OF WORK

Activities should include the following:

- (a) A review of the global and regional climate change models and integrated models used in the Stern study and an analysis of their applicability to the Caribbean for an eventual Stern-type study in the Caribbean. This will also include models for the downscaling of regional scenarios (Intergovernmental Panel on Climate Change (IPCC) and others) for the Caribbean
- (b) Analysis of each of the different available models, indicating the limitations and/or adaptations required for their application to the Caribbean
- (c) Preparation of the draft terms of reference for an eventual Stern-type study for the Caribbean, complete with timelines and budget
- (d) Recommendations for the use of an appropriate model for costing the impacts of climate change on Caribbean economies
- (e) Collaboration with the Economic Commission for Latin America and the Caribbean (ECLAC) consultant collecting and mapping data and studies on climate change in order to identify the key data and information needed for an eventual Stern-type study on the Caribbean
- (f) Presentation of the draft study at an Expert Meeting to be held at ECLAC at a proposed date in January 2009
- (g) Presentation of the study to the United Kingdom Department for International Development
- (h) Presentation of the study to the Meeting of the Council for Trade and Economic Development in November 2008 (or date at which the meeting is scheduled)
- (i) Presentation of the study to the Association of Caribbean States Ministerial Council planned for January 2009

C. DELIVERABLES

Key outputs will include:

- A draft document detailing the model to be employed for the costing of the economic impacts of climate change

- A final document that incorporates the comments of all stakeholders

The report should be submitted in English. The study and all other related work produced by the consultant during the execution of this consultancy will be the exclusive property of ECLAC.

D. DURATION

The consultancy will be for the period 4 November 2008 to 23 December 2008, as specified by signed contract.

I. FEASIBILITY OF THE PROJECT

For the major objective of Phase I, to establish the scope and feasibility of carrying out a study on the costs/benefits of taking action on climate change adaptation and cost effectiveness of mitigation in the Caribbean compared to a “business as usual” scenario, the answer is yes. There are enough reports, information and studies concerning climate change on the Caribbean region that provide an important basis for the conduct of such a study. Some of these reports and studies are as follows:

- Glimpses of the future. A Briefing from the PRECIS Caribbean Climate Project, Caribbean Community Climate Change Centre, Belmopan, Belize
- Caribbean Sea Ecosystem Assessment, The University of West Indies, The Cropper Foundation, (as part of a five-year global project known as the Millennium Ecosystem Assessment, MA)
- The Caribbean and Climate Change. The Cost of Inaction, SEI-Tufts University, 2008
- Climate Change impacts on coastal and marine biodiversity, Group Report, 2008 (CCIBC)
- First National Communications to the United Nations Framework Convention on Climate Change and Second National Communications, a process that will end in 2010.

Other studies and contributions will follow subsequently.

“A number of studies have shown that sector assessment of climate change impacts in Caribbean countries is possible. The results from integrated impact assessment approaches in the agriculture and water resources.... suggest that the integrated negative impact on food production would be larger than the independent impact of climate change on agricultural yields only. This kind of information is what is needed to explore adaptation options that would improve resiliency and alleviate the anticipated negative impacts... the use of high resolution climate change scenarios as obtained through regional models like PRECIS will therefore significantly improve the ability to reflect what should be expected and what will be the best possible adaptation option in a given climate change sensitive sector”.
Glimpses of the future, p. 19

A considerable amount of data exists on recent (10-20 years) changes in coastal and marine biodiversity for the region, collected by different projects, countries and institutes. A priority is to compile and analyze this information in a comprehensive manner so as to prepare a new regional baseline against which future changes can be compared. CCIBC, p 47.

Such a study is not only feasible but also desirable, because of the necessity of an early and accurate response to the threats of climate change.

Priorities for the region considered by Global Environment Outlook reports prepared by UNEP are:

- Sea level rise (vulnerable, but little control)
- Land use (little capacity to accommodate often conflicting land use needs, land use developed primarily as a result of historical demand in developed countries for tropical exports crops)
- Forest management
- Water supply
- Marine and coastal areas (70% of population in the Caribbean living on low-lying coastal areas, coral reefs, mangroves, and fisheries resources)
- Biodiversity (due to high biodiversity per unit of land area)
- Waste management and pollution
- Natural disaster management

Caribbean Community Climate Change Center (CCCCC) has already identified the need for an adaptation assessment for: tourism, water resources, agriculture, food security, human health, coastal zones, and biodiversity.

The proposed project could use an economic approach to assess the impacts of climate change using the methodology of the Stern Report, introducing complementary methods and software so as to guarantee the success of this important effort, considering that the Caribbean region is a small, vulnerable one. The project activities should balance the question arising on how deeply are climatic and social variables to be analyzed, in order to produce a sound assessment of both, providing also evidences of gaps of knowledge and future research needs. Of particular note is the fact that the region consists of almost 90% of water systems, the Caribbean Sea, which makes the methodology and the report approach different to that other regional studies.

Other recent literature on climate change and the Caribbean region are an important contribution to the project feasibility:

1. ECLAC (CEPAL) (2007a). Addressing the impacts of climate change: Focus on the Caribbean, Economic Commission for Latin America and the Caribbean.
2. Haites, E., D. Pantin, M. Attzs, J. Bruce and J. MacKinnon (2002). Assessment of the Impact of Climate Change on CARICOM Countries. Environmentally and Socially Sustainable Development — Latin America and Caribbean Region, the World Bank.
3. The Caribbean and Climate Change, The cost of Inaction. Tufts University, 2008.
4. Toba, N. (2007). Economic Impacts of Climate Change on Caribbean Community — DRAFT. Environmentally and Socially Sustainable Development—Latin America and Caribbean Region, the World Bank.
5. Trotz, U. O. D. (2008). “Climate Change and Development in the Caribbean Sub-Region.” Caribbean Community Climate Change Center.
6. United Nations Environment Programme (PNUMA) (2005). Perspectivas del medio ambiente en el Caribe. Nairobi, United Nations Environment Programme.
7. Vergara, W. (2005). Adapting to Climate Change: Lessons Learned, Work in Progress, and Proposed Next Steps for the World Bank in Latin America. *Latin America and Caribbean Region, Environmentally and Socially Sustainable Development Department*. The World Bank.
8. Zapata Marti, R. (2006). Los efectos de los desastres en 2004 y 2005: la necesidad de adaptacion de largo plazo. *Estudios y perspectivas*, CEPAL.
9. Rivero, R.E (2008) Workbook of Climate Change Impacts Assessments in Agriculture: Basic Knowledge, Methodologies and Tools. INSMET / CCCCC / Commonwealth Secretariat, Belmopan, Belize, July 2008, 148 pp.

