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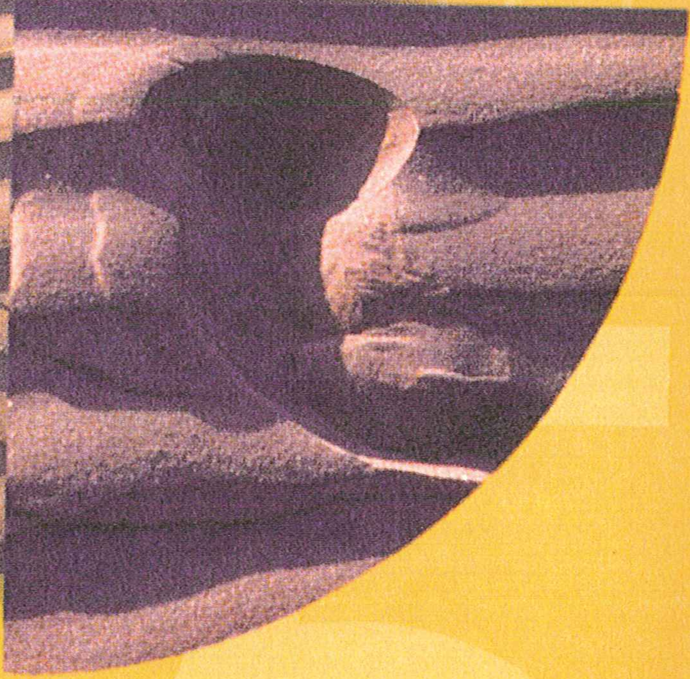
Socio-economic Tools for Sustainability Impact Assessment

The Contribution of EU Research to Sustainable Development



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EUROPEAN COMMISSION
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SOCIO-ECONOMIC TOOLS FOR SUSTAINABILITY IMPACT ASSESSMENT

THE CONTRIBUTION OF EU RESEARCH TO SUSTAINABLE DEVELOPMENT

Edited by
Marialuisa Tamborra

Environment and sustainable development programme
Policy aspects – Unit I.1

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SOCIO-ECONOMIC TOOLS FOR SUSTAINABILITY IMPACT ASSESSMENT.

THE CONTRIBUTION OF EU RESEARCH TO SUSTAINABLE DEVELOPMENT

Edited by Marialuisa Tamborra

"*Sustainable Development should become the central objective of all sectors and policies. This means that policy makers must identify likely spillovers – good and bad – onto other policy areas and take them into account. Careful assessment of the full effects of a policy proposal must include estimates of its economic, environmental and social impacts inside and outside the EU.*" – A sustainable Europe for a better world, A European Union Strategy for Sustainable Development,

"*Proposals must be prepared on the basis of an effective analysis of whether it is appropriate to intervene at EU level and whether regulatory intervention is needed… the analysis must also assess the potential economic, social and environmental impact, as well as the costs and benefits of that particular approach. A key element in such as assessment is ensuring that the objectives of any proposal are clearly defined.*" – European Governance, a White Paper

FOREWORD

The EU Strategy on Sustainable Development adopted by the European Council in Göteborg in June 2001 sets new scientific, technology and policy challenges, which have been stressed again in the international arena during the Johannesburg Summit.

With its Communication on Impact Assessment, the Commission intends to contribute to the achievement of Sustainable Development. However, its implementation is requiring extensive know-how in the fields of policy appraisal, forecasting and policy simulation.

The European Commission - DG Research has initiated and financed the implementation of a series of projects that have developed well-established impact assessment tools. The main objectives of this project series have been two-fold, namely:

- to build integrated models that combine economic and ecological dimensions for scenario building and policy analysis;
- to estimate the external costs of human activity, i.e. the value of health and environmental damages in monetary terms, so that they can eventually be reflected in the "right prices" of goods and services.

The Climate Change issue explains to a large extent the significant developments of new approaches and methods during the ninties. The tools for facing the Climate Change challenge are today operational and they will constitute with the necessary adaptations the starting point for assessing the impacts of policies and measures to be implemented as part of the EU Strategy for Sustainable Development.

It is hoped that the EU Sustainable Strategy will allow similar major developments and best practices to be developed as it was for the Climate Change Strategy design.

Pierre Valette

Head of Unit

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Director

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PART A: Introducing the methodologies for Impact Assessment

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1. BACKGROUND

The background for this booklet is the adoption of the Communication on Impact Assessment, in which the European Commission committed itself to perform an Impact Assessment of all major policy proposals (COM(2002)276final). This Communication is one of a series of initiatives on “Better Regulation”.

Its aim is to improve the quality and coherence of the policy development process. It will contribute to an effective and efficient regulatory environment and to a more coherent implementation of the European Strategy for Sustainable Development.

With this Communication, the Commission responds to its Göteborg commitments to implement Sustainable Development and to establish a tool for Impact Assessment for achieving Sustainable Development objectives. Moreover, at the Laeken Council the Commission made commitments to implement better regulation principles including a regulatory Impact Assessment mechanism. This followed the Commission’s own White Paper on European Governance.

This Communication explains how the process of Impact Assessment will be implemented in the Commission, gradually from 2003, for all major policy initiatives.

The new Impact Assessment method integrates all existing specific assessments of the direct and indirect impacts of a proposed measure (i.e. business Impact Assessment, gender assessment, environmental assessment, small and medium enterprises assessment, trade Impact Assessment, regulatory Impact Assessment etc.) into one global instrument. This single instrument will replace the existing situation of a number of partial and sectoral assessments. This approach to Impact Assessment is intended to integrate, reinforce, streamline and replace all the existing separate Impact Assessment mechanisms for Commission proposals.

2. HOW TO ASSESS ENVIRONMENTAL, ECONOMIC AND SOCIAL IMPACTS

The objective of the Impact Assessment is to provide a set of quantitative and qualitative decision variables that will guide and support policy-makers in taking decisions. The ultimate goal of the Impact Assessment is to analyse the positive and negative impacts associated with a given policy proposal, enabling informed political judgements to be made and identifying trade-offs in achieving competing objectives.

Impact Assessment is an aid to decision-making, not a substitute for political judgement. An Impact Assessment does not necessarily generate clear-cut conclusions or recommendations. It does, however, provide an important input by informing decision-makers of the consequences of policy choices.

The Impact Assessment is also an effective and valuable communication tool. Consultations with interested parties generate useful discussion and bring in valuable information and analysis that are required by the Communication on general principles and minimum standards for consultation (COM(2002)277final).

Impacts are described in qualitative, quantitative, and in monetary terms when reliable estimates are possible. Expressing all impacts in monetary terms makes it easier to compare different impacts, because everything is then expressed in the same units. However, not all impacts can be quantified in monetary terms, and the main effort should go into describing and quantifying impacts in their own terms.

In some cases, the level of uncertainty may be too high to make precise quantified estimates. In these cases, ranges of plausible values should be given. The treatment of risks and uncertainties associated with specific costs and benefits should also be included. In some cases one has to deal with cumulative uncertainties arising from incomplete knowledge of key physiological, chemical and biological processes or of human behaviour. If it is not possible to produce analytical results due to significant uncertainties or to the fact that some variables cannot be treated analytically (e.g. where there are ethical issues), then at least a qualitative assessment should be given.

The following sections first describe the tools that can help in identifying impacts (section 2.1), with particular emphasis on those models that have been developed at the EU level. Then, they illustrate the analytical methods commonly used for assessing trade-offs and support decision-making, such as cost-effectiveness, cost-benefit and multi-criteria analysis (section 2.2). Finally, section 2.3 deals with the treatment of risk and uncertainties.

2.1 Tools to Assess Impacts

Quantitative tools will often be useful to explore the outcomes of different possible options and so provide useful information for the assessment. The analysis of environment-economy linkages has been developed under the general heading of Integrated Assessment. This analysis may include the social dimension, although this is not necessarily subject to modelling.

Integrated Assessment is "a structured process of dealing with complex issues, using knowledge from various scientific disciplines and/or stakeholders, such that integrated insights are made available to decision-makers" (Rotmans, 1998).

