growth of food plants and the melting of ice. This was investigated for the barnacle goose as an example. The model predicted that an earlier growth of food plants would allow the birds to arrive at the breeding grounds earlier, and with an increased body mass, the result being more successful breeding. The computations make it clear that satisfactory, precise climate scenarios are required, which can predict changes of temperature and other factors, like wind velocity, at all locations.

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Integrated modelling of mankind and the environment

• by Marco Janssen

The influence of human activities on the environment has reached such a scale and complexity that unequivocal solutions to the disruption can no longer be given. That is why increasing use is being made of integrated assessment, which is a multi-disciplinary process, having as its objective the integration of scientific knowledge drawn from a variety of areas. One instrument that is used in this process is the computer simulation model. There are various types of these integrated assessment models (IAM), as they are called. In general, these models are a combination of simplified versions of different expert models, allowing future scenarios to be analyzed of the entire problem area.

Integrated assessment modelling is a young field of science that rests heavily on other disciplines. The methods and techniques that are used for these models are not always the most suitable ones to describe the problem. The world around us is more recalcitrant than most models suppose. Ideally, the exploration of possible futures should take better account of uncertainties, changes in trends and norms and values.

In the thesis *Meeting Targets: Tools to support integrated assessment modelling of global change* (1996), Janssen has developed and applied several new methods and techniques in integrated assessment modelling. These methods and techniques are used on a number of case studies, some of which are discussed below.

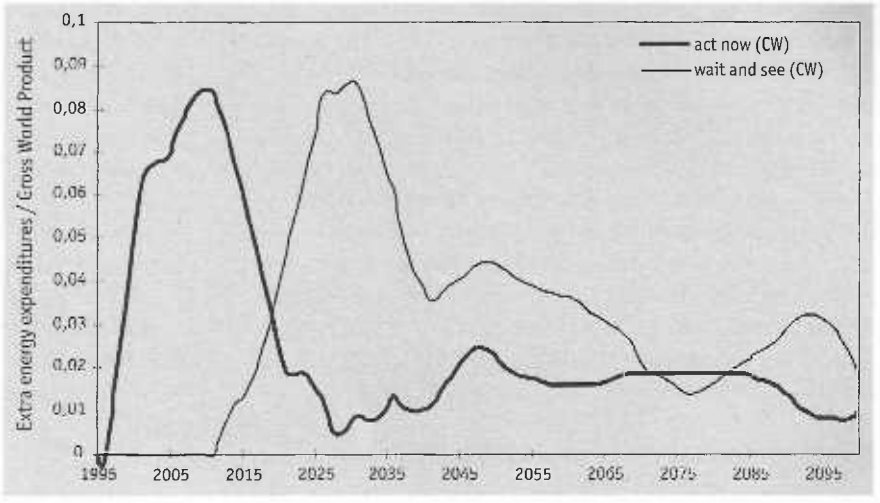
Optimisation

Many (economic) integrated assessment models make use of optimisation, which involves a radical simplification of the human–environment system in order to allow the application of classical optimisation techniques. The thesis investigates the consequences of these simplifications and explores an alternative approach. This first point is illustrated by replacing the environmental component of the economy–climate model DICE by the natural science-oriented IMAGE 1 model. Since the climate system in DICE is based on an extrapolation of the trend in historical atmospheric changes, the model is not suitable for giving a sufficiently satisfactory description of breaks in the emission trends, and this has consequences for the 'optimum' policy that will be needed if we are to meet our targets. Further, optimisation experiments have been conducted using the climate and energy related part of TARGETS. One of the conclusions of this exercise is that delaying measures will not be cost effective if one wishes to meet long-term targets (Figure 1). If policy gets off to a speedy start, then technological developments are encouraged and the restructuring does not need to be so drastic. This cancels out the cost advantages of delaying measures, i.e., lower costs of alternative energy due to technological progress.

Evolutionary modelling

The current generation of integrated assessment models is dominated by a mechanistic view of the world. The increasing pressure of human activities on the environment gives rise to a disturbance of the natural balance. A stable system is a permanent condition in this mechanistic world view.

Figure 1. Relative costs of policy on a global scale if a start is made towards achieving targets (stabilisation of CO2 concentration at 550 ppmv) either now or later.



Another approach is that of the evolutionary perspective, in which the system is seen as a changing, adapting whole, consisting of an heterogeneous collection of actors. Systems have a buffering capacity, they can roll with the punch. A disturbance of a stable situation is not by definition risky since social and ecological systems can adapt themselves to the changed circumstances. Risks occur if the changes happen so fast that the systems have no time to adapt. In this view, sustainable development involves a co-evolution between humankind and its environment.