These Caribbean islands and the adjacent sea areas are immensely varied, ranging from very low sandy cays to high volcanic islands and seismic activity with land areas of less than 1 km² to more than 100,000 km², while offshore the topography ranges from deep ocean trenches to extensive barrier reefs.

The Caribbean Sea is the second largest sea in the world, covering an area of approximately 2,515,900 km² (other sources estimate the area to be more than 3 million km²), and comprising some of the territorial waters and coastal areas of 39 bordering countries and territories. The 116 million people living within 100 km of the sea are highly dependent on the services it provides as an ecosystem. Critical among these is the unique character of its coastlines and open waters, making it a desirable place to live and to visit. This desirability translates into a range of cultural services based on the recreational and aesthetic value of the land and seascape. A biodiversity hot spot, meriting global priority for conservation purposes (Myers et al. 2000).

The CARSEA report notes that the Caribbean islands meet the criteria of a hot spot because they have less than 30% remaining of primary vegetation (the Caribbean figure is 11.3%) and contain, as endemics, at least 0.5%, i.e., 1,500 of the world's known vascular plant species (the Caribbean figure is 2.3%). The number of endemic vertebrate species, 779, accounts for 2.9% of the world's total. Myers et al. ranked the Caribbean as the fifth 'hottest' hot spot according to various criteria, after Madagascar, Philippines, Sundaland, and Brazil's Atlantic Forest.(CARSEA; P:1).

In 2006, the United Nations General Assembly passed the final of a series of resolutions recognizing the importance, uniqueness, and vulnerability of the Caribbean Sea, and stressing the need to take an integrated approach to its management.

For the purpose of the present report, the following countries and territories are concerned: Anguilla, Antigua and Barbuda, Netherlands Antilles, Aruba, Bahamas, Barbados Cuba, Dominica, Grenada, Guyana, Haiti, British Virgin Islands, United States Virgin Islands, Jamaica, Montserrat, Puerto Rico, Dominican Republic, Saint Kitts and Nevis, Saint Vincent and the Grenadines, Saint Lucia, and Trinidad and Tobago.

**Table 1: Climate Predictions for the Insular Caribbean
(Based on global predictions from IPCC WGI, 2007)**

VARIABLES	PREDICTED CHANGE
Air temperature	Increase of 1.8 – 4.0°C by 2099
Global sea level	Rise of 0.18 – 0.59 m by 2099
Carbon dioxide	Reduction in pH of the oceans by 0.14 - 0.35 units by 2099
Hurricanes	More intense with larger peak wind speeds and heavier precipitation
Precipitation	Unclear

II. MODELS

Models are a simplification or reduction of reality into a more comprehensive, but simple, framework and have been largely in use in economics to assess policies whose purpose is to produce the best outcome. As science and especially social sciences, like economics, are better fitted to explain human behaviour rather than to predict outcomes, modelling is a difficult and controversial task itself.

In the case of climate change, the Integrated Assessment Models (IAM) in use are supposed to find a crucial point about the best policy based on a large number of controversial magnitudes and assumptions that:

- Produce an assessment of physical impacts and damages on natural and human capital and, in this special case, on infrastructure or estimate monetary losses to GDP
- Assess the monetary values of the damages and the costs of adaptation
- Give an assessment of the timing of mitigation and adaptation strategies in order to compare present and future benefits
- Permit estimations of future human welfare
- Deal with uncertainty, environmental thresholds, to relate with data that are exogenous to the model and to address the problem of decision-making under complex circumstances.

A major challenge for models is the assumption on which these are constructed, namely, if world and regional economy will continue to grow, what emission scenario is going to be used, among others.

Another important challenge in the choice of the model is to determine what processes really need to be included in detail, and which can be omitted, simplified or treated exogenously. This could be done by the design of scenarios to be coupled with the model for sensitive analysis. Priorities must be set as to what is important and what is not important in the construction because the computational feasibility is crucial and cannot be the result of coupling together different systems and versions of different models because running the model would not be feasible with current computers.

For the project two types of models are best designed, simulation and welfare maximization models. General Equilibrium and Partial Equilibrium, and also Cost Minimization Models are less interesting for the project¹.

Welfare Maximization Models are simple, pursuing the objective so as to maximize discounted present welfare.

Simulation Models, like PAGE, were used by the STERN team² to produce the Report.

¹ Equilibrium has his roots in Ethical Theory; GE model is a complete mathematical description of the relationship between each market in an economy. Excellent GE models are built around five conditions, 1) the utility function and budget constraints of each household; 2) production functions of each firm; 3) government's budget constraint; 4) general resource constraint; and 5) assumptions about consumer and producer behaviour. These models are solved by finding a set of prices that have the effect of "clearing" all sectors simultaneously. An approach that assumes that only one market is affected by the policy and examines the effects in this market only, is called partial equilibrium. CMs are very complex and best designed to match a cost effective solution to mitigation rather than adaptation.

² Ackerman argues that SM "are based on off-line predictions about future emissions and climate conditions; climate outcomes are not affected by the economic set of emissions values by period dictates the amount of carbon that can be used in production, and model output includes the cost of abatement and cost of damages. Simulation models cannot, in and of themselves, answer questions of what policy makers *should* do to maximize social welfare or minimize social costs". From this point of view they are less relevant for the project.

