



A blueprint for integrated assessment of climate change

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This is the final report from Tyndall research project IT1.3 (Evaluation of approaches to integrated assessment: a 'blueprint project'). The following researchers worked on this project:

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Introduction

The Blueprint Project was set up to reach key decisions on how the Tyndall Centre will develop its plans for integrated assessment modelling over the years 2002 to 2005. The Blueprint Project now forms the first stage of the work carried out under the theme 1 flagship project on Integrating Frameworks. As a result of the work carried out under this project, the plans for integrated assessment modelling work have now been laid out and are under way.

Thus, the Tyndall Centre is now taking a lead role in developing a next generation Community Integrated Assessment Model (CIAM) which will bring together climate models, socio-economic models, models of technological change, policy models, transport models, models of social behaviour and decision making, hydrological models, agricultural models, and models of climate change impacts such as biome shifts, human health and extreme events. During the past few months, vital decisions have been made regarding the questions the model will answer, the structure it will take and how it will be realised.

Method

Rachel Warren has been working at the Tyndall Centre as Research Fellow in Integrating Frameworks since January 2002, and is coordinating a large team of research partners within and without the Tyndall Centre to assemble the CIAM and also to make key decisions concerning model design. Her collaborators include scientists at the Potsdam Institute for Climatology (PIK, Germany) and at the International Centre for Integrative Studies (ICIS, Netherlands).

To assist in the model design, information was also gathered from expert integrated assessment modellers, and representatives from industry, government and other organisations, through a series of Blueprint Workshops organised by Jean Palutikof and Clair Hanson in June 2001 and February 2002. Further information was gleaned from a literature review by Clair Hanson within Goodess et al. (in press), other literature (Dowlatabadi 1995, Hulme 2001, Matsuoka et al. 1995, Palbeck and Hope 1996, Tol 1999, Batjes and Glodewijk 1994, Jaeger et al 2002, Rotmans et al. 1994) and through visits to the University of Cambridge, and the International Institute for Applied System Analysis (IIASA) in Austria. Jonathan Kohler (theme 1 manager) attended all the workshops whilst Rachel Warren attended the final two. Project leadership was transferred from Jean Palutikof to Rachel Warren shortly after her appointment as Tyndall Research Fellow in January 2002.

In parallel with the IAM, an Integrated Assessment Process (IAP) is being set up, coordinated by Alex Haxeltine. This process will continue to gather information from a wide range of stakeholders in government, NGOs, industry and the financial sector who are potential users of the model or its results, and will assist in the ongoing evolving design of the model. A meta-framework will be designed to achieve stakeholder interaction, which will utilise formal qualitative techniques. Decision making will be explored in the IAP initially using a scenario approach. Later on agent-based models and virtual decision theatres will be used to simulate the decision making process. A break-out group at the February 2002 blueprint workshop has helped to inform the planning of the IAP.

Insights from the Blueprint Workshops

The blueprint workshops assisted the model design in four ways:

- (i) in suggesting scientific approaches to integrated assessment
- (ii) in suggesting practical ways forward in building a distributed and modular CIAM

- (iii) in providing advice on how to handle a consortium of model builders from a set of different institutions
- (iv) on matters relating to stakeholders in the integrated assessment process.

The following summarises some of the important points made at the various workshops and indicates whether or not those points can be taken forward into the project plan.

1. The Potsdam Meeting 7 March 2001

At this meeting three options were discussed for IA development. The first considered building a show case, comprehensive, harmonised model. The second was to provide crucial modules missing from present IA development, such as tourism, aviation, advanced health models, links with pollution, transport issues, extreme weather events, globalisation, abrupt climate change, and biodiversity. The third was to set up demand-command IAM frameworks, in which stakeholders would interact with the model via a sophisticated interface.

2. The Start-up Meeting 9 April 2001

At this meeting it was decided to focus on the second and third options discussed at the Potsdam meeting. It was felt that Tyndall could make a major contribution in the areas of stakeholder involvement and social discourse. The desirability of a modular and flexible structure was emphasised at the this meeting and this has been retained throughout the blueprint project.

3. The June 2001 Workshop

21 attendees including Guy Engelen (RIKS), Jan Rotmans (ICIS), Chris Hope (University of Cambridge) and Nebojsa Nakicenonovic (IIASA) discussed the tools to be used in constructing the IAM and the key features it should encompass. At this workshop it was decided that:

- the model should handle uncertainty;
- short term issues should be investigated in the light of long term outcomes
- local issues should be investigated the context of global scales

All three ideas have been carried through to the current model design. Peter Challenor suggested use of a Bayesian approach to uncertainty analysis in the IA which has now been funded as a round 2 project.

At the workshop presentations on the existing IA models IMAGE and MODULUS, and Jan Rotmans' overview of how IAMs had evolved through 1st generation (IMAGE and DICE) through second generation (GCAM and ESCAPE) to third generation (IMAGE2 and AIM) provided a suitable context for decision making with regard to model design. Issues of multiple scale modelling, agent-based modelling, and stakeholder involvement were all considered useful features to include. In fact the current model plans include all of these aspects. Jan also recommended the "soft" flexible modular approach which remains at the core of the current model design plan.