Integrated assessment is an iterative, continuing process, where integrated insights from the scientific and stakeholder community are communicated to the decision-making community, and experiences and learning effects from decision makers constitute inputs for scientific and social assessment. Although participation of stakeholders is not necessarily a prerequisite, the engagement of non-scientific knowledge, values and preferences into the IA process through social discourse will improve the quality of IA by giving access to a wider range of perspectives and options.

However, in reality two main categories of IA can be identified. The first class includes analytical methods and is based on model analysis, scenario analysis and risk analysis. The second one relies on social sciences and mainly consists of participatory methods. In some cases, when complexity is high, multiple diverse approaches are needed, including both analytical and participatory methods.

Rotmans and Dowlatabadi (1988) distinguish between two main types of existing models, namely:

(a) macroeconomic-oriented models representing decision-analytic formulations of complex problems, based on an equilibrium framework and economic concepts, downplaying environmental dynamics, and

(b) biosphere-oriented models, which represent process-oriented descriptions of geophysical and biochemical processes and feedbacks, but do not adequately represent the socio-economic system.

Integrated models aim to combine knowledge from various disciplines in an analytical framework. A full integration of disciplines still constitutes a challenging research objective.

Figure 1 shows that the assessment and the decision-making process are two separate but mutually influencing activities and that the assessment needs to start at an early stage of the decision-making process in order to be effective. It also illustrates that impacts related to the three dimensions of Sustainability are not captured completely by the Sustainability Impact Assessment. Technical change is to be regarded as an important component of the assessment, as it influences environmental, economic and in many cases also social variables. Note that all of the techniques illustrated in figure 1 will be explained in the following sections.

As figure 1 depicts, such an assessment will provide a set of quantitative and qualitative assessment variables on both positive and negative impacts, that will guide and support policy-makers in taking decisions.

Impact Assessment is usually done using cost-benefit analysis, cost-effectiveness analysis or Multi–criteria analysis. Other methods are available such as risk analysis, cost assessment, risk-risk assessment, cross-risk analysis, etc.

Before comparing the costs and benefits of a policy proposal, the impacts should be estimated. Some of the tools for calculating those impacts have been developed within the EU research programmes. **Quantitative tools and analytical methods**, **participatory approaches** as well as **process methods** are important components of Impact Assessment. In fact, quantitative variables derived from analytical tools would be of little use without the right process tool to bring it to action. Social sciences are asked to develop methodologies, tools for better communication and social learning processes to manage large multi-disciplinary groups of stakeholders.

However, this publication focuses primarily on analytical tools and models, and in particular on those that have been developed in the context of EU-funded research. These will be described in more detail in the following sections and in Part B in particular.

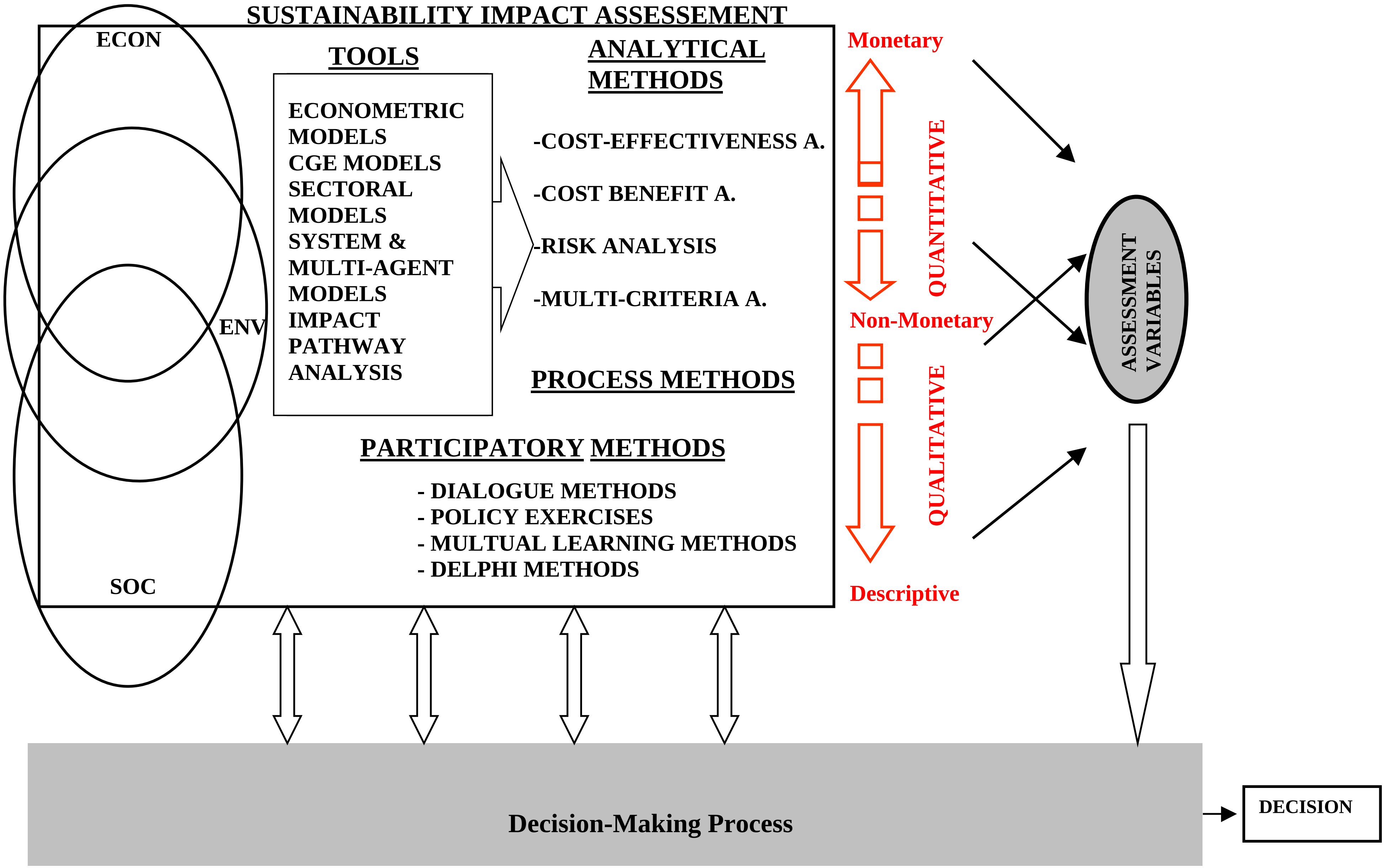

Fig. 1 : Diagram of tools and methods used for Sustainability Impact Assessment

Most relevant and well-developed ***quantitative tools*** for impact analysis purposes consist in models that can be classified into:

(1) Computable General Equilibrium (CGE) models: CGE models calculate a vector of prices such that all the markets of the economy are in equilibrium, implying that resources are allocated efficiently. They are based on economic theory and theoretical coherence (i.e. the Walrasian representations of the economy). Therefore, parameters and coefficients are calibrated with mathematical methods and not estimated as in econometric modelling. They can be static - comparing the situation at one or more dates - or dynamic, showing developments from one period to another. CGE models require an input-output table to model interrelations between productive sectors.

Examples of EU-funded CGE models

GEM-E3 is an example of a successful CGE model developed with European Commission (DG RTD) funds. It is an applied general equilibrium model for the European Union Member States, taken individually or as a whole, which provides details on the macro-economy and its interaction with the environment and the energy system. The model is being used to evaluate policy issues for the European Commission. Applications of the model have been (or are currently being) carried out for several Directorate Generals of the European Commission (economic affairs, competition, environment, taxation, research). At present, the model is operational for EU-15 Member States, while further development is under way. Further details are provided in part B, section 3.1.

(2) Sectoral models: these models are constructed on the equilibrium of one specific sector of the economy. These models are usually very detailed but are not able to capture the effects on other markets.