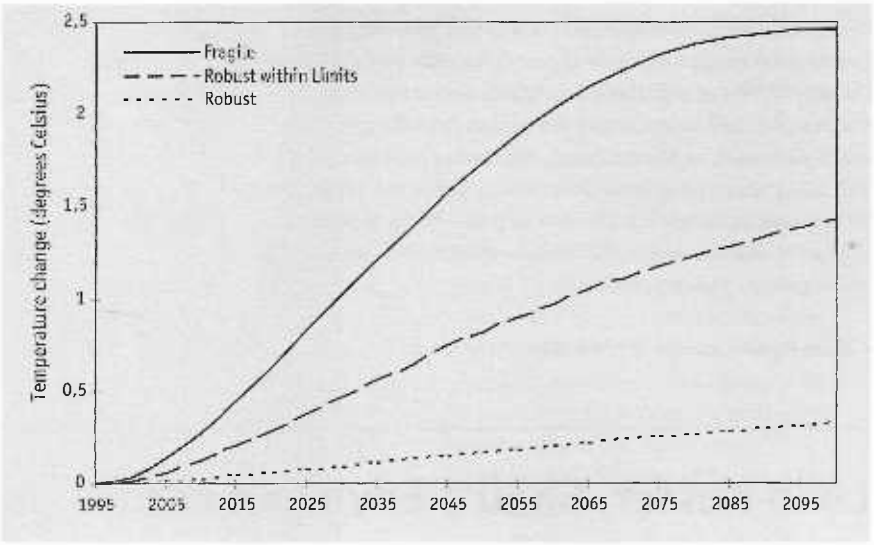


Figure 3: Average temperature increases according to different views on the functioning of the global system.

In the model area, especially in biology and economics, use is increasingly being made of what are called evolutionary modelling techniques. This approach studies the structural change of systems, and is thus interesting for integrated assessment modelling.

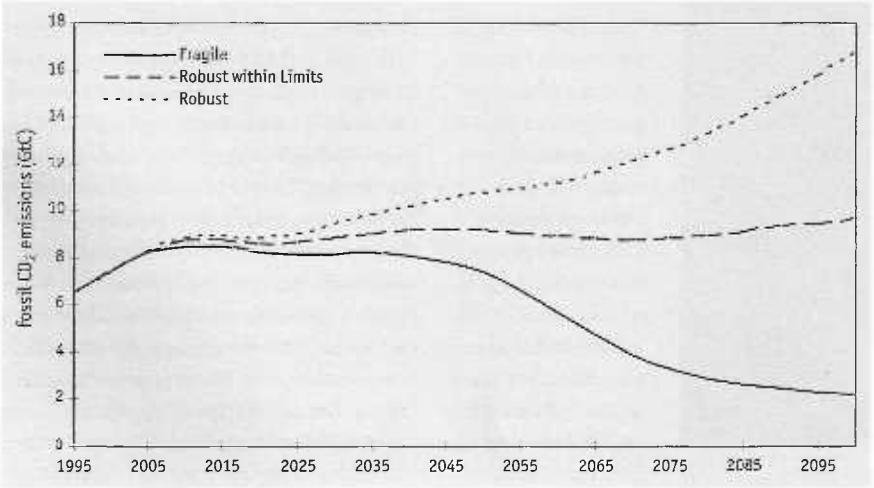
One of the areas in which this modelling technique is being used is that of the malaria problem. Malaria mosquitoes and parasites adapt to the use of insecticides and medicines, which means that malaria is difficult to combat in some areas. Malaria remains one of the major infectious diseases, even apart from any possible increase in the disease as a result of climate change.

World views

Uncertainty is often regarded as a statistical artefact, even though it is often the different interpretations of the world about us that ensure that uncertainties remain about future developments. The thesis uses different perspectives and/or world views to supply a consistent and quantitative analysis of subjective opinions on the functioning of the global system. Since there are different opinions about the problem, there will also be different preferences for the types of policy. The environmental movement, for example, thinks that the climate problem is far more serious than the government supposes, and would support more far-reaching measures than would the government.
One application of this is a model in which the actors are assumed to have different views. This is the Battle of the Perspectives. In the case study of climate change it is supposed that, within a broad margin of uncertainty, there are three types of climate system that are all equally plausible: climate change as expected according to conventional wisdom and the suppositions of the IPCC (robust within limits), a climate that is far more sensitive to human interference (fragile), and a climate that is barely influenced by human actions (robust).
The actors in the model hold different hypotheses about the climate problem. The actors may modify their hypotheses as new information comes to light. It is further assumed that the actors' policy will accord with their hypotheses about the climate problem. We thus arrive at different future scenarios that are consistent with changing insights.