Nebojsa Nakicenovic stressed the importance of modelling technical change endogenously, which remains a key aim of the current model design plan.

He also encouraged the inclusion of feedbacks, a suggestion which has been taken on board.

At this workshop methods of participative stakeholder interaction processes were discussed and these ideas have also been taken forward. The success of the RAINS model in the policy process was highlighted as an example of the success of such participatory processes.

It was also suggested that the model should be a non-optimising model (a position which has been retained) and that the question of “what is dangerous climate change” should be addressed.

Mark Strathern provided an overview of possible technical approaches to distributed modelling. Some of these ideas have been taken forward in the SOFTIAM project (see below). The first ideas for model structure were presented by Sarah Raper, and these have also been taken forward in the current design.

There was also a suggestion to collect layers of modules of differing complexity to ensure balance and meet run-time constraints. Each layer would cover the same range of topics in increasing detail. This idea has not been carried forward since it is now thought that only simple or medium-complexity modules are suitable for use in an IA, and also because only a limited number of modules are currently available. Rather, it has been recognised that Tyndall may need to build additional reduced form modules for use in IA in cases where only complex modules exist.

The question of which modules Tyndall might need to build to fill gaps in the IA structure was also raised. A number of the round 2 projects are building such components which will ultimately be used in the IA.

4. The February 2002 Workshop

32 attendees responded to a presentation by theme 1 members (Rachel Warren, Jonathan Kohler and Alex Haxeltine) outlining the plans for integrated assessment modelling and the integrated assessment process at the Tyndall Centre. This plan included the construction of a flexible, modular IA beginning with the construction of a prototype model, and proposing a nested structure for spatial scales (Appendix 1). IA modellers were well represented, including Hadi Dowlatabadi, Tsuneyuki Morita, Joseph Alcamo, Tom Downing and Richard Tol. Although a number of invitations were sent out to industry and NGOs, unfortunately there was a poor response from these sectors with only one or two attendees from each of these categories. The following outlines the main suggestions made at the meeting, both in response to the presentation and in a series of break-out groups.

A. General

1. John Shepherd emphasised the challenge of identifying the correct compromise in terms of complexity when building an integrated assessment model. In practice this will also be affected by the availability of modules, but when selecting modules (see below) model complexity and run-time have been taken into account. In practise it has been recognised that Tyndall may need to develop additional reduced form models in place of complex ones in order for a balanced and holistic IA to be produced.
2. Quite separately from the sharing of modules in the CIAM, it was suggested that there could be international cooperation on: exchange of information especially amongst young researchers; exchange of data on regions, contributing to a central database; and participation in the IAP.
3. John Schellnhuber encouraged an exploration of robustness to paradigm shifts. This was in response to Richard Tol’s warning that some modules may have incompatible paradigms.
4. There was an encouragement to achieve consistency with UK CIP and use some of the same models used under this programme.
5. The participants agreed on the need to incorporate uncertainty analysis into the model, although some felt that this had already been done in previous IA models. In fact under CIAM we would address this in a more mathematically advanced way than has been done previously.

B. Suggestions for novel “use cases”

The participants made a large number of suggestions as to how the CIAM could break new ground in the integrated assessment modelling of climate change.

C. Putting climate change in the context of sustainable development

1. It was suggested that the CIAM should place climate in the context of sustainable development.
2. It was also suggested that a quality of life database could be built and used in the modelling system. This was deemed a good suggestion but it is too advanced for the CIAM prototype.
3. It was also suggested that CIAM could investigate how to promote sustainable development by identifying what are environmentally sound investments.
4. John Schellnhuber pointed out that a regional ensemble approach allows links with sustainable development which must be modelled at this scale.

D. Issues of scale

1. All parties agreed with the proposed nested structure for the CIAM, since it became apparent that different attendees favoured an emphasis at different spatial scales (i.e. global, national, regional and local). The nested structure avoids having to make a choice about this, although concern was raised about the validity of the boundary conditions necessary to implement the nesting.
2. Concern was also raised that not all regional models have been created equal, so that there was a danger of bias. To avoid this, it was suggested that a protocol should be drawn up to set some kind of standard for the use of regional models in the CIAM. Concern was also raised about the issue of boundary conditions which strongly influence model results and are a feature of models with nested structure. It was decided that such problems should be addressed on a case by case basis.
3. The question of whether all models should be required to have the same time step was raised. In practice, what is important is that models nest in a valid way, so time steps should match but may be multiples of each other.
4. The issue of boundary conditions between nested modules was raised. Clearly this is an area where great scientific care is needed to ensure an unbiased calculation, and in some cases robustness to assumptions about boundary conditions will need to be investigated.

E. Decision to construct a prototype model

The plan to construct an initial prototype model was reinforced by the following two responses from workshop attendees:

1. It was suggested that before moving on to complex use cases, the model should be validated using simpler standard use cases which may be compared with state of the art IA model results. A prototype model will allow the early running of a standard use case which may be compared with other IAMs, as well as two more novel use cases. More advanced versions of the model will address more complex issues such as adaptation and vulnerability.
2. Several participants stressed that a number of years would be required to get the system up and running. Owing to this the production of a prototype model has been planned to allow the Tyndall Centre and the CIAM to produce meaningful results and publications during the interim phases of model construction.