Examples of EU-funded sectoral models

PRIMES is a simulation model focusing on EU energy markets and as such is very useful in analysing in detail the impacts of various forms of carbon emission trading on energy markets, although its focus on the EU means that, it cannot capture some of the impacts of carbon emission trading in the wider economy (e.g. exchange rate effects, trade balances). PRIMES generates results for each of the 14 Member States (Luxembourg excluded), and has also been used to investigate the effects of carbon emission trading being limited to a subset of Member States. Because of the detailed sectoral breakdown it also allows the analysis of the effects of carbon emission trading being restricted to a number of economic sectors. The equilibrium is static (within each time period) but repeated in a time-forward path, under dynamic relationships. PRIMES is specially conceived for scenario construction and policy impact analysis. Further details are provided in part B, section 3.2.

POLES is a partial equilibrium world-wide energy market model. Its geographical coverage is different to that of PRIMES, as it covers the whole world but has a less detailed breakdown of EU Member States. This renders it an excellent tool to shed light on the consequences for international energy markets of EU carbon emission trading. On the other hand, POLES is less suited to illuminate in detail the effects of sectorally and geographically limited permit markets, because of its wide scope. Also PRIMES does not capture general economy-wide effects like changes in international trade. Further details are provided in part B, section 3.3.

Examples of EU-funded sectoral models (cont.)

TREMOVE is a sectoral simulation model developed by DG Environment. It allows the simulation of consumer behaviour with regard to the choice of modes of transport and vehicle types (i.e. size and technologies). The demand for each mode is determined by taking into account the interactions between the various modes of transport. This model allows an analysis of the extent to which policies can affect these choices and the subsequent atmospheric emissions. Moreover, it calculates the cost of policies to society. The cost components modelled in TREMOVE are the cost to transport users, transport producers, and governments. The output of TREMOVE includes, inter alia, annual forecasts of transport flows, vehicle stock size and composition, costs to society from transportation, and emissions from transport both in the base case and in any variant thereof. More information on this model can be found on: http://europa.eu.int/comm/environment/air/tremoveassessment.htm

FUND was originally set up to study the role of international capital transfers in climate policy, but soon evolved into a test bed for studying the impacts of climate change in a dynamic context, and it is now often used to perform cost-benefit and cost-effectiveness analyses of GHG reduction policies and to support game-theoretical investigations into international environmental agreements. FUND is an integrated assessment model that links scenarios and simple models of population, technology, economics, emissions, atmospheric chemistry, climate, sea level, and impacts. Climate change impacts include changes in agriculture and forestry production and consumption, energy production and consumption, health (morbidity and mortality) and ecosystems (wetland loss, land loss in km^2 etc). Impacts are functions of climate change as well as exposure and adaptive capacity, which in turn depend on population and the economy. Impacts also affect population and economic growth. Further information at: http://www.uni-hamburg.de/Wiss/FB/15/Sustainability/fund.html

SAFIRE is an engineering-economic bottom-up supply and demand model for the assessment of first-order impacts of rational (renewable and new non-renewable) energy technologies on a national, regional or local level against a background of different policy instruments and scenario assumptions. SAFIRE consists of a database and a computer model that provides decision-makers with a tool to evaluate the markets and impact of new energy technologies and policies. SAFIRE covers 33 European countries and 8 other countries world-wide. It can be applied to assess the impact of energy technology and associated policies on a number of economic indicators, such as market penetration, net employment creation, pollutant emissions (6 types), value added, import dependency, capital expenditure and external costs. SAFIRE has been used for a large number of applications and include supporting the European Commission in developing renewable electricity targets for the EU15 and for 12 Accession States. Further details are provided in part B, section 3.7.

(3) Macro-econometric models: These models are empirical and are therefore developed using coherent datasets. The parameters of the equations are estimated with econometric methodologies. They are fundamentally designed to evaluate macro-sectoral impacts of economic policies, although they have been extended to incorporate environmental dimensions.

The strength of macro-economic models relies on the validation of the equations of the model with statistical methods and on the model's ability to provide short-medium term forecasting and to evaluate the impact of policies. Moreover, these models ensure a coherent framework of analysis for analysing inter-linkages between variables.

Examples of EU econometric models

NEMESIS is a very detailed econometric model estimated on the basis of long time series. It includes 30 productive sectors and 27 consumption categories. A detailed Energy/environment module allows energy prices, volumes and subsequent pollutant emissions (CO_2, SO_2, NO_X, etc.) to be calculated. Moreover, it describes sectoral dynamics with interdependencies among activities. Another important characteristic of this model is the introduction of endogenous R&D and innovation decisions that allows for a new assessment of policies, such as energy, environmental, fiscal, R&D ones.

The NEMESIS model can be used for several policy applications. First of all, it can be used to run forecasts on short and medium term. Then, it enables energy and environment-related policies and economic, fiscal, R&D policies etc. to be assessed. Moreover, the model can assess the effects of EU RTD policy on competitiveness, employment, innovation and Sustainable Development. All results for simulations are available for each EU country or Europe as a whole both at macro and sectoral level. Further details in part B, section 3.6.

(4) System theory and system models: System theory is an interdisciplinary theory that looks at reality as organised complexity (systems) composed of more elementary elements maintaining the relationships (structure).

These systems are embedded in environments with which they exchange matter, energy and information. The behaviour of a system results from the interplay between its internal structure and interactions with its environment. System structures are characterised by positive or negative feedback loops, responsible for the often counter-intuitive and non-linear behaviour of complex systems. One of the main difficulties in building a system dynamics model has to do with the amount of data necessary for their identification and estimation. Moreover, parameter estimations remain a difficult exercise.

A new generation of system theory is called complex system theory and tries to overcome the limitation of systems that have immutable structures. **Multi-agent models** belong to this new generation. These models mainly simulate whole populations of autonomous “agents” interacting with each other inside an artificial environment having specific properties that represent real territories with their ecological, social and geological properties.

⇒ System dynamics played an important role in the emergence of the Sustainable Development concept, when the World 3 system dynamics model was used by Donella and Denis Meadows in the “Limits to growth” analysis in 1972.

(5) Impact Pathway Analysis: This is a bottom-up approach for estimating external costs starting from a particular process and its emissions, and moving through their interactions with the environment to a physical measure of impact (the main component being health), and eventually a monetary valuation. In the Dose-Response step of analysis, data from the physical, biological sciences and epidemiology are used to link a particular pollutant at different levels (the dose) with different levels of physical damage to human health and ecosystems. The calculation process is highly site-sensitive, as the aggregate impact is determined by the geographical distribution of victims or receptor ecosystems.

The EXTERNE methodology has allowed the Commission to review many of its decisions in the environmental sphere, in order to reach a better compromise between economic and environmental objectives. There have been many applications of the methodology (see Part B) where it has helped, through a quantification of the environmental and health damages, to make policy decisions that are better-informed and more consonant with the goals of Sustainable Development.

Impact Pathway Analysis in EU-funded projects

The most well known example of implementation of the Impact Pathway Analysis is the project **EXTERNE**. This is the first comprehensive attempt to use a consistent 'bottom-up' methodology to evaluate the external costs associated with a range of different fuel cycles in different locations in Europe. Local, regional and global impacts are calculated with the Ecosense software, although uncertainty attached to global impacts is still very high. Uncertainties are treated with a systematic application of the sensitivity analysis. This methodology has proved its potential also in the transport sector, in industrial technologies and in the waste sector.

Externalities analysis has a wide number of policy applications, when environmental costs borne by society need to be taken into account, such as in the definition of environmental taxes. Further details are provided in part B, section 3.8.

One offshoot from EXTERNE that is beginning to guide policy-makers in following a sustainability pathway is **GREENSENSE**, which looks both at the national/global impacts of economic activity as well as the costs associated with different thresholds of sustainability. By comparing the two, and taking account of future impacts and uncertainty in a careful way, it will provide some guidance on how adequate current policies are and where they need to be strengthened. Further details are provided in part B, section 3.9.

The uses to which EXTERNE and its associated tools have been put can be classified as follows. First, it has been used to estimate external costs, so that policy makers know how much market prices need to be adjusted to account for the full costs to society. This has been and still is highly relevant to the broader decision-making on energy and transport pricing, for example. Then, specific applications to policy decisions were carried out: how should particular directives that set standards be framed, and what level of standard was appropriate when both benefits and costs over society were taken into account? The third category of applications consists of comparisons between the costs and benefits of meeting e.g. the environmental *acquis communautaire* to the candidate countries. Another example of broader decision-making is the development of green accounts, provide a better picture of a country's economic performance, including the effects of environmental damage and depletion.