III. AN ASSESSMENT FOR THE CARIBBEAN REGION USING IAM

The Caribbean region, especially small islands, are known to be highly vulnerable and adaptation falls more into “passive” adaptation because these islands/territories have small physical and economic possibilities and options to adapt to sea level rise (causing impacts and damages to coastal zones, marine ecosystems and fisheries and also to freshwater supply). Such impacts will harm the economics of the region based mainly on tourism, fisheries, agriculture, and mining, with fewer options to rebuild the economy and the society based on other, different options that have shaped the region for several hundred years.

The main question that could be raised by models related to the best climate policy and long-term welfare changes concerns the impacts and how to adapt best to future restrictions, especially in future decades due to the high vulnerability of the islands. The time frame for an adaptation assessment should be consistent with regional vulnerability focusing on the next 20- 40 years with a perspective up to 2030- 2050 but, if possible, lasting until 2100.

This policy includes mitigation in order to obtain benefits from emission reduction policies and projects, to lessen the dependency on fossil fuels and to learn about financial and technological options to introduce solar energy in a cost-effective way. This is quite different to developed and bigger developing countries, whose concern on mitigation is related to the burden and costs of the commitments on emissions reduction and to energy policy and possible future commitments, respectively.

No doubt, if the region selects and introduces a sound adaptation strategy, this would be the best legacy to future generations. This approach is intimately related to a precautionary approach to the study, rather than one focusing only on a cost benefit or a cost effectiveness approach.

This means that an approach dealing with a social discounted cost of carbon, or discounted long-term adaptation benefits, to determine an optimal path much in use for global assessment of climate policy is meaningless for the region, and low discount rates should be used for most of the adaptation assessment³. This idea has an important precedent in the Kutrilla-Fisher Criterion for so called “amenities” (see annex).

Mitigation policy may be assessed using other approach related to discounting but also including co benefits and possible benefits from Certified Emissions Reductions (CER).

An IAM for the region should meet two general criteria:

- Model structure (welfare maximization or simulation models) should be subordinated to the type of results desired
- Damage assessment is central to the modelling effort (see annex on damage assessment)

Other important criteria are:

(a) Inclusion of estimates of sea level rises in response to temperature increase and, if possible, also changes in precipitation patterns using PRECIS estimates

(b) Assessing impacts to natural (marine, coastal and terrestrial ecosystems providing important support, providing and scientific and cultural services), man-made (infrastructure,

³ Using low discount rate without distinction for instance, a desalination project may favour this option with regard to the target of reducing water demand and increase recycling.

housing, instalments) and human capital in physical terms in a way that these impacts could be translated into quantitative measures of GDP

(c) Assessing impacts on main sectors of economic activities (tourism, agriculture, fisheries, mining)

(d) High time resolution to assess, if possible, yearly cumulative impacts from baseline year to 2030, 2050 and 2100. Timing is an important criterion to provide a sound cost effective adaptation

(e) Permitting sensitive analysis and assessing uncertainties⁴

(f) Assessment of extreme events or discontinuities

As already mentioned, the study can be conducted as an economic assessment similar to the Stern Report, but with some differences: first, the focus of climate policy in the Caribbean region should be a precautionary approach to support preventive adaptation and to avoid, if possible, severe impacts. On mitigation, more than considering a traditional mitigation study, as conducted for the National Communications to UNFCCC, there is a need to study the efficiency of present energy and transportation systems (due to countries with high per capita emissions, high Human Development Index) and especially the transition to solar energy in conditions of future energy systems for small islands, an especially difficult task.

The assessment of the applicability of the different climate change models leads to the conclusion that Page 2002 and the Framework for Uncertainty, Negotiations and Distribution (FUND) may be used in the assessment but important changes must be introduced to the models. From both, FUND, in particular, seems to be more flexible to be adapted to Caribbean conditions because impacts can be assessed yearly to natural, human and real capital, providing resolution for sea level rise.

Strength of PAGE, however, as a simulation model consists of the possibilities to assess scenarios, the costing of adaptation and preventive adaptation, better resolution for uncertainties and sensitive analysis, and assessment of future discontinuities or impacts of extreme events⁵.

Developing a modified IAM should be seen as a productive investment for the future, because such an assessment should be repeated afterwards. The starting point should be discussing what outputs are needed, not model structure.

It is important also to take into account that a special analysis should be conducted for the Caribbean Sea, using a predictive circulation model to assess changes in different marine and coastal components and also to obtain better conclusions on potential sea level rise and especially important marine ecosystems and biodiversity.

There should be an assessment on how to integrate both kinds of models to match conditions of the region, with the main purpose of not being dependent on global models with other kinds of resolution. For the downscaling of global climate models, a response is given in activities devoted to modify the IAM selected. There already very good capacities and experiences on the region.

⁴ Sensitive analysis is a technique for evaluating risky decisions based on changing assumptions. Simulation is a complex sensitive analysis. Monte Carlo is a technique that simulates outcomes after probabilities have been assigned.

⁵ “Where there is a tension between delivering the best study and following common assumptions the emphasis should be on delivering robust locally relevant work”. (Summary, A1 Breakout Sessions Stern Team).