F. Issues of combining resources from different institutions

1. It was felt that greater success would be achieved in pooling modules if incentives were offered so that people saw an advantage to joining the modelling system. It was suggested that pressure applied at a higher level might be effective in achieving this aim. It was also suggested that the more novel the proposed IA approach, the more participants would be attracted. It was recommended that a sound evaluation procedure should be used when considering modules for incorporation.

2. Richard Tol requested a workplan listing optional ways forward so that people could indicate which plans they would be happy to participate in. This has not been carried out so far, since PIK and ICIS have already seemed happy to participate given the existing plans. However, this approach will be used when drawing up protocols for the incorporation of modules into the CIAM.

F. Concerning interaction with stakeholders

1. We were encouraged to engage DEFRA in policy debates. The local interests of many stakeholders was highlighted, reinforcing the need to nest models at regional and local scales into the CIAM structure. This will be done in the latter stages of CIAM development.

2. There was considerable discussion of the very advanced and distant stage of the CIAM at which point stakeholders could interact automatically with the CIAM, asking it questions which would then be filtered by a processor and expressed mathematically, to send standard sets of results back. This is the demand-command IAM framework discussed as option 3 of the Potsdam meeting on 7 March 2001.

Principles of Model Design

- The model will be flexible and multi-modular to allow a range of policy questions to be addressed, thus facilitating iterative interaction with stakeholders.
- It will be distributed, that is deployed across a wide range of institutions within and without the UK, allowing the system to cream off the best available international expertise and pool it into a single modelling framework available to all participants.
- It will be based on state of the art grid technologies which allow models to communicate with each other remotely regardless of operating system or computer language.
- The model's name will be CIAM (Community Integrated Assessment Model) reflecting the joint ownership of the model by all the institutions which contribute components or technology to it.
- It will address the global climate policy problem, taking into account issues of sustainable development where appropriate; and its design will be guided by the integrated assessment process as well as by modellers.
- The model will be global in scale, using nested regional models to evaluate regional economics and impacts.
- The model will be dynamic, looking forward in time from the present day until 2100 at least, but able to examine smaller increments within that time frame.
- The model will contain representations of feedback processes
- The model will be capable of representing technical change endogenously
- The model will contain a full uncertainty analysis to be developed under a round 2 project led by Peter Challenor
- The model should ideally cover the whole basket of 6 COP gases.

An initial prototype model (IPM) will be built by April 2003, which will consist of a small number of modules linked together. Following this, a full scale model (FSM) will be developed by September 2005 which will contain a large number of modules from a wider range of international institutions and will be capable of addressing a wide range of policy questions at the request of stakeholders. To facilitate extension of the model to additional institutions, protocols are being drawn up to lay down guidelines for joining the modelling scheme.

The model should include particularly detailed coverage of the UK situation, so a UK-scale integrated assessment module will be built to simulate mitigation and adaptation options in the UK, making use of the work being carried out in theme 2 on “decarbonising modern societies” in which a range of renewable energy technologies and options for carbon sequestration are being evaluated in terms of cost-effectiveness, public acceptability and security.

The Blueprint Project has resulted in a successful bid for Tyndall round 2 funding in a project entitled SOTFIAM led by Rachel Warren. This will develop the computational ability to implement the distributed, modular, and flexible CIAM. The project will fund IT specialists at the University of Manchester (Graham Riley and Michael Bane), another IT specialist to work at Tyndall (to be recruited) and will also fund Tim Mitchell (Tyndall HQ) in aiding scientific communication between integrated modellers and IT specialists. It will ensure that CIAM is designed such that the model is capable of continual expansion and development.

Project plan for CIAM development

We have developed a time plan for the development of CIAM, which incorporates (of necessity) the time plan for the SOFTIAM project. The CIAM will develop in two stages, the first stage being the construction of a Prototype IAM and the second stage being the evolution of that into a Full CIAM. The prototype CIAM will contain some 3-5 modules (see “Selection of Modules” below), and each module will exchange up to 10-15 parameters with other modules. Models will be coupled in a simple non-automated way between August and November 2002, whilst the XML toolkit is assembled by the SOFTIAM team. By April 2003 the Prototype CIAM will be implemented running on a single machine or a dedicated minigrid at Tyndall HQ. By December 2003 this Prototype CIAM will be deployed at a number of locations across the Tyndall Consortium. During 2003 the numbers of modules included will increase, and the complexity of the operations will increase, as the number of use cases for which the model is designed increase. In 2004, the fast efficient climate models developed by John Shepherd’s team will be incorporated. In this manner, the prototype CIAM will evolve and eventually, it will mature into the multi-institutional Full CIAM. The most advanced version will be completed in September 2005.

A UK-scale model for mitigation and adaptation will be constructed in 2003 and 2004, and nested within the CIAM by December 2004.