Models should be accompanied with an **analysis of risks and uncertainties** inherent to modelling. This can be done using different techniques, i.e. attaching probabilities to different outcomes or using **sensitivity analysis**. When risks cannot be estimated properly, then a **scenario analysis** should be provided (see section 6.8). Here we mainly refer to uncertainties regarding the functional form of models arising from subjective judgements, systematic errors, inherent randomness etc.

The tools illustrated above are well suited for devising impacts in a quantitative way, so that they can eventually be analysed in physical terms if multi-criteria analysis is applied in policy appraisal, or translated into monetary terms if cost effectiveness and cost-benefit analysis are to be used.

As a complement to quantitative tools and analytical methods, and especially when high uncertainties are involved, ***participatory approaches*** should be considered. These methods generally refer to social preferences, and in most cases they either refer to policy-makers' choices or expert choices. A possible classification includes:

(1) Dialogue methods: the intended users are considered as a source of information necessary for the analysis to perform the assessment. One way to do this is to involve the policy-makers and/or relevant stakeholders in the analytical process.

(2) Policy exercises: these build upon the tradition of simulation games. A policy exercise can be described as a flexibly structured process designed as an interface between scientists and policy-makers. In general, a game, usually computer-supported, is set up to represent a negotiation process in which teams of players represent parties to the negotiation (i.e. countries or regions). A policy exercise is a way to generate information on human behaviour and policy preferences.

(3) Mutual learning methods: these methods involve stakeholders and citizens who will enrich the assessment by a multiplicity of perspectives, skills and competencies. They are considered as co-producers of knowledge. Most common forms of mutual learning are: the focus group approach in which scientists play the role of facilitators and observers, and the interactive approach in which scientists are actively involved as participants.

(4) Delphi method: The aim of the Delphi method is to obtain a balanced assessment from experts, by facilitating the exchange of ideas and information while enabling each participant to have an equal input; thus preventing bias due to position, status or dominant personalities. The method involves a panel of experts who each respond separately to a specific enquiry via a series of questionnaires. Their responses are anonymous; none of the others knows who is included in the group. Responses obtained from the panel are collated by a central co-ordinator, and fed back to the respondents in a synthesised form. The respondents are then asked for a further response allowing them to revise their initial position if they so wish. The process is then repeated. The aim of this iterative process is gradually to produce a consensus amongst the group.

2.2 Methodologies for Deciding about Different Options

The tools described above help the analyst in identifying the relationships between the different components of sustainability and the impacts on these components of the policy under consideration. The next step consists in estimating these impacts and providing a final overall assessment of the policy. Experience in both Europe and USA (Navrud and Pruckner 1997) has shown that CBA and other analytical methods using environmental valuation techniques constitute an input in environmental decision-making, but cannot be taken as a stand-alone decision-making device.

The analytical methods used for the assessment can be more or less aggregated depending on the type of method used. These methodologies are often used for taking decisions about public goods and therefore often involve goods that do not have a market value. This is why the analysis should also involve the valuation of environmental goods and of external costs.

The main methodologies available are:

A) Cost-effectiveness analysis

The term 'effectiveness' implies that a measure is capable of achieving its intended results. This relates the effects of an intervention to the total amount of inputs (total costs) needed to produce these effects, with the aim of minimising the costs. Typically, cost-effectiveness analysis involves calculating a cost-effectiveness ratio using the 'least-cost method', which holds the output constant and seeks the cheapest way to achieve it (e.g. least cost per unit of CO_2 abated). Full cost-effectiveness analysis can also be used, which includes external costs in the calculation.

B) Cost-benefit analysis

Cost-benefit analysis (CBA) entails the identification and monetary evaluation of anticipated economic and social benefits and costs of proposed public initiatives. A measure is considered justified where positive net benefits can be expected from the intervention. The main difference between CBA and cost-effectiveness analysis is that the results are evaluated and translated into net monetary benefits.

CBA as the fundamental applied tool of welfare economics is based on individual preferences, and will ensure that these preferences are taken into account when decisions are made. Environmental valuation techniques based on individual preferences are consistent with the basic welfare economic principles underlying CBA. Techniques based on the preferences of decision makers, interest groups or experts can be used as an alternative or complementary decision tool to CBA.

C) Multi-criteria analysis

This term covers a wide range of techniques that all share the common aim of combining a range of positive and negative impacts in a single framework to allow easier comparison of scenarios and decision-making. The technique can be useful where the decision-maker needs to appraise projects for which there is a large amount of information on a number of different impacts, and where that information is in different formats. Impacts are presented as a mixture of qualitative, quantitative and monetary data, and show varying degrees of uncertainty.

In fact, there are many analytical techniques that could be acknowledged as Multi-criteria analysis (MCA) and consequently, many different softwares that are designed to support the analyst when performing these usual key steps:

- identification of the objective and options to achieve the objective;
- establishment of criteria to be used to compare the options (must be measurable - at least in qualitative terms);
- scoring of how well each option meets the criteria;
- assignment of weights to each criterion to reflect their relative importance to the decision;
- ranking of the options by combining their respective weights and scores.

D) Risk analysis

Risk analysis refers to assessing the risk to individuals and to society of the occurance of an undesirable event, and the possible consequences if it occurs (i.e. impact identification). Risks appraisals can then be used to determine what options are available to reduce or eliminate the risk and/or its consequences. Risk management is an activity conceptually distinct from risk assessment or valuation, involving a policy of whether and how to respond to risks to health, safety, and the environment. The appropriate level of « accepted risk » is a policy choice rather than a scientific one.

Other variants of these methods exist and can be used when appropriate. Examples are cost assessment, risk-risk assessment, cross-risk assessment etc.

Table 1 below illustrates major advantages and disadvantages of each method.

Table 1. **Advantaged and disadvantages of alternative approaches for impact analysis**

Concept	Advantages	Disadvantages
A) Cost-effectiveness analysis (CEA)	- It is used in cases where it is difficult to express benefits in monetary terms. - CEA can be useful as a comparative tool when there are a number of alternative measures under consideration, which are expected to have the same outcome.	- It does not resolve the choice of the optimal level of benefits. - CEA concentrates on a single type of benefit (which is the objective that needs to be reached), namely the intended effect of the measure, excluding possible side effects. - Moreover, CEA provides no assistance as to whether a regulatory proposal would provide net gains to society.
B) Cost-Benefit analysis (CBA)	- CBA is the most comprehensive analytical method for IA since it accounts for all (negative and positive) effects of policy measures. Therefore, it enables the analyst to compare the path of costs with the path of benefits of the proposed regulation over time. - It calculates those effects on society as a whole (e.g. business, consumers, governments, health, environment), having social welfare in mind. - CBA can also be used to rank alternative (including non-regulatory) proposals in terms of their net social gains (or losses).	- It is difficult to establish certain effects for which no quantitative or monetary data exist. - Other difficulties include the definition of the social discount rate. In fact, some important benefit components may not be quantified and consequently given less weight. While methods exist that try to value intangible impacts (e.g. environmental or health benefits), these generally rely on critical assumptions, which implies that results may be highly uncertain.

Concept	Advantages	Disadvantages
C) Multi-criteria analysis (MCA)	- It recognises multi-dimensionality of sustainability, and allows for different types of data (i.e. monetary, quantitative, qualitative) to be compared and analysed under the same framework with varying degrees of certainty. - It is a means of simplifying complex decision-making tasks, which may involve many stakeholders/decision-makers, a diversity of possible outcomes and many and sometimes intangible criteria by which to assess the outcomes. - It provides for a transparent presentation of the key issues at stake. - It allows for distributional issues and trade-offs to be clearly outlined.	- MCA includes elements of subjectivity, especially in the weighting stage where the analyst needs to estimate relative importance weights to attach to the criteria. - Also, because of the mix of different types of data, MCA cannot always show whether the benefits outweigh the costs. - Finally, time preferences may not always be reflected in MCA.
D) Risk analysis	- Scientific assessments of risks make crucial contributions to regulatory decisions, especially in the areas of public health and safety, environmental protection, resource exploitation, wealth creation, innovation and national security, indicating whether the policy will be effective in significantly reducing risks.	- Risk impacts may be diverse and not commensurate. - Risk analysis does not normally involve an assessment of the costs likely to occur if the undesirable event does happen. - Nor does it take account of any negative and positive impacts other than risks that may be linked to the proposed measures to deal with the risk and/or its consequences.