KEY ISSUES OF INTEGRATED ASSESSMENT MODELS (IAM) FOR CLIMATE CHANGE

1. MODEL	PAGE 2002 (POLICY ANALYSIS OF THE GREENHOUSE EFFECT 2002) (HOPE, 2006) BUILDED UPON PAGE95. EXCEL APPLICATION WITH LATIN HYPERCUBE TO DEAL WITH UNCERTAINTY	DICE (DYNAMIC INTEGRATED MODEL OF CLIMATE AND THE ECONOMY)	RICE REGIONAL DYNAMIC INTEGRATED MODEL OF CLIMATE AND THE ECONOMY (NORDHAUS AND BOYER, 1999). REGIONAL VERSION OF DICE. LAST KNOWN VERSION 2001.	FUND CLIMATE FRAMEWORK FOR UNCERTAINTY, NEGOTIATION AND DISTRIBUTION. (RICHARD TOL, UNIVERSITY OF HAMBURG. LAST VERSION AVAILABLE IS FUND 2.8.
2. Type of model	Simulation	Welfare maximization, Global	Welfare maximization, regional	Welfare maximization, regional, includes exogenous scenarios and endogenous perturbations.
3. Most powerful for	Flexibility for the development of scenarios. Do not give advice on policy options to minimize social costs and maximize welfare.		Economic analysis and policy options. Welfare maximization like FUND.	More detailed calculation of sectoral impacts. Uses an approach to maximize welfare over time estimating how much emission abatement (costs) is best at each time period.
4. User guide	No		Yes	No
5. Regional disaggregation	8 regions		8 regions but not regional ones. Caribbean divided into 3 regions (high, middle and low income)	16 regions, including SIS.
6. Greenhouse gases considered	(CO ₂), (CH ₄) and (SF ₆)		CO ₂ from industrial sources	CO ₂ , CH ₄ , (N ₂ O) also (SO ₂) and influence in radiative forcing
7. Emissions and concentrations of GHG	Calculates overall emissions based on temperature increases and emissions scenarios			Calculates emissions based on population and GDP. Concentrations calculated by an special model
8. Climate variables	Calculates radiative forcing and temperature increase based on gases considered. Excludes sea level rise and precipitation		Calculates radiative forcing and temperature increase based on gases considered. Excludes sea level rise and precipitation	Calculates radiative forcing and temperature increase based on gases considered. Sea level rise on the basis of temperature increase.

				Excludes precipitation.
9. temperature	Estimated on the basis of radiative forcing		Estimated on the basis of radiative forcing	Estimated on the basis of radiative forcing
10. Sea level rise	No		No	Yes , based on temperature
11. Precipitation	No		No	No
12. Damage assumptions	Damages are modelled by all these IAM as losses to income or consumption leaving capital stocks and productivity undiminished for future use. An unrealistic assumption. FUND seems to produce some physical damages due to sea level rise and life years lost due to disease and morbidity, some as a fraction of GDP, but need more clarification.			
13. Impacts calculation and adaptation	Aggregate impacts discounted from GDP PAGE used in STERN assumes that in developing countries, 50 percent of economic damages are eliminated by low-cost adaptation		Aggregate impacts discounted from GDP	Disaggregated for agriculture, forestry, energy use, water, impacts from sea level rise, human health, (different diseases, morbidity and mortality) ecosystems and species.
14. Adaptation	Estimated costs of adaptation for each region. Estimated cost of preventive adaptation		Considers adaptation, especially for agriculture, but not explicit.	Some impacts are the continuity of impacts from earlier years, specially in agriculture
15. Disaggregated impacts per sector	No		No	Yes
16. Uncertainty and sensitive analysis	Strong, Monte Carlo. Latin Hypercube added.			Strong, Monte Carlo
17. Emissions reduction costs	Not included		Not included	Included but not explicit
18. Extreme events or discontinuities	Yes. Estimates future discontinuities or impacts of extreme events at great scale when temperature surpasses a tolerable given level. Damage function discontinuous when Temperature rises above 4 to 6 Celsius.		Yes. Estimates future discontinuities or singularities at great scale when temperature rises up to 3 degree Celsius and beyond that.	On development to include impact of decrease of termohaline circulation.

19. Availability	Not free, also @risk needed		Free but GAMS needed	Free
20. Time frame resolution	10 variable periods For 2000/ 2200		10 years periods between 1995 and 2335.	Yearly for 350 periods

Based on: www.climatepolicy.com

RICE. Available at <http://www.econ.yale.edu/~nordhaus/homepage>.

FUND Available at <http://www.fnu.zmaw.de/FUND.5679.0.html>. Other versions of the model available.

Turtos. L. "An introduction to IAM's for Climate Change, ECLAC/ CEPAL, April 2008, Spanish.

Copyright © 2007 GAMS Development Corporation, Washington, DC, USA.

Copyright © 2008 Palisade Corporation, (<http://www.palisade.com>).

Climate and Development: The need for a new economic model. CRED prospect, SEI, 2008

Did the Stern Review underestimate U.S. and global climate damages? Ackerman, F. Stanton. E, Hope. C. Albert. S., October 17, 20

The economics of inaction on climate change: a sensitivity analysis, Ackerman, F. Finlayson, and I.J.

KEY ASSUMPTIONS FOR A MODIFIED IAM FOR THE CARIBBEAN REGION

Variable	Criteria	Comments
1.Scale	Regional model, independent from global ones comprising the Caribbean Region.	Only countries included on the project to avoid “noisy” running
2.Type of model	Simulation or Welfare Maximization	PAGE, FUND
3.Greenhouse gases considered	CO ₂ , CH ₄ , (N ₂ O) also (SO ₂) and influence in radiative forcing	FUND
4.Emissions of GHG	Calculates emissions based on population and GDP and emissions Reduction goals.	FUND
5.Climate variables	Can be exogenous to the model. Temperatures increase are global with regional resolution from scenarios and other Models. Need more discussion	To explore up to which extent Model to be improved in this sense
6.Temperature	Same	Same
7.Sea level rise	Estimated with temperature increase, but also by means of PCM for different scenarios	FUND
8.Precipitation	Estimated, PRECIS provides information	
9.Damage assumptions	Damages to be modelled as losses to capital stocks, productivity and ecosystems services as impacts for future use. Also for disease and morbidity and mortality	FUND in some cases. Links to PCM
10.Impacts calculation	As a fraction of GDP and sector output,	Links to PCM
11.Adaptation	Adaptation costs and benefits to be assessed as estimates per sector	-
12.Uncertainty and sensitive analysis	Strong, Monte Carlo. Latin Hypercube.	PAGE
13.Extreme events or discontinuities	Future discontinuities or impacts of extreme events at great scale when temperature surpasses a tolerable given level.	PAGE, FUND See comments on damage function
14.Time frame resolution	Yearly for X periods	FUND
15.Emissions reduction costs	Costs and benefits estimates are possible as ranges	Technology development assessment

IV. MODELS AND SOFTWARE TO BE USED ON THE PROJECT

To conduct a study on the economics of climate change, different approaches are feasible, but the use of models and software are also indispensable in informing the choice of models by experts. All these tools should be available to guarantee a high probability of success for the project. Models and software recommended for the project are as follows:

(a) For general purposes an IAM should be selected and modified to match the requirements of the region as already assessed. It seems that FUND, and with less possibilities PAGE, can be the basis for the modelling effort. Expertise already exists in the region to introduce changes to one of both models. The IAM can be linked to a Geographic Information System to strengthen assessment of sea level rise.