A basic user interface will be developed in early 2004, allowing stakeholders from a wide range of disciplines and institutions to use the IAM, thus facilitating the Integrated Assessment Process (IAP). This will be refined during the remainder of the project.

Technical Information: SOFTIAM project

The softIAM project will use open-source software and protocols, in particular XML (www.w3.org/XML) will be used to define the protocols, and describe the interfaces between modules. Globus (www.globus.org) will be used to address the main challenge, which is the secure, scalable, and co-ordinated sharing and use of computing resources across the Tyndall network that is required in order to carry out the integrated assessment. In addition, Condor (www.cs.wisc.edu/condor) may be used to harness the power of workstations.

Many of the technical issues were discussed at a software and modelling breakout group at the February 2002 workshop, where it was suggested that work should build on PIK's work in developing interface protocols. This led to a meeting between the University of Manchester Tyndall IT experts and those at PIK, where it was discovered that the PIK approach was completely compatible with the Manchester approach, since the aim of the latter is to be able to incorporate other systems regardless of platform or language.

Model coupling will begin with a design phase, in which each module must be described together with its coupling requirements, the data it makes available, the data it requires, and a set of transformation functions. The interface definitions will be coded in XML, under a predefined set of protocols. Next follows a composition phase in which module interfaces are put together, at XML level, into a model. Finally the model will be deployed, that is the XML model composition will be processed to create a "program" of the model complete with communications, which can be run. The model will take a set of resource and usage constraints (eg user priorities, machine availability, where modules can be executed etc) and be run with Globus.

In the period August to December 2002 the following elements of an XML toolkit will be developed:

1. XML protocols for the interfaces between modules.
2. A basic editor/application to manipulate XML
3. A scripting language by which to compose modules into a model in XML.
4. A 'compiler' to deploy the XML-based model with Globus.

Between April and December 2003, the following will be required to implement the prototype CIAM across the Tyndall network:

- (i) Hardware: either (a) centralised computing resources (in the form of a Linux cluster, or workstations), or (b) a machine for use as a Grid node (for example a Linux machine running Globus) at each location in the network.
- (ii) Most contributory institutions must have client Globus installations, or both client & server Globus installations.

Future work will involve further development of more sophisticated tools for the Full CIAM, using alternative sources of funding (notably eScience). We envisage future developments including sophisticated user interfaces (virtual decision theatres) which will assist with the integrated assessment process (IAP).

Selection of Use Cases

A "use case" is analogous to a requirement specification for the model. It describes the question that the model must be designed to answer. Since the model is flexible, it will ultimately be able to answer a great many questions. However, this can only be achieved by building up the model from a prototype stage at which time it is specifically designed to answer some carefully selected questions.

A number of basic use case types are common in modelling systems. They include:

- Forward simulation, that is investigating the consequences of a certain energy policy or climate change scenario.
- Optimisation, that is using economic theory to balance mitigation, adaptation and climate change damage costs
- Identification of phase changes or singularities
- Backcasting (reverse of forward simulation)
- Guard-rail approach (that is identifying tolerable windows of climate change)
- Alternative approaches that provide answers that are very robust to uncertainty.

Three well defined uses cases have been selected for the prototype model.

Model Structure and Selection of Modules

The envisaged model structure is shown in Figure 1. It consists of four main categories of linked modules:

(i) modules which simulate the energy-economy system

This includes modules which simulate the energy system; the effect of energy policies and induced technical change; regional and global economics; regional and global transport networks; regional and global agricultural models.

(ii) modules which simulate the climate system

These include analogue GCMS linked to downscaling tools to give global and regional climate change patterns; regional climate models; and fast efficient climate modules for ocean and atmospheric circulation, the carbon cycle and other biogeochemical cycles, and land-atmosphere-ocean interactions in general.

(iii) modules which simulate the impacts of climate change on humans and ecosystems

This covers modules of global biomes, biodiversity, forest cover, human health, hydrology, and extreme event frequencies.

(iv) modules which integrate the human dimension

This category describes the human response to climate change, and includes models of adaptive capacity; vulnerability indices; and agent-based models allowing the user to explore the consequences of a sequence of decisions made by a set of people (or agents) across the globe. This category is not yet shown on the diagram since ongoing studies such as the theme 3 flagship project, and the derivation of vulnerability indices by Nick Brooks, and the integrated assessment process, will determine how best to incorporate these in the model. There is a provisional plan to incorporate adaptation via the modification of damage functions to be produced under Nigel Arnell's round 2 project.

Where feedbacks exist between processes represented by the model, they will be represented in the model whether or not their magnitudes are known. However, in the prototype model only a small number of feedbacks will be included. In the full version of the IA, the link between impact damage and economics will be made quantitative so that the "loop" structure of the model is closed. Examples of feedbacks that could ultimately be incorporated in the CIAM are:

- (i) feedbacks within the climate system e.g. changes in cloud cover, albedo changes due to or ice melt, the interaction with stratospheric ozone.