Figures 2 and 3 give future projections for the three possible climate systems. One severe simplification in the model is that the actors are only preoccupied with the climate problem. The information that is acquired over time will steer emission reductions policy. If no climate change is observed, then cost considerations will cause an initially preventive emissions policy to be countermanded. On the other hand, if a severe climate change should occur, such a consensus on the climate problem will emerge that radical global emission reductions will be achieved, so that the climate change will stabilise. This exercise illustrates the importance of a flexible and robust policy in the face of uncertainties that are as large as they are in relation to the climate problem.

Figure 2: Average CO_2 emissions according to different views on the functioning of the global system



The conclusions recommend that specific attention be paid to the incorporation of multiple (modelling) paradigms in integral assessments. There is no such thing as

the correct model of reality. That is why it is necessary to incorporate alternative approaches to the complex matter of global change. The thesis contains a number of alternative approaches that may be used in integrated assessment modelling in order make allowance for uncertainties, evolutionary change, diversity, and unexpected occurrences. In this way, slowly but surely, a toolkit will emerge which will allow us to gain a better picture of unwanted disturbances to the human–environment system, thus making better policy possible.

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Leen Koster, Shell's Environment Manager: "Preferably no CO_2 storage"

• By Baud Schoenmaeckers

Shell is known throughout the world. The multi-billion dollar company employs more than 10,000 people and operates in 120 countries. Shell was recently requested to collaborate in a CO2 storage project. In the same period the first Health, Safety and Environment report appeared — a wide-ranging annual environmental report. "If you do something like that you know that it will attract criticism" says Ir. Leen Koster, Royal Dutch Shell's Manager of Environmental Affairs, in an interview about CO2 storage, the environmental report, gas flaring and Shell's standards.

Royal Dutch Shell's headquarters are in Rotterdam. The yellow-red Shell logo can be seen from far off among the mirrored windows of the skyscrapers along the city's waterfront. Ir. Leen Koster (58) has his office on the 24th floor: you can guess what the view is like. The skyline of Rotterdam's modern downtown area blends in the distance into the forest of smokestacks in Pernis where, along with others, Shell's petrochemical plant is housed. It's only a small step to CO_2 emission. Koster: "I just want to clear up a misunderstanding. The Dutch Government has set aside funding to get the rising line of CO_2 emissions down. In that context, we were approached by the Ministry of the Environment, which had established that a million tons of CO_2 would be emitted when we started up our new plant in Pernis, PER+. Now, that's not a crime, but because the Environment Ministry wants to get total CO_2 emissions down, they suggested we stored this CO_2 underground. If you look at the price per ton of CO_2 avoided, then this is a cheaper option than subsidising windmills; that's how the Ministry put it. Our cooperation was requested. The Dutch press then carried reports that we would get money for it. What Shell said was, 'We are willing to collaborate on the lowering of CO_2 emissions, but we believe that we can get a good enough result by going down the road of efficiency improvement. So, even if it were to be a financially interesting proposition for us, we still wouldn't do it.' So we didn't ask for a grant — because we really don't know whether this is the right option."

Koster: "Emitting CO_2 is no crime"

Shell did agree to collaborate in research into the possibilities of CO_2 storage. "After all, that CO_2 does come from our plant. We know the geology there. And furthermore, we are the concessionaires", says Koster. A research proposal has since been sent to the NRP steering committee to see how far storage is necessary and feasible, including the political aspects.

The total emission of CO_2 in the Netherlands amounts to about 185 million tons. So it is worth the trouble to prevent the emission of an extra million tons of CO_2 at Pernis. But Koster states that this is *not* extra CO_2 emission. "The new plant transforms hydrocarbons into hydrogen and CO_2. We use the hydrogen to upgrade products like gasoline. Across the board, our products now contain more hydrogen than they did — so they are cleaner. That means that this one million tons, which now goes up our chimney, was previously emitted by our customers, puffing out of their exhaust pipes. So these new products reduce our customers' emissions; the total emission remains the same, but it is more concentrated. Technically speaking, the environmental picture remains unchanged. It's just that a situation has been created for