2.2.1 Valuing costs and benefits: concepts and techniques

The total of the discounted costs and benefits of a policy option is called its net present value. In principle, if it has been possible to put money values on all impacts, and the distribution of costs and benefits among different social groups is acceptable, the policy option with the greatest net present value is the most desirable.

When valuing benefits (or costs) for appraisal the basis for their valuation should be their "*opportunity cost*", where the opportunity cost is defined as the value foregone by pursuing an action.

Valuing benefits and goods for which a market exists:

Generally, market prices reflect opportunity costs, because households and firms have the best knowledge of their own costs and preferences and a strong incentive to respond to market signals and to put resources to their best possible use. However, market prices may not be available for all impacts, e.g. many environmental ones, and market values may not be reliable when for example price distortion and market failures are pervasive.

Valuing non-marketed benefits and costs:

Techniques have been developed to measure the external costs and benefits of goods that do not have a market value, describing the "willingness to pay" for or the "willingness to accept" a particular outcome. They include stated preference methods (i.e. contingent valuation, conjoint analysis, choice experiments) and revealed preference methods (travel cost method, hedonic pricing). **Revealed preference methods** are based on evidence from market transactions, for example the correlation of noise disturbance with house prices can be estimated via the use of hedonic pricing or demand for recreation that can be estimated with the travel cost method. **Stated preference methods** can be obtained by constructing hypothetical markets and asking people via questionnaires and interviews the value of a given outcome. These techniques have been used to value reduction in risks of premature deaths and non-fatal injuries, and existence values of the environment and historic buildings. While Revealed Preference and Stated Preference techniques are based on individual preferences, and are rooted in welfare economics, other methods for economic valuation of environmental and cultural amenities have also been proposed. These methods are based on the preferences of policy makers, scientific experts or specific interest groups.

Whereas revealed preference methods produce monetary values of the direct use of the environment, contingent valuation is based on primary data collected via surveys that are able to capture both direct and indirect use values of the environment. Such indirect uses include: maintaining the option of future uses, preserving it for future generations and maintaining the existence of an entity for its own sake.

Public policy, especially environmental policy, in most cases addresses costs that are not internalised in production and consumption processes and are subsequently borne by the society as a whole, without any compensation. These costs can be estimated primarily using the so-called Impact Pathway Analysis. However, the values derived are often specific to a particular area of application, and a high degree of uncertainty is usually attached to them.

Benefit/cost transfer:

Benefit transfer involves using environmental values estimated in previous valuation studies in different policy analysis exercises, rather than undertaking a costly and time-consuming valuation study for each new exercise. The literature usually refers to benefit transfers (BT), rather than value transfer. However, the transfer can involve both benefits and costs. BT is promising because it allows a database that was designed for a unique purpose (so-called "study site") to be applied to a different purpose (so-called "policy site"). Clearly BT increases uncertainty of valuation, but it can be helpful if there are time and money constraints. Value transfer involves different choices concerning first, the unit to be transferred and second, the technique to be used. The main techniques available are Unit Value transfer and Function transfer.

Simple unit transfer is the easiest approach to transferring benefit estimates from one site to another. This approach assumes that the wellbeing experienced by an average individual at the study site is the same as that which will be experienced by the average individual at the policy site. Thus, we can directly transfer the mean benefit estimate (e.g. mean WTP/household/year) from the "study site" to the "policy site". The second method involves the adjustment of a function that was developed for another purpose with appropriate adjustment factors. Finally, a meta-analysis can be conducted in order to avoid selective inclusion (i.e. choosing arbitrarily a function that is not suitable for the policy study), since a larger collection of results stemming from several individual studies is taken into account.

Databases of valuation studies have been developed to make the technique of benefit transfer easier. You can find an evaluation of the possibility of adapting one such database for use in the EU at http://europa.eu.int/comm/environment/enveco/others/evripart1.pdf. Moreover, DG RTD is developing a database for externalities called RED (Review of Externalities data), which intends to gather data from various projects on externalities that used Impact Pathway analysis, including EnternE and EXTERNE Transport, described in Part B.

2.3 How to treat Risk and Uncertainty

The effects of regulatory actions frequently are not known with certainty, but can be predicted in terms of their probability of occurrence. An assessment should take account of risks and uncertainties in the estimates of costs and benefits. Often the term "uncertainty" is used in a broad sense, however the definitions of "risk" and "uncertainty" are distinct.

In economics and decision analysis, according to Stirling (1999), the well-established formal definition of risk is that it is a condition under which it is possible both to define a comprehensive set of all possible outcomes and to attach a discrete set of probabilities (or a density function) across this array of outcomes. In some cases, probabilities are estimated explicitly and used in formal, quantitative risk analysis, while in others probabilities are not precisely stated.

Uncertainty applies to a condition under which there is confidence in the completeness of the defined set of outcomes, and there is no valid theoretical or empirical basis for assigning of probabilities to these outcomes.

Finally, Stirling (1999) defines a condition of "ignorance". This applies in circumstances where first, there is no basis for the assigning of probabilities (as under uncertainty), and second, the definition of a complete set of outcomes is also problematic. Here, it is not only impossible to rank the options, but even their full characterisation is difficult. Under a state of "ignorance", it is always possible that there are effects (outcomes) which have been entirely excluded from consideration.

In practice, the distinction between risk and uncertainty is rarely clear-cut. A probability may be assigned to a particular event, but it is seldom with absolute certainty. At the same time, the techniques for risk analysis do depend upon the precision with which probabilities are known.

The situation of "risk" is the domain under which the various probabilistic techniques of risk assessment (statistical methods) are applicable, permitting the full characterisation and ordering of the different options under appraisal. In the case of uncertainties, the analytical toolbox is less well developed, and scenario analysis is the best alternative for assessing impacts associated to different scenarios. Whilst the different options under appraisal may still be broadly characterised, they cannot be ranked even in relative terms.

Risk *assessments* should be conducted in a way that permits their use in a more general cost-benefit framework, just as the cost-benefit analysis should attempt to capture the results of the risk assessment and not oversimplify the results (e.g., the analysis should address the benefit and cost implications of probability distributions).

Risk *management* is an activity conceptually distinct from risk assessment or valuation, involving a policy of whether and how to respond to risks to health, safety, and the environment. The appropriate level of protection is a policy choice rather than a scientific one.

Depending on the degree of uncertainty, one of the following three approaches can be considered:

(a) ***Risk assessment*** involves the assessment of outcomes associated with regulatory action to address risks to health, safety, and the environment. Some of the scientific difficulties are the quality and reliability of the data, models, assumptions, scientific inferences, and other information used in risk analyses. Analysts rarely, if ever, have complete information. Little definitive information may be available about the structure of key relationships and therefore about appropriate model specification. Data relating to effects that can be identified may be sketchy, incomplete, or subject to measurement error or statistical bias. Exposures and sensitivities to risks may vary considerably across the affected population. These difficulties can lead, for example, to a range of quantitative estimates of risk in health and ecological risk assessments that can span several orders of magnitude. Uncertainties in cost estimates also can be significant, in particular because of lack of experience with the adjustments that markets can make to reduce regulatory burdens, the difficulty of identifying and quantifying opportunity cost, and the potential for enhanced or retarded technical innovation. All of these concerns should be reflected in the uncertainties about outcomes that should be incorporated in the analysis.

(b) In most appraisals, the analysis of uncertainties can be best handled by ***sensitivity analysis***. Sensitivity analysis is the calculation of how changes in particular assumptions affect the relative output of the various options being considered. Sensitivity analysis needs to be well designed and clearly presented, in order to focus on those alternatives that are most important.