- (ii) feedbacks between the climate system and ecosystem/agricultural impacts e.g. carbon uptake/release by ecosystems, methane release from permafrost, N₂O release from soil respiration, Nitrogen fertilisation, albedo changes due to biome shifts
- (iii) feedbacks between impacts and the economy e.g. changing agricultural yields, the costs of repairing damage due to extreme events, valuation estimates for damage to human health, timber resources, etc.
- (iv) feedbacks via the human response to the climate system e.g. adaptation. This includes both autonomous adaptation e.g. the additional use of air conditioning, reduced use of heating, and non-autonomous adaptation, such as altering the choice of crops to be grown, developing irrigation systems, building sea walls, etc.

The interaction with air pollutants such as SO_x, NO_x and particulate matter is dealt with below.

Many previous integrated assessment models designed to address climate change have been focused mainly on impacts, or alternatively on economic considerations. The aim is that the CIAM modelling framework should provide a balanced approach in which both economics and impacts are examined at a similar level of detail.

A comprehensive survey of modules available at PIK, Tyndall and ICIS has been carried out, resulting in a selection of modules for use in the prototype CIAM. The following section lists the modules obtained, expected and requested:

<i>Obtained</i>	<p>Category (ii) MAGIC-SCENGEN climate model (UEA, (Hulme et al. 2000))</p> <p>Brief description: set of reduced form models emulating GCM. Calculates annual-mean global surface air temperature and sea-level implications of emission scenarios for GHGs and SO₂. The SCENGEN database uses a pattern-scaling method to deduce climate change fields at 5 degree resolution, followed by a simple downscaling method to produce fields at 0.5 degree resolution.</p>
	<p>Category (i) ICEMODE economics model (PIK, (Leimbach, 2001))</p> <p>Brief description: Assesses optimal economic growth by maximising social welfare. Describes time evolution of GNP, per capita income, CO₂ emissions, etc, using an endogenous capital accumulation cycle and a technological diffusion model. Utilises a time-dependent CO₂ mitigation cost function. Multiregional global model predicting forward to 2100.</p>
	<p>Category (iii) MIASMA health module (ICIS, (Martens 1998))</p> <p>Brief description: set of 5 modules simulating thermal stress induced mortality in 20 cities, skin cancer changes in Netherlands/Australia, and changes in populations at risk to three major vector borne diseases in various areas as a result of climate changes.</p>

- Imminent* Category (iii) VECODE simple biome model (PIK, (Cramer et al. 2001))
 Brief description: Dynamic global vegetation model showing response of ecosystem processes to rising CO₂ concentrations. Includes interactions of ecosystem carbon and water exchanges. Outputs potential natural vegetation, net ecosystem production, etc.
- Expected Dec 2002* Category (i) ETECH economics MODEL ((Kohler 2002),will replace ICEMODE in prototype)
 Brief description: Global economics model considering 12 world regions and 20 sectors, incorporating a novel treatment of waves of technical change. Will allow simulation of joint implementation, clean development mechanism, carbon trading, etc. The model will be capable of representing major individual nations such as India and China.
- Category (iii) ICLIPS IMPACT ASSESSMENT TOOL (PIK, Fussel, 2002))
 Brief description: a set of climate-impact response functions and a graphical user interface
- Requested* Category (iii) THC (thermo-haline circulation) model
 Description: not yet known.

The prototype model will contain several of the above modules. In particular, within category (ii) the climate model used will be the MAGICC model which is a reduced form GCM. The use of this model allows the full range of COP gases to be covered in the analysis as planned.

- Expected* Category (ii) Fast efficient climate modules from John Shepherd's project
Requested Category (iii) LPJ Global Ecosystem Model
 Category (iii) COMPONENTS OF DINAS COAST global coastal assessment (PIK)
 Category (i) Agricultural modules (Silsoe)
 Category (iii) Extreme event modules (Tyndall)
 Category (iii) Hydrological modules (Tyndall)
 Category (i) Transport module (seeking funding)

These modules will be incorporated in 2003 and 2004 as the Prototype CIAM is developed into the Full CIAM. Some of these modules do indeed provide coverage of aspects not previously incorporated into IA models of climate change, thus fulfilling the second of the model objectives suggested at the 7 March 2001 Potsdam meeting.

The demand-command IAM structure, also suggested at the 7 March 2001 Potsdam meeting is still regarded as desirable. However, it has been recognised that this is an extremely ambitious goal, and interim steps must be taken in working toward this. The first step is clearly to model particular use cases and then frame those as questions which the user may choose to have answered. This can be facilitated by the user interface to be developed under the softIAM project. To move on to a system for automatically answering a more or less random question from a stakeholder is a much more ambitious undertaking. At this stage, the demand-command structure will be implemented in CIAM via the two-way interaction between stakeholders and model designers.

Proposed linkage with air pollution models

The CIAM system will be extended to examine not only potential future climate change but also long-range trans-boundary air pollution (LRTAP) levels in Europe and their associated impacts on human health. The advantages in linking such a next-generation climate change model and an established LRTAP integrated assessment model such as RAINS (Alcamo et al. 1990) in order to assess these two health-relevant policy areas are compelling. Most research to date has considered trans-boundary atmospheric pollution and climate change separately, even though they share many common drivers and methods of mitigation. The extension will allow comparison of future health burdens under specific environmental and mitigation strategies.