(b) For CARSEA, a predictive circulation model is needed to assess circulation changes and to examine various scenarios to predict changes to environmental services and economic benefits, and make recommendations on the most effective adaptation measures. Such a model should be identified as a crucial part of the project. If such a model is not available, then an assessment through contrasting quantitative scenarios based on experts' criteria is needed.

(c) The Long Term Energy Alternative Planning System is a multipurpose software developed by the Stockholm Environment Institute and is commonly in use in the region. It is recommended by the National Communication Support Program to assess mitigation studies, but is also used with success to construct scenarios and to conduct cost-benefit analysis. It is available

(d) Novel Approach to Imprecise Assessment and Decision Environment (NAIADE) is a software for multicriteria analysis and a proper tool for making decisions that include social and economic conflicts, and objectives for preserving the environment. It is used when a plurality of measure scales comes together (physical, monetary and quality ones). The greatest advantage of the multicriteria methods is that they allow a vast number of data, relations and objectives to be considered and these are generally present in a specific problem that may be studied in a multidimensional way. On the other hand, multicriteria analysis includes the possibility to assess uncertainty margins, and fuzzy numbers. NAIAD E was developed by G. Munda from the Autonomous University of Barcelona. It can be used to assess mitigation options and policy and also as a decision tool for adaptation. It is available.

(e) A tool is needed to model low-carbon technologies to assess future energy systems based on solar energy. A model should be identified for this purpose, but it is also possible to combine LEAP with technology and costing scenarios if such a model is not available.

V. PROJECT ACTIVITIES AND TERMS OF REFERENCE

A. PROJECT RATIONALE AND ORGANIZATION

The logical framework and sequence from Phases II and III have been adjusted to match the conditions of the Caribbean region; the need to conduct an assessment on the Caribbean Sea and the circumstance that Second National Communications (SNC) are in the process of development in almost all countries of the region, a process that could finish by 2010. Very few countries will finish their SNC by 2008.

The general idea is that after activities devoted to coordinating, planning and implementation of the project, the main task would be:

- Studies on extreme events and international context which should provide information for sector and mitigation studies, but also for modelling and adaptation (adaptation funding possibilities)
- Development of socio-economic aspects and scenarios to provide information for sector studies that should also provide later information for the modelling effort. Sector studies are planned to be conducted early to assess modelling, adaptation design and mitigation studies in a way that data and information obtained can be used as inputs to the modelling process, the mitigation policy and country studies
- Several studies on transportation systems, infrastructure and housing (to give inputs for modelling, adaptation and mitigation), cooperation and integration and also cultural, scientific and natural heritage, which are included to guarantee that most economic and social sectors are covered by the project
- After the IAM-adaptation-mitigation assessment, two subregional workshops are planned to discuss these results, providing useful inputs for the country studies
- Extended activities to create special climate scenarios are not included. Data and experiences can be obtained and, if necessary, downloaded directly from SRES and PRECIS database to fit the IAM and sector studies. This task could be accomplished to a great extent with activities included in the regional assessments, devoted to a regional assessment using an IAM and other models. Creation of a special climate scenario is very costly and a balance is needed between going deeper now in climate studies or on modelling and socio-economic issues, the latter being the most desirable method
- Modelling should have some space later in the project so as to review the main results of country studies and improve the models in use
- Crucial for the project are marine and coastal areas, both as a sector study and modelling effort due to major uncertainties. The modelling should include several scenarios so as to help to understand responses from species, coastal areas and important services. Although several modelling outputs should be important, results from sea level rise scenarios are particularly important for project results

The proposed activities are divided into the following phases:

Phase II: Regional studies, (including coordination, planning and implementation, sector studies and the modelling effort). Regional Thematic Groups are not needed as there will be specialized studies, the Project Co-ordination Unit and CCCCC already exists.

Phase III: National studies (that should improve results already obtained by national teams, by extending modelling efforts to national level, including deep review of sector studies already finished or extending the scope of the study to sector or activities more important for the implementation of national strategies).

Phase IV: Strengthening of Institutional and Scientific Capacities.

The first of these phases includes all the actions related to the project's administration, coordination and planning.

Phase II

1. COORDINATION AND PLANNING

- 1.1. Steps for the implementation of the project.
- 1.2. Establishment of the Steering Committee, the Regional Technical Committee, and
- 1.3. Planning of activities by PCU
- 1.4. Meetings of the Regional Technical Committee
- 1.5. Support for the implementation and dissemination of the Project
- 1.6. Support for the Project's Web Page

2. METHODOLOGICAL ASPECTS FOR REGIONAL AND SECTORAL AND SECTOR STUDIES

- 2.1. Gathering and assessment of previous studies in the Caribbean Region including national communications to UNFCCC
- 2.2. Lessons learned from the different studies, including the Stern Report and regional studies and from other studies from DC
- 2.3. Recommendations for the conduction, scope and development of the different studies.

3. SOCIO-ECONOMIC ASPECTS AND SCENARIOS

- 3.1. Construction of a baseline socioeconomic and environmental scenario with which adaptation options, Costs, benefits and scenarios could be compared. The baseline scenario should be a benchmark for further research and should be a most comprehensive one, including indicators on GDP, PPP, physical indicators of economic activity, population, migration, gender, poverty, resource availability, climatology, health, food, energy, land use, transportation and several indicators needed for future assessment. (Team members should coordinate data with team members of sector studies)
- 3.2. Economic structure and development options
- 3.3. Environmental problems included in sustainable development plans and programs and national environmental strategies
- 3.4. Macroeconomic strategies, fiscal policy and debt
- 3.5. Construction of economic, social and environmental scenarios for the region
- 3.6. Baseline and projections on social vulnerability, poverty, inequality and gender problems.
- 3.7. Analysis of potential impacts generated by CC.