It may be that a single factor is crucial to decide whether or not an option is worth implementing. In such cases a useful form of sensitivity analysis would have to test how much this factor has to decrease (if it is a benefit) or increase (if it is a cost) to make it not worth undertaking the option. This value is called a switching value or point.

(c) In other cases, the level of scientific uncertainty may be so large that a risk assessment can only present discrete alternative scenarios without a quantitative assessment of their relative likelihood. ***Scenario analysis*** can be regarded as a more complex form of sensitivity analysis. For example, in assessing the potential outcomes of an environmental effect, there may be a limited number of scientific studies with strongly divergent results. In such cases, the assessment should present results representing a range of plausible scenarios, together with any information that can help in providing a qualitative judgement of which scenarios are more scientifically plausible.

The assessment should provide sufficient information for decision-makers to understand the degree of scientific uncertainty and the robustness of estimated risks, benefits, and costs. The choice of models or scenarios used in the risk assessment should be explained.

In order to evaluate outcomes involving risks, risk assessments must provide some estimates of the probability distribution of risks with and without the regulation. Whenever it is possible to quantitatively characterise the probability distributions, some estimates of central tendency (e.g., mean and median) must be provided in addition to ranges, variances, specified low-end and high-end percentile estimates, and other characteristics of the distribution.

Overall risk estimates cannot be more precise than their most uncertain component. Thus, risk estimates should be reported in a way that reflects the degree of uncertainty present in order to prevent creating a false sense of precision. The accuracy with which quantitative estimates are reported must be supported by the quality of the data and models used. In all cases, the level of precision should be stated explicitly.

Overall uncertainty is typically a consequence of uncertainties about many different factors. Appropriate statistical techniques should be used to combine uncertainties about separate factors into an overall probability distribution for a risk. When such techniques cannot be used, other methods may be useful for providing more complete information. The following list provides some explanatory examples of such methods, but is not exhaustive:

- **Monte Carlo analysis** and other simulation methods can be used to estimate probability distributions of the net benefits of alternative policy choices. It requires explicit quantitative characterisation of variability to derive an overall probability distribution of net benefits. This approach has the advantage of weighing explicitly the likelihood of alternative outcomes, permitting evaluation of their relative importance. However, care must be taken to consider the entire output of the analysis rather than placing undue reliance on any one statistic.

- **Sensitivity analysis** is carried out by conducting analyses over the full range of plausible values of key parameters and plausible model specifications. Sensitivity analysis is particularly attractive when there are several easily identifiable critical assumptions in the analysis, when information is inadequate to carry out a more formal probabilistic simulation, or when the nature and scope of the regulation do not warrant more extensive analysis. One important form of sensitivity analysis involves estimating "switch points," that is, critical parameter values at which estimated net benefits change sign. Sensitivity analysis is useful for evaluating the robustness of conclusions about net benefits with respect to changes in model parameters. Sensitivity analysis should convey as much information as possible about the likely plausibility or frequency of occurrence of different scenarios (sets of parameter values) considered.

- **Delphi methods** involve derivation of estimates by groups of experts and can be used to identify attributes of subjective probability distributions. This method can be especially useful when there is diffuse or divergent prior knowledge. Care must be taken, however, to preserve any scientific controversy arising in a Delphi analysis, and to make systematic differences between constituencies transparent.

- **Meta-analysis** involves combining data or results from a number of different studies. For example, one could re-estimate key model parameters using combined data from a number of different sources, thereby improving confidence in the parameter estimates. Alternatively, one could use parameter estimates (elasticities of supply and demand, implicit values of mortality risk reduction) from a number of different studies as data points, and analyse variations in those results as functions of potential causal factors. Care must be taken to ensure that the data used are comparable, that appropriate statistical methods are used, and that spurious correlation problems are considered. One significant pitfall in the use of meta-analysis arises from combining results from several studies that do not measure comparable independent or dependent variables.

PART B: EXAMPLES OF EU-FUNDED PROJECTS CONTRIBUTING TO IMPACT ASSESSMENT

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3. Introducing the Tools of the EU Research

This part highlights main characteristics of some of the analytical tools developed by DG RTD and that are currently used by the European Commission and national policy-makers for supporting policies. The models PRIMES, POLES and GEM-E3 are the main integrated models that the European Commission has developed and implemented over the last few decades in the framework of the research programmes in the fields of energy, environment and sustainable development. These models have been regularly updated over time and, in some cases, they have been expanded with additional satellite models according to specific purposes. This is the case with GECS and CCGT, which constitute further developments and applications of different models (among others POLES and GEM-E3).

The same applies for Impact Pathway Analysis, where first the description of the EXTERNE methodology for energy and transport is described and then a specific application and further development is presented with the project GREENSENSE.

3.1 The GEM-E3 Model

by Nikos Kouvaritakis

Summary

GEM-E3 is an applied general equilibrium model that provides details on the macro-economy and its interaction with the environment and the energy system. It is an empirical, large-scale model, written entirely in structural form. The model computes the equilibrium prices of goods, services, labour and capital that simultaneously clear all markets under the Walras law. Therefore, the model follows a computable general equilibrium approach. In brief, the model can be characterised as follows:

- It is a multi-country model, treating each region separately and linking them through endogenous trade of goods and services.
- It includes multiple industrial sectors and economic agents, allowing the consistent evaluation of distributional effects of policies.
- It is a multi-period model, involving dynamics of capital accumulation and technological progress, stock and flow relationships and backward looking expectations.

In addition, the model covers the major aspects of public finance including all substantial taxes, social policy subsidies, public expenditures and deficit financing, as well as policy instruments specific for the environment/energy system. The model determines the optimum balance of energy demand and supply, atmospheric emissions and pollutant abatement, simultaneously with the optimising behaviour of agents and the fulfilment of the overall equilibrium conditions. In this sense, the model analyses the interactions between the economy, the energy and the environment systems.

The results of GEM-E3 include projections of full input-output tables by country, national accounts, employment, and capital flows, balance of payments, public finance and revenues, household consumption, energy use and supply, and atmospheric emissions. The computation of equilibrium is simultaneous for all regions covered by the model and foreign trade links.

A major achievement of GEM-E3 in supporting policy analysis is the consistent evaluation of distributional effects across countries, economic sectors and agents. The burden sharing aspects of energy supply and environmental protection are fully analysed, while ensuring that the economy remains at a general equilibrium condition.

Two model versions have been developed:

- *GEM-E3-World*: This covers the whole world (divided in 21 regions). In the absence of a world energy model, GEM-E3-World could serve as a tool for analysing international implications of alternative abatement strategies involving Kyoto-Annex B countries (e.g. USA, Canada, Japan, Australia and New Zealand, the FSU) as well as extensions in the longer term to include non-Annex B countries. It is being applied in the framework of the GECS and CCGT projects described later on (sections 3.4 and 3.5), in the latter case simulating imperfect competition in the market.

- *GEM-E3-Europe*: This covers EU Member States and a number of EU candidate countries individually. It is currently being used in the Commission's TCH project

(DG Research) designed to examine the economic cost of meeting CO_2 targets in the presence of endogenous growth mechanisms. GEM-E3-Europe has been used extensively in the past to examine inter alia issues of “double dividend” arising from environmental taxation given alternative ways of distributing proceeds.

Publications

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Capros P., P. Georgakopoulos, D. van Regemorter, D. Willenbockel (1998) “Aggregate Results of the Single Market Programme”, within “General Equilibrium Macro-Economic Ex-post Evaluation of the EU Single Market Programme”, Office for Official Publication of the European Communities, Luxembourg, ISBN 92-827-8810-5, Catalogue no: C1-72-96-005-EN-C. Kogan Page, Earthscan, London, ISBN 0 7494 2342 0.

Capros P. , P. Georgakopoulos, D. Van Regemorter, S. Proost, T. Schmidt, H. Koschel, K. Conrad, E.L. Vouyoukas (1999) “Climate Technology Strategies 2-The Macro-Economic Cost and Benefit of Reducing Greenhouse Gas Emissions in the European Union”, Springer-Verlag, Physica-Verlag, Berlin, ISBN 3-7908-1230-7.