In Europe, integrated assessment modelling has been used to study changes in acidification and eutrophication under the UN ECE Convention on Long-Range Trans-boundary Air Pollution. This body selected the Regional Air Pollution Information and Simulation Model (RAINS) model of IIASA as the official model to support European policy development. This European-scale model and its counterpart, RAINS-Asia, are now being extended to the problem of reducing atmospheric particulate concentrations. It is these two models which are planned to be included in the CIAM.

Cross-Tyndall Issues

A. Implications

The model will be at the core of the Tyndall Centre's research, allowing scientists to conduct a holistic investigation into adaptation and mitigation strategies for climate change.

B. Scenarios

The CIAM will be both a source and a sink of scenarios. At a recent meeting at SPRU it was agreed that SRES and UKCIP scenarios should be explored across Tyndall, and thus they will be examined in the CIAM, which may provide input data for detailed studies within the Tyndall Centre on particular topics or regions. However, the exploration of energy policies will mean that the CIAM will provide its own solutions to the climate change problem, thus initiating new scenarios that could also be examined across the Tyndall Centre.

Both Alex Haxeltine and Rachel Warren emphasised the usefulness of a nested hierarchy of scenarios involving (for example) the derivation of a set of UK scenarios consistent with each of the main 4 SRES storylines. Thus, a 1 to many correspondence was suggested between scenarios at different scales in the integrated assessment model.

C. Tyndall Centre Links

Within Tyndall a large number of discussions have taken place to identify how work from other Tyndall projects in themes 1 to 4 can be incorporated into the integrated assessment modelling. The IA will facilitate project integration across Tyndall by making direct use of the following models/results:

1. Under the round 2 ETech+ project Jonathan Kohler will produce a global dynamic economic model allowing the modelling of novel energy policies and induced technical change and will provide new emissions scenarios for analysis.

2. With theme 2 and with Dennis Anderson's ETech+ team, we are discussing the potential creation of an integrated assessment module for UK decarbonisation.
3. Fast and efficient climate modules produced by John Shepherd's team.
4. Bayesian uncertainty analysis methods and non-standard fuzzy logic style approaches to be developed by Peter Challenor's round 2 project
5. The IA will make use of damage functions, hydrological models, and other linkages between climate drivers and impacts to be produced by Nigel Arnell's round 2 project "Interfacing climate and impacts modules in integrated assessment systems"
6. With theme 3 we will research a methodology for representing adaptive capacity at different scales in the IA model

Policy Relevance

The timescale of the development of the prototype model has been chosen to coincide with internal Tyndall quarterly/annual assessment targets. However, it has also been drawn up to facilitate the channelling of integrated assessment modelling results towards the Kyoto process. A completed model in April 2003 allows time to contribute work to the international community prior to or at the annual autumn COP meeting or at the meeting of the subsidiary body (SBSTA). Ideally, one of the main uses of the model would be to highlight certain aspects of the climate change problem to policy makers in the run up to the second commitment period of the Kyoto Protocol. The integrated assessment process should help identify the aspects of the problem which could be usefully highlighted to policy makers.

Theme 1 members have agreed that it is desirable to link the integrated assessment modelling work with policy makers within and without the UK, as far as is possible. Attendees at the February Blueprint Workshop also agreed that a focus on the second commitment period was appropriate and to be encouraged. However, it was also agreed that this should not be to the detriment of either (i) longer term modelling studies which should also be catered for within the CIAM or (ii) issues that have not been covered under the Kyoto Protocol, such as the interaction with conservation and biodiversity.

The degree of engagement that the Tyndall centre will have with policy makers is not yet known, but there are several efforts to forge a closer relationship with government departments.

Wider Relevance

It will result in the development of new methodologies for integrating different modelling approaches to the climate policy problem. The launch of the CIAM (Community Integrated Assessment Model), through the use of modules from PIK, ICIS and beyond, will create a community-owned IA system harnessing some of the best expertise in IA of climate change.

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APPENDIX 1

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Plans for IAM Construction and the development an Interactive Integrated Assessment Process: Theme 1, Tyndall Centre for Climate Change Research

The Tyndall IA team (Alex Haxeltine, Jonathan Koehler (manager), Rachel Warren) has agreed that the first phase of work on an integrated assessment modelling framework should include the construction of a simple prototype or pilot IAM. This will be a self contained model constructed largely in Tyndall which sets the scene for the construction of a next generation IAM which enables a larger number of modules and feedbacks to be considered. This will have a flexible modular structure and will be distributed between various institutions, allowing expertise from a range of organisations to be combined, and allowing a range of policy questions to be addressed by a wide range of users. Work on this will begin now and continue through 2002.

In parallel to this work we have also initiated a project to develop a conceptual meta-framework for an Interactive Integrated Assessment Process (IIAP). The meta-framework will guide the form and content of interactions with stakeholders. Its purpose will be to ensure that the research is “optimally tuned” to pertinent real-world decision-making processes. The IIAP will facilitate a reflexive

methodology where continual interactions with stakeholders will identify relevant (policy) questions; and where the development of the modelling framework itself will be aided by consultations with stakeholders. We will also seek to identify and develop highly innovative approaches for interacting with stakeholders. This may, for example, include the development of “virtual decision theatres” and/or internet-based “gaming simulations”.