4. THE INTERNATIONAL CONTEXT

- 4.1. Assessment of the negotiation process towards a new climate regime after 2012. Possible scenarios for DC and SIS and the implications for the Region.
- 4.2. Options and instruments in discussion to create incentives and regulations to reduce emissions in DC and SIS including different approaches to generate CERS.
- 4.3. Impacts derived from a new Climate regime for the world economy, implications for cooperation, trade agreements and also for development assistance and funding.
- 4.4. Emerging strategies and instruments for promoting the funding of adaptation studies, policies and programs.
- 4.5. Emerging policies towards sector standards and funding of technology transfer for DC and SIS

5. ANALYSIS OF EXTREME EVENTS

- 5.1. Learning from extreme events, “natural disasters” and induced natural disasters. Type of events, policy response, preventive adaptation and adaptation, estimate costs and insurance response.
- 5.2. Assessment on hurricanes in the Caribbean region, history, possible relation with CC and expected future behaviour
- 5.3. Analysis on ENSO. Factors related to frequency and intensity. Relation with CC
- 5.4. Analysis of seismic events, history, frequency and possible relation with CC through sea level rise (induced Seismicity) and other causes.
- 5.5. Study on regional vulcanology, history, causes, frequency and possible relation to CC.
- 5.6. Study on droughts, causes, frequency and intensity, adaptation and possible relation to CC.
- 5.7. Events from far abroad: The Sahara dust: could it be exacerbated by CC? What could be the impacts?

6. REGIONAL ASSESSMENT USING MODELS

- 6.1 Assessment of global climate models, regional climate scenarios, regional experiences and capacities
- 6.2 Analysis on SRES and PRECIS Experiences for the use of IPCC scenarios.
- 6.3 Assessment to select IAM and other models and software
- 6.4 Modifications to the IAM Model for the Caribbean Region
- 6.5 Applications to verify the model
- 6.6 Identification and selection of a model for the Caribbean sea
- 6.6 Applications to verify the model
- 6.7 Selection of climate scenarios, parameters and data to be used in the Carsea model
- 6.9 Regional assessment for different scenarios by means of IAM model
- 6.10 CARSEA assessment for different scenarios by means of a model
- 6.11 Analysis of the results of both models
- 6.12 Analysis of the possible integration of both models
- 6.13 Comparative assessment of IAM results with sector analyses
- 6.14 Design of an adaptation strategy for the region based on the physical and economic impacts obtained from the models and a MCA.
- 6.15 Preparation of the models for country and future studies

7. MITIGATION

- 7.1 Gathering of data on GHG emissions and emission patterns by country/ sector and for the region
- 7.2 Study of available information on emissions in main sectors to assess overall efficiency in resource use

- 7.3 Construction of mitigation scenarios
- 7.4 Design of possible mitigation policy for the region including carbon capture and storage. Assessment of Potentials and barriers
- 7.5 Assessment and design of policy for energy efficiency, the introduction of solar technologies and for future energy systems
- 7.6 Assessment on regional potential for biofuels based on different sources and a technology including an analysis of energy balances.
- 7.7 Assessment on adaptation strategies related to mitigation potential and sustainable development (afforestación, reforestation)
- 7.8 Assessment of the study using MCA
- 7.9 Assessment of mitigation strategies related to adaptation and sustainable development (electricity based on renewable instead of Fuel wood).

8. SUBREGIONAL WORKSHOPS

- 8.1 Organisation of the workshops with the results of the models assessment, sector results, adaptation strategies and options and results from the mitigation study and synergies adaptation/mitigation.
- 8.2 Workshops with participation of consultants for regional, regional sector studies and country participation, including P.C.U.

Regional sector studies

9. WATER RESOURCES

- 9.1. Estimations of a water balance including water availability and use, potentials, consumption by uses, and unmet demand.
- 9.2 Creation of baseline and scenarios. Estimate of runoff and future water availability related to the different climatic and socioeconomic scenarios.
- 9.3 Possible impacts derived from sea level rise
- 9.4 Assessment of policies to reduce water use and enhance supply, including technologies like desalination.
- 9.5 Water pollution and sanitation
- 9.6 Identification of the main risk factors and factors (climatic and non-climatic) that increase the sector's vulnerability.
- 9.7 Assessment of adaptation actions and future adaptation strategies. Estimation of costs and benefits of adaptation.

10: AGRICULTURE

- 10.1. Assessment of a baseline for the sector. Socioeconomic importance and relevance.
- 10.2. Use of soil. Soil quality, degradation and erosion.
- 10.3. Representative crops and analysis of the main vulnerabilities and possible adaptation strategies
- 10.4 Construction of scenarios to assess impacts, vulnerability and adaptation options and strategies.
- 10.5. Estimate of the sector's potential for mitigation
- 10.6 Estimated cost and benefits of adaptation. Adaptation options related to mitigation.

11: FORESTRY

- 11.1 Assessment of a baseline for the sector. Socioeconomic importance and relevance.
- 11.2 Use of soil. Soil quality, degradation and erosion.
- 11.3 Services (providing, supporting and cultural & scientific) provided by the sector.

- 11.4 Representative type of forests, analysis of the main vulnerabilities and possible adaptation strategies
- 11.5 Construction of scenarios to assess impacts, vulnerability and adaptation options and strategies to maintain services.
- 11.6 Estimate of the sector's potential for mitigation
- 11.7 Estimated cost and benefits of adaptation. Adaptation options related to mitigation.