European Commission (1995) “Computable General Equilibrium Model for studying Economy-Energy-Environment Interactions” GEM-E3, DG XII, EUR 16714, Brussels.

Model Characteristics

Disaggregation of the Model:

- *Products and sectors:*
    - *20 products and sectors (GEM-E3-World)*: Agriculture, Coal, Petroleum Refineries, Distribution of Gaseous Fuels - Manufacture of Gas, Electricity, Ferrous and Non Ferrous Metals, Chemical Products, Other Energy Intensive Industries, Electronic Equipment, Transport equipment, Other Equipment Goods, Other Manufacturing products, Construction, Food Industry, Trade and Transport, Textile Industry, Other Market Services, Non Market Services, Crude Petroleum, Natural Gas Production.
    - *18 products and sectors (GEM-E3-Europe)*: Agriculture, Coal, Oil, Natural Gas, Electricity, Ferrous & Non-Ferrous Metals, Chemical Products, Other Energy-Intensive Industries, Electrical Goods, Transport Equipment, Other Equipment Goods Industries, Consumer Goods Industries, Building and Construction, Telecommunication Services, Transport, Services of Credit and Insurance, Other Market Services and Non-Market Services.
- *4 economic agents*: households, firms, government and foreign sector.
- *9 government revenue and income flow categories*: direct taxation, indirect taxation, energy and environmental taxation, ad valorem taxation, property taxes, capital taxes, social security, social benefits, subsidies (production and exports), import duties and foreign sector transfers, and social security and revenues from government enterprises.

- *13 household expenditure categories*: Food, Beverages and Tobacco, Clothing and Footwear, Housing and Water, Fuels and Power, Housing Furniture and Operation, Heating and Cooking Appliances, Medical Care and Health Expenses, Transport Equipment, Operation of Transport Equipment, Purchased Transport, Telecommunication services, Recreation, Entertainment, Culture, etc., and Other Services.
- *2 primary production factors*: labour and capital.
- *Pollutant emissions*: CO_2, SO_2, NOx + greenhouse gases in GEM-E3-World.
- *Annual time path*: the model is solved annually and follows a time-forward path.

The most important results provided by GEM-E3 are as follows:

- Dynamic annual projections in volume, value and deflators of national accounts by country.
- Full Input-Output tables by country/region and for EU-15/World as a whole, for the sectors mentioned above.
- Distribution of income and transfers in the form of a social accounting matrix by country/region.
- Employment, capital, and investment by country/region and sector.
- Atmospheric emissions, pollution abatement capital, purchase of pollution permits and damages.
- Consumption matrix by product and investment matrix by ownership branch.
- Public finance, tax incidence and revenues by country/region.
- Full trade matrix for EU-15 and the rest of the World (GEM-E3-Europe) or for the whole World by region (GEM-E3-World).

3.2 The PRIMES Energy System Model

by Nikos Kouvaritakis

Summary

PRIMES is a modelling system that simulates a market equilibrium solution for energy supply and demand in the Member States of the European Union. The model determines the equilibrium by finding the prices of each energy source such that the quantity supplied matches the quantity demanded. The equilibrium is static (within each time period) but repeated in a time-forward path, under dynamic relationships.

PRIMES is intended for forecasting, scenario construction and policy impact analysis. It covers a medium to long-term horizon. It is modular and allows either for a unified model use or for partial use of modules to support specific energy studies. The model can support policy analysis in the following fields:

- standard energy policy issues: security of supply, strategy, costs etc,
- environmental issues,
- pricing policy, taxation, standards on technologies
- new technologies and renewable sources
- energy efficiency in the demand-side
- alternative fuels
- energy trade and EU energy provision
- conversion decentralisation, electricity market liberalisation
- policy issues regarding electricity generation, gas distribution and refineries.

Although behavioural and price driven, PRIMES simulates in detail the technology choice in energy demand and energy production. The model explicitly considers the existing stock of equipment, its normal decommissioning and the possibility for premature replacement. At any given point in time, the consumer or producer selects the technology of the energy equipment on an economic basis and can be influenced by policy, market conditions and technology changes. The model is particularly technology-rich and is therefore suitable for exploring the possibilities offered by technological developments including the impact of policies that induce technical change. Due to its high level of disaggregation, it is capable of simulating permit market configurations to a very high degree of refinement.

Environmental impacts are also integrated into PRIMES. The optimisation modules simultaneously consider energy and environmental costs. Constraints are built in to represent environmental regulation. The technology choice mechanisms also consider abatement equipment. The main policy instruments for the environment, as considered in PRIMES, are regulations by sector and by country, environmental taxation, pollution permit market and subsidisation of abatement costs for electricity and steam.

Policy Applications

PRIMES has been extensively used for analysing climate change strategy by DG Research (technological aspects), DG Environment (sectoral targets, permit trade, climate negotiations), the European Environment Agency (monitoring and projections of atmospheric pollution) and DG TREN (energy policy issues and uncertainties). It is currently being used as the centrepiece in the context of a major study by DG TREN covering a wide range of energy policy issues.

Publications & Website:

Capros P., L. Mantzos, D. Petrellis, V. Panos, K. Delkis, J-F. Guilmot and E.L. Vouyoukas (1999), "European Union Energy Outlook to 2020", special issue of "Energy in Europe", European Commission Directorate General for Energy, November 1999, ISBN 92-828-7533-4.

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European Commission (1995) PRIMES, DG XII, EUR 16713, Brussels.

http://www.e3mlab.ntua.gr/manuals/PRIMsd.pdf

Model Characteristics

Regions*:* 14 EU Member States (Luxembourg is excluded)

Fuel types: 24 energy fuels in total: Coal, Lignite and Peat, Crude Oil, Residual Fuel Oil, Diesel Oil, LPG, Kerosene, Gasoline, Naphtha, Other oil products, Bio-fuels, Natural and derived gas, Thermal Solar (active), Geothermal low and high enthalpy, Steam (industrial and distributed heat), Electricity, Biomass and Waste, Hydrogen, Solar electricity, Wind, Hydro.

Energy Demand Sectors:

- Residential: The residential sector distinguishes five categories of dwelling defined according to the main technology used for space heating. Dwellings are further subdivided in energy uses. The electric appliances for non-heating and cooling are considered as a special sub-sector, which is independent of the type of dwelling.
- Commercial: The commercial and agriculture sector distinguishes 4 sub-sectors, which are further subdivided by energy uses defined according to the pattern of technology. In total 7 sub-sectors and more than 30 end-use technology types are defined.
- Industry: The industrial model separately formulates 9 industrial sectors, namely iron and steel, non-ferrous metals, chemicals, building materials, paper and pulp, food drink tobacco, engineering, textiles and other industries. For each sector different sub-sectors are defined (in total about 30 sub-sectors, including recycling of materials). At the level of each sub-sector a number of different energy uses are represented.
- Transports: The transport sector distinguishes passenger and goods transport as separate sectors. They are further subdivided in sub-sectors according to the mode of transport (road, air etc.). At the level of sub-sectors, the model structure defines several technology types; 6 to 10 alternative technologies for each mode are included.

Energy Supply Sectors:

- Electricity production: 148 different plant types per country for the existing thermal plants; 678 different plant types per country for the new thermal plants; 3 different plant types per country for the existing reservoir plants; 30 different plant types per country for the existing intermittent plants. Chronological load curves, interconnections, network representation; three typical companies per country; Cogeneration of power and steam, district heating.
- Refineries: 4 refineries with typical refinery structure; 6 typical refining units (cracking, reforming etc.)
- Natural gas: Regional supply detail (Europe, Russia, Middle Africa, North Sea etc.); Transportation, distribution network.

Time Horizon

PRIMES runs for the period 2000-2030, in 5-year intervals.

Output (Dynamic Annual Projections in Specific Units)

- Full detailed EUROSTAT Energy Balance sheets per country and per year
- Energy costs, producer and consumer prices
- Power generation park, load curves, load factors, investment and marginal costs (central systems, combined heat-power, exchanges)
- Refining units, expansion, costs
- Natural gas transport and distribution: flows, capacities, costs
- Endogenous treatment of energy savings and new technologies
- Atmospheric emissions (CO_2, NO_x, SO_2), abatement equipment and standards

Software: GAMS v. 2.25 with PATH solver and Cplex (or OSL), MS EXCEL v. 7.0 or later.