The scale of the modelling work will be global, but there will be specific regional modules, and the work will include a study of the UK situation.

The remainder of this document lists the methods proposed for the design of the integrated assessment model for the construction of both the simple prototype and the full IAM.

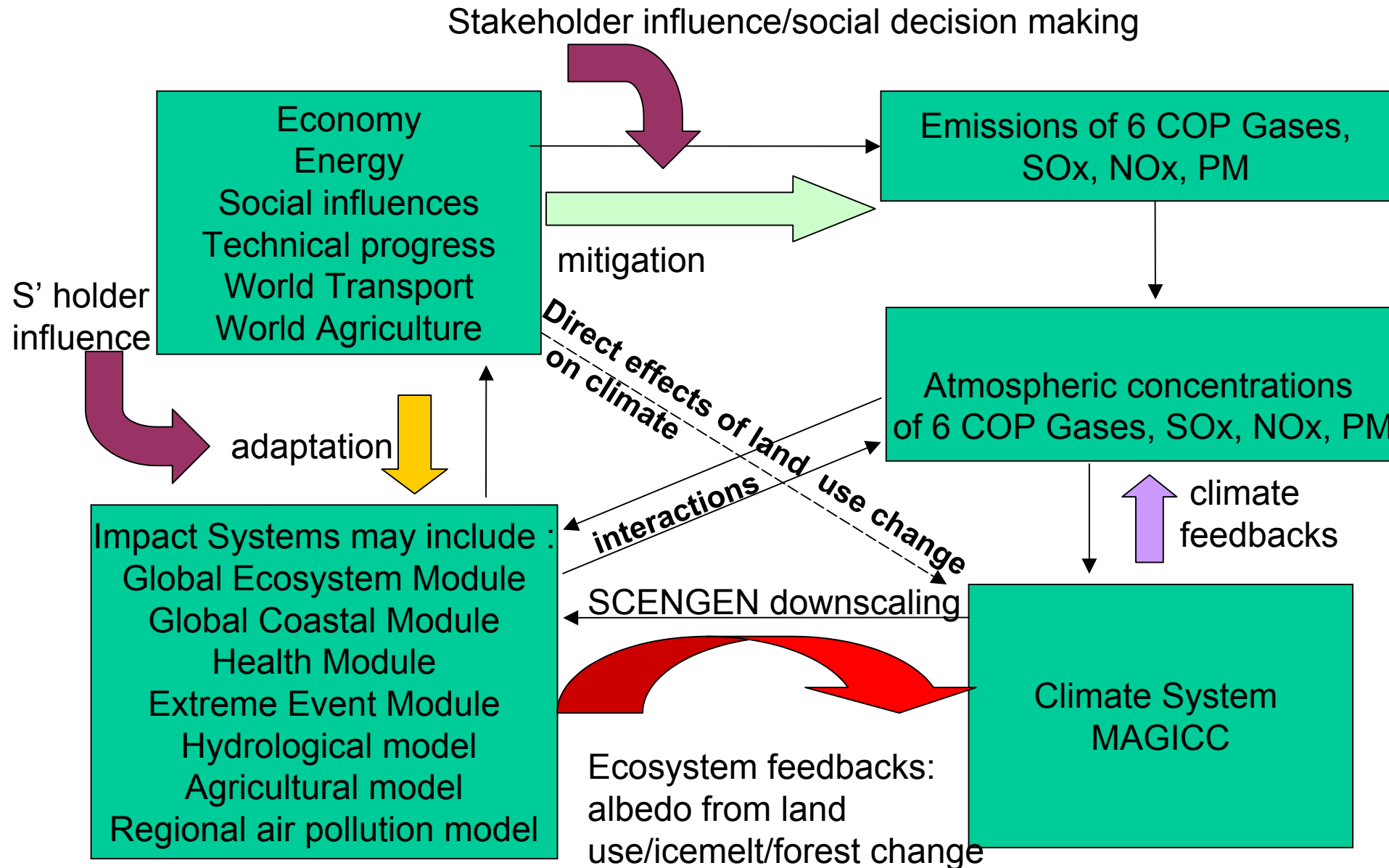
Design of the integrated assessment model