12: THE HUMAN HEALTH SECTOR

- 12.1. Assessment of the sector's current conditions and creation of a baseline. Relevance of the sector for human capital.
- 12.2. Diseases related to weather, climate and water that are relevant for the region. Costs and current policies on disease prevention
- 12.3. Building of potential impact scenarios in the sector, based on the climate-change and socioeconomic scenarios.
- 12.4. Identification of the main risk factors and of factors (climatic and non-climatic) that increase the sector's vulnerability and the possible future evolution.
- 12.6. Economic analysis of impacts from climate change and assessment of co benefits from mitigation, also from actions related to improve water quality and supply.
- 12.7. Evaluation of adaptation options and strategies costs and benefits.

13: THE ENERGY SECTOR

- 13.1. Assessment and baseline for the sector. Technologies, mix of fuels, domestic fuels, population served with electricity, overall supply efficiency, efficiency in final demand. Identification of the main risk factors and impacts related to CC.
- 13.2. Projections of supply and demand through scenarios for energy supply with different technologies (renewable Sources, cogeneration, rational use of energy) and different sectors (spatially electricity generation, but also transportation, industry, domestic fuels)
- 13.3. Alternative energies and technological changes for the region. Technical and economic feasibility
- 13.4. Analysis and prospects of transportation sector (cargo, passenger, and public)
- 13.5. Estimation of the sector's mitigation potential (market, economic and technological). Barriers. Economic and MCA assessment.
- 13.6. Assessment on technologies for bio- and agro fuels. Costs and energy balances.
- 13.7. Estimation of the potential impacts of climate change on the sector, on the supply and the demand sides.

14. TERRESTRIAL ECOSYSTEMS AND BIODIVERSITY

- 14.1. Baseline for biodiversity. Assessment of actual services (supporting, providing, cultural & scientific) and potential threats. Identification of main risk and vulnerability factors.
- 14.2 Hot spots and threatened species.
- 14.3 Construction of scenarios of potential impacts and estimation of biodiversity losses for the different climate change scenarios, including the impacts caused by alterations in climate, forests, sea level rise, water resources and agricultural sector.
- 14.4 Assessment of adaptation actions, strategies and possible costs.

15. MARINE AND COASTAL AREAS

- 15.1 Baseline for marine biodiversity and marine conditions. Main services provided by marine and coastal system (supporting, providing, Cultural & scientific).

- 15.2 Possible scenarios for marine and coastal systems. 1) Coastal wetlands, Forests, Dunes, Beaches, Cliffs and Rocky Shore, 2) Sea grass and Coral reefs, 3) fish species and fisheries, 4) seabirds, coastal waterfowls, mammals and other species.5) connectivity and circulation Changes 6) sea level 7) acidification, 8) diseases and invasive species, 9) algal blooms and plankton.
- 15.3 Species responses in changes of temperature.
- 15.4 Impacts on marine and coastal services and possible adaptation and adaptation costs.
- 15.5 Impacts on fisheries, coastal zones and beaches.
- 15.6 Assessment of possible impacts of CC on the main regional rivers (Orinoco and Magdalena) and consequences for the Caribbean Sea.
- 15.7 Climate change impacts in main rivers and threats to coastal zones.
- 15.8 Gaps in knowledge, research and conservation needs.

16. TRANSPORTATION SYSTEMS

- 16.1 Baseline of transportation systems in the Region. (passenger, cargo, tourism, road, rail, air, coastal and marine). Technologies and fuels in use. Conditions of efficiency and competitiveness. Situation of main harbours and technological instalments.
- 16.2 Future development of transportation systems and technologies.
- 16.3 Regulations for the Sea transport on the Caribbean sea.
- 16.4 GHG Emissions from transportation sector and mitigation possibilities and co benefits.

17. INFRASTRUCTURE AND HOUSING

- 17.1 Assessment of infrastructure, population and economic activities in coastal zones and zones prone to impacts of sea level rise and extreme events by means of GIS. Estimated mean values of land and output per area.
- 17.2 Conditions of infrastructure and housing to resist sea level rise and extreme events. Adaptation costs and benefits. Alternatives to improve and change present conditions, methods and regulations.

18. CULTURAL, SCIENTIFIC AND NATURAL HERITAGE

The study should assess the possible impacts, costs and irreversible losses due to impacts of climate change on the Caribbean region, based on the other sector studies, scenarios and on own information, on the cultural, natural and scientific inheritance of the region.

The study should include a brief review of the history of the region from this perspective.

19: COOPERATION AND INTEGRATION

For the Caribbean Region several cooperation arrangements already exist. Nevertheless climate change impacts could create a new scenario for integration and cooperation towards the adaptation to climate change and the design of long term strategies to deal with an altered climate. (CCCCC is already a new cooperation instance for the region. The study should assess and explore these possibilities)

20: DEVELOPMENT OF RECOMMENDED PUBLIC-POLICY OPTIONS

21: DRAFTING OF THE REPORT

Phase III

NATIONAL STUDIES ON CLIMATE CHANGE IMPACTS, ADAPTATION AND MITIGATION.

22. Country studies (the use of IAM for impact assessment and adaptation is planned).

Phase IV

STRENGTHENING OF INSTITUTIONAL AND SCIENTIFIC CAPACITIES

23. Activities for strengthening institutional and scientific capacities.
- 23.1. Drafting of a document of the Project, with information from all the studies carried out.
- 23.2. Drafting of a document on gaps on knowledge and scientific assessment of climate change, needs and resources to improve regional scientific capacities.
- 23.3. Holding Workshops on the main results achieved methodological approaches, scientific and social uncertainties, policy instruments and future research needs for the Region for selected participants of each country (government, universities, chambers of private sectors, NGOs, funding agencies, consultants, etc.).

General terms of reference for drafting studies or research

The development of the different research components should include:

- (a) Analyzing previous studies that have been prepared for the region and carrying out the necessary studies to complete the information required to make the envisaged economic assessment
- (b) Analyzing the interactions among sectors (water, agriculture, forests, ecosystems and biodiversity and energy) that could increase or diminish the region's vulnerability to the climate change, where feasible
- (c) All the products and results obtained for each priority sector should provide estimations of uncertainty and be accompanied by proposals for handling uncertainty in decision-making. For climate change, a risk and uncertainty assessment should be based on a comprehensive approach, including risk analysis/assessment and risk management. (See methodology used by IPCC 4AR)
- (d) Providing quantitative and/or qualitative estimates of impact for each of the priority sectors and for the region's economic growth and development. Carrying out estimates of cost/effectiveness or costs/benefits of adaptation and avoided climate change damages and the potential benefits and co-benefits of mitigation and trade in emission reduction certificates, where feasible. Cost and benefits concepts should be presented as a part of a broader set of decision framework (MCA). Caution is requested with economic cost-benefit approaches in view of limitations of this approach
- (e) Documenting the methodologies used (adapted, created, etc.) in carrying out the different global and sector studies
- (f) References, providing separate references for scientific peer reviewed literature and grey and other literature.

Annex I

MODELS AND DAMAGES ESTIMATES

One important controversy for the Caribbean region concerns the magnitude of the expected impacts of climate change. There are not yet good estimates for those impacts. Generally, Stern's global estimates, based on results from the PAGE2002 model, were found to be substantially greater than those produced by many other models, leading experts to suggest that Stern had overestimated damage figures.

Other experts (Ackerman & Co) reached a completely opposite conclusion in a recent application of PAGE2002, in a study of the costs to the United States economy of inaction on climate change. This article explains the conclusion from Ackerman's team that the model runs used in the Stern Review may well underestimate United States and global damages. Stern's estimates that mean business-as-usual damages in 2100 would represent just 0.4% of GDP for the United States and 2.2 % of GDP for the world, Ackerman's review of the model suggest that damages in 2100 could reach 2.6% of GDP for the United States and 10.8% for the world.

That models do not solve problems by themselves is a conclusion derived from recent literature. Independent from model choice assumptions behind them seems to have same or more relevance for a Study⁶.

PAGE used by Stern assumes that in developing countries, 50% of economic damages are eliminated by low-cost adaptation. In OECD countries, the assumption is even stronger: 100% of the economic damages resulting from the first 2 degrees of warming, and 90% of economic damages above 2 degrees, are eliminated. For non-economic, non-catastrophic damages, adaptation is assumed to remove 25% of the impact everywhere. The question arises: Is adaptation possible in the Caribbean Region with temperatures rising more than 2 degree Celsius?

Stern used a threshold temperature, with minimum, most likely, and maximum values of <2, 5, 8> degrees Celsius⁷. Thresholds temperatures of < 2, 3, 4 > suggested by Ackerman seems more accurate, **but scenarios with thresholds of < 2, 2.5, 3> are more desirable for a precautionary approach.** The strength of simulations models becomes evident when such different scenarios can be assessed.

Removal of total Greenland Ice sheets could produce a sea level rise of 7 meters but scientific assessment for this region has found that there was an Ice sheet covering Greenland with temperatures 5.5 degree Celsius higher than now. (Conference in Havana, January 2008).

⁶ Ackerman argues that some "models surprisingly conclude – in direct contradiction of the urgency expressed in the scientific literature – that rapid, comprehensive emissions abatement is both economically unsound and unnecessary. And some models seem to ignore (and implicitly endorse the continuation of) gross regional imbalances of both emissions and income".

⁷ He continues "Discussion of potential catastrophes, such as the loss of the Greenland or West Antarctic ice sheets, has suggested that they become possible or even likely at temperatures "most likely" threshold of 5°C of warming; indeed, the narrative portions of the Stern Review make this suggestion. For this reason, the PAGE baseline assumption about threshold temperatures seems too conservative".

Ackerman explains that

$$\text{Damages} = aT^N$$

Where there is a constant, T is the temperature increase, and N is the exponent governing how fast damages rise. If N = 2, then 4° is four times as bad as 2°; if N = 3, then 4° is eight times as bad, etc.

“PAGE treats the exponent N as one of the uncertain parameters that is allowed to vary in the Monte Carlo analysis, with the minimum, most likely, and maximum values, respectively, set at <1, 1.3, 3>. There is essentially no evidence bearing directly on the value of this exponent, but the “most likely” value of 1.3 seems almost timid: it implies that 4° is only about 2.5 times as bad as 2°” (Ackerman).

The “cost of inaction” gives other estimates for the Caribbean Region: (total Caribbean)

YEAR	MM US\$	% OF GDP
2025	10,7	5,0
2050	21,9	10,3
2075	33,7	15,9
2100	43,2	21,7

For Europe and the United States, large territories, adaptation seems more easy and feasible. A conclusion of all these studies is that scientific community is moving towards higher damage estimates, crucial for small islands.

Annex II

The Kutrilla Criterion

John V. Kutrilla can be credited with first introducing the concept of existence or non use value into mainstream economic literature. In his classic article “Conservation Reconsidered”, he argued that individuals do not have to be active consumers of a resource and someone can capture this option in order to derive value from the continuing existence of unique, irreplaceable environmental resources.

He wrote: “when the existence of a grand scenic wonder or a unique fragile ecosystem is involved, its preservation and continued availability are a significant part of real income of many individuals”. He suggested that “ these individuals would be the spiritual descendants of John Muir, the present members of the Sierra Club, the Wilderness Society, the National Wildlife Federation, the Audubon Society and others to whom the loss of species or the disfigurement of a scenic area causes acute distress and a sense of genuine relative impoverishment” (1967). He continues in a footnote: “(the) phenomenon discussed may have an exclusive sentimental basis, but if we consider the bequest motivation in economic behavior... it may be explained by an interest in preserving an option for one’s heirs to view or use the object in question” (1967).

There are two conclusions from Kutrilla: (a) use value is only a fraction of total economic value, hence adaptation benefits could be underestimated, and (b) in such cases, high discount rates contributes to preclude correct assessment of adaptation policies.

For the conservation of the Caribbean, adaptation actions and preventive adaptation should be assessed first in physical terms and then as fractions of GDP, or an adaptation project using a low or zero discount rate. It is not clear if for any event an adaptation would be possible to preserve unique or fragile ecosystems or sites. An impact assessment in such a case could help to understand what are going to be the costs for the Caribbean region of years of inaction towards a new equitable climate regime.