1. **Modules** from within the Tyndall centre and hopefully one or two from outside will be linked together to form a prototype model. At the moment, we plan to include MAGICC-SCENGEN or similar model; a new economic model incorporating long-term endogenous technical change; and a range of impacts modules, including a set of hydrological damage functions. The current plan for the model is shown. A code of practise is being drawn up to make sure that linkages with other institutions are carried out in a way which respects IPR and so on. At a later stage, many other modules will be linked in, forming a full third generation IAM. It is hoped that this will be facilitated by the setting up of a cooperative international integrated assessment modelling framework.
2. As far as possible the **prototype model** will pave the way for the full model in terms of **software and hardware**, taking into account what sort of protocols may be required for multi-institutional models e.g. workstations/pcs, suns/irix, unix/linux, GIS version, as well as conventions on data formatting and information/documentation of models and scenarios. **However**, a multi-institutional model may well be **web-based**, and it will not be possible to construct the prototype model in this manner. Also the initial interfacing for the prototype is likely to require completion without a software expert and this will be borne in mind. A software expert will be recruited to the project for late 2002.
3. **Policy questions to be addressed.** Some climate policy IAMs are used to provide policy makers with the effects of global/regional policies on land use/ecosystems/human systems (type 1) whilst others are used to conduct cost benefit analysis (type 2). Ultimately the full version of the IAM will do both and also answer other types of policy-related questions. The modular approach will allow flexibility here. Although valuation of benefits is useful for some stakeholders, the inclusion of this in the prototype model would delay its completion unacceptably. However, the prototype will focus on the type 1 approach, since this is the most immediately available approach.
4. Which approach should the IAM use to **link emissions to climate change and resultant effects?** Some models use a baseline climate to which is added GCM modelled output scaled by temperature rise derived from a simple parameterised climate model such as MAGIC-C which is easily accessible. Initially the prototype will rely on this approach. However the various more advanced down-scaling methods available will be reviewed and made use of if possible. In the full IAM it would be useful to allow a variety of approaches to this process.
5. **Feedback processes.** One of the main strengths of the IAM will be its ability to include feedbacks and interactions between and within different components of the model. The ability to investigate the sensitivity of important conclusions to the strengths of various feedbacks will be key. This feature will be present in the prototype IAM, although the number of feedback processes included will be smaller, and also the way in which they are represented will be

much cruder, i.e. the feedback *pathway* will be in place but the user may have to enter a value for the assumed magnitude of the feedback process. The prototype model could be used to explore the relative importance of different feedback processes to the overall model results.

6. **Mitigation and Adaptation.** The full IAM will include both processes. Initially the prototype will only address mitigation. However, should revised damage functions become available for adaptation scenarios then these could readily be made use of.
7. **Spatial Scale.** As explained the models (prototype and full) will be global. For example, MAGICC is global, the economic model will be global, and we have plans to construct a global model for transport. However, nested within the global models will be modules that look at regions only, which take inputs from the global models. This means that we assume certain boundary conditions for regional models. At first we may set up some global scenarios which the regional/local models use but later on we will allow the user to construct their own scenarios. The model will include an ability to focus on questions relevant to specific regions such as local mitigation policies and climate impacts. The UK will be one of these specific regions.
8. **Temporal Scale.** The full model will have the capability to look at a variety of temporal scales, both the next 20 years (relevant to the second commitment period) and the next 100 years. An important facet will be the ability to determine the implication of effects over 100 years for policy within the next 20 years. The prototype model's temporal scale will likely be determined by the temporal scale of the modules currently available for its construction.
9. **Extreme events.** Within each of the boxes shown in the full version of the IAM, there should be a facility to estimate the probabilities of extreme events. Such probabilities, if available, could be incorporated in the prototype model.
10. The construction of both the prototype and full IAMs will allow for some means of **sensitivity and uncertainty analysis**. Work will be carried out under Tyndall centre's round 2 funding (2002-2004) in order to determine how best to do this. Therefore, at the prototype stage the treatment of uncertainties will be simpler, involving the use of simple probability distributions, but it is important to pave the way for a more complex treatment of uncertainties in the full IAM.
11. The model's treatment of the emission projections will be **disaggregated into industrial/commercial sectors**. This will enable stakeholders to answer the 'what does it mean for us' question.
12. Environmental **impacts other than climate change** will be taken into account e.g. acidification, eutrophication, and effects on human health. This will allow estimation of "ancillary benefits" and "co-benefits".
13. The whole basket of **COP6 gases** should be included. Tyndall prototype could be seen as progressive if it did so.
14. The concept of a time-variant tolerance to temperature rise is very useful (i.e. the idea that it is the rate of temperature change that is important and hence, obviously, the model should be **dynamic** and not just consider a final equilibrium state.

Figure 1 Flow Chart for an Early Version of CIAM



The inter-disciplinary Tyndall Centre for Climate Change Research undertakes integrated research into the long-term consequences of climate change for society and into the development of sustainable responses that governments, business-leaders and decision-makers can evaluate and implement. Achieving these objectives brings together UK climate scientists, social scientists, engineers and economists in a unique collaborative research effort.

Research at the Tyndall Centre is organised into four research themes that collectively contribute to all aspects of the climate change issue: Integrating Frameworks; Decarbonising Modern Societies; Adapting to Climate Change; and Sustaining the Coastal Zone. All thematic fields address a clear problem posed to society by climate change, and will generate results to guide the strategic development of climate change mitigation and adaptation policies at local, national and global scales.

The Tyndall Centre is named after the 19th century UK scientist John Tyndall, who was the first to prove the Earth's natural greenhouse effect and suggested that slight changes in atmospheric composition could bring about climate variations. In addition, he was committed to improving the quality of science education and knowledge.

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Warren, R. (2002). **A blueprint for integrated assessment of climate change**, Tyndall Centre Technical Report 1.