3.3 The POLES model: Prospective Outlook on Long-term Energy Systems

by Patrick Criqui

Summary

The POLES model has been developed under different projects of the JOULE programs and Fifth Framework Programme of DG Research under the co-ordination of IEPE (Institut d'Économie et de Politique de l'Énergie - CNRS). In these projects, fruitful co-operations have been involved in further developments of the model, in particular with IPTS and ICCS-NTUA.

POLES is a global model for the world energy system to 2030. It has been designed in the framework of a hierarchical structure of interconnected sub-models at the international, regional, national level. The dynamics of the model is based on a recursive (year by year) simulation process of energy demand and supply with lagged adjustments to prices and a feedback loop through international energy prices.

The main advantages of the model are its comprehensive *and* detailed structure – both in terms of regional or sectoral disaggregation – and the fact that it allows the fundamental variables in energy market developments and in inter-technology and inter-fuel competition to be determined. The model is also particularly suited for the study of energy technology scenarios under environmental constraints.

Being a partial equilibrium model with exogenous world economic projections, the POLES model, however, does not account for macro-economic feedbacks and indirect impacts of energy and environment policies.

Policy Applications

Since its full implementation in 1997, the POLES model has been used by the European Commission (DG Research, DG Environment and DG-Transport and Energy) and other public national institutions[1]. The main areas for policy applications have been the following:

- detailed world energy scenarios to 2030 with outlooks on energy demand, supply, trade and prices by world region;
- simulation of CO2 emission constraints, whether for the Kyoto “First Commitment Period” or for longer-term international climate regimes. These studies have produced insights on (i) abatement costs by region and by sector, (ii) in-depth analyses of the impacts of flexibility instruments and flexibility regulations in the Kyoto Protocol negotiation process and (iii) aspects of international equity and effectiveness in the long run;
- technology scenarios and endogenisation of technical change. The studies are based either on the development of a set of exogenous hypotheses defining possible major technological breakthroughs, or on an endogenous technological change approach that takes into account the impact of learning by doing and of R&D on technology performance.

[1] In France it has been used by the Ministry of Environment, Mission Interministérielle sur l’Effet de Serre.

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Criqui P., Kouvaritakis N. and Thonet C.- « World post-Kyoto scenarios: benefits from accelerated technology progress ».- *International Journal of Global Energy Issues*, 14 (1, 2, 3), 2000, p. 184-203.

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European Commission (1996) POLES 2.2, DG XII, EUR 17358, Brussels.

Model Characteristics

The POLES model is a partial equilibrium model of the world energy system. The recursive simulation process (year by year) for energy demand and supply allows the lagged adjustments to the variations in international energy prices to be accounted for, while a feedback loop derives endogenous price changes from the supply and demand balance in the previous period.

The predominance of price adjustment mechanisms in every module of POLES allows consistent simulations of environmental policies to be produced, through the introduction of "penalties" for greenhouse gas emissions. These penalties can be the result the result either of environmental taxes or of emission permit systems.

The model has been initially designed in order to provide simulations of the impacts of long term energy scenarios, but the developments rapidly aimed at providing detailed economic assessments of abatement policies and of their consequences on energy technologies' performances and markets.

Quantitative characteristics:

In the current geographic disaggregation of the model, the world is divided into 38 countries / regions. The largest countries in terms of energy and emissions are identified and treated with a detailed model. In the current version, these countries are the G8 countries and all EU Member States plus five key developing countries: Mexico, Brazil, India, South Korea and China. The remaining sub-regions are dealt with more compact and homogeneous models.

For each region, the model articulates four main modules dealing with: final energy demand by main sectors; new and renewable energy technologies; the conventional energy and electricity transformation system; the fossil fuel supply.

In the detailed demand models the consumption of energy is disaggregated into 15 homogeneous sectors which allow the identification of the key energy-intensive industries, the main modes of transport and the residential and tertiary activities.

Twelve technologies are considered in the New and Renewable Energy module, from biomass gasification to fuel cells, wind and photovoltaics. Twelve technologies are also considered for large-scale power generation form "clean coal" to GTCC (Gas Turbine Combined Cycle) and "Third generation" nuclear power plants.

Software:

Most development and uses of the POLES model have been performed with the TROLL Software, while a VENSIM version of the model has been recently developed at IPTS.

Inputs:

The energy balance data for the POLES model are extracted from the ENERDATA database[2]. International macro-economic data concerning GDP, the structure of economic activity, deflators and exchange rates come from the CEPII-CHELEM database[3]. Techno-economic data (energy prices, equipment rates, power plant capacities, costs of energy technologies...) are gathered both from international and national statistics.

Outputs:

The model provides all information on energy flows for each country / region in a structure similar to that of a standard IEA-type energy balance. A summary balance provides a synthesised information on energy consumption and transformation, new energy technologies and electricity production capacities.

From the model's simulations Marginal Abatement Curves are also produced (at national or sectoral level), in order to study the impacts of flexibility mechanisms and the structure of tradable emission permit markets4.

[2] The database ENERDATA stems from national and international ststistical sources (ONU, OECD-IEA, Eurostat).
[3] The database CHELEM is based on the data of ONU, The World Bank Mondiale and FMI.
[4] They can be introduced in the ASPEN Software (Analyse des Systèmes de Permis d'Emission Négociables).

3.4 The GECS project - Greenhouse gas Emission Control Strategies

by Patrick Criqui

Summary

The goal of the GECS project is to develop global modelling tools and scenarios in order to analyse the impacts of climate policies with emission reduction for the 6 GHGs included in the "Kyoto Protocol" and under hypotheses of both "what" and "where" flexibility. The aim of the project is to fully analyse the spectrum of issues resulting from the mechanisms established at the Kyoto conference and furthermore to extend the analysis for the post-Kyoto perspectives.

The purpose of the project is twofold. First of all, it allows – on the methodological side – for a significant improvement in the scope and relevance of the partial and general equilibrium models that have up to now been used in Europe for the economic assessment of climate policies. These methodological improvements, based on the co-ordinated use of different models, enhance the capability of each modelling system and open up the way for further developments. Second, the GECS project produces analyses of the consequences of the introducing multi-gas flexibility at world level in different long term policy settings, and helps in defining EU climate strategies, both in terms of international negotiation and domestic policies, as well as measures on R&D and agriculture and land use.

The project is based on the synergies between the POLES model of the world energy sector and the world general equilibrium GEM-E3, as complementary tools for the economic analysis of the climate negotiation. The IMAGE model developed by RIVM (The Netherlands) provides crucial sets of data and projections for GHGs other than CO_2, while a new modelling tool – the AGRIPOL model (CIRAD-AMIS, France) – has been developed for the assessment of the impacts of GHGs in agriculture. Further insights are provided concerning market imperfections and transaction costs regarding flexibility mechanisms (ZEW, Germany).

New model developments take place through the introduction of modules concerning the emission projection and Marginal Abatement Costs curves for greenhouse gas other than energy related CO_2, particularly as concerns land-use and agricultural activities. For these new developments, contributions from the IMAGE and AGRIPOL models allow a new dimension to be introduced, through the explicit modelling of land use and associated emission functions by region. This considerably increases the relevance of the existing energy or economy models in terms of coverage, and enhances their appropriateness to the issues discussed in the negotiation of the Kyoto Protocol.

Policy Applications

The project allows European decision-makers and negotiators to be provided with analytical and quantified information on the sectoral and economy-wide impacts of alternative schemes of emission entitlements, flexibility systems and policy instruments. It thus provides insights on the impact on the economy of "multi-gas" abatement policies and helps to define a European strategy in the international negotiation, while taking into account the issue of Sustainable Development at world level.

Publications and Web-site

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3.5 The CCGT project - Climate Change and Global Trade

by Christopher Böringer

Summary

The CCGT model is a large-scale multi-region, multi-sector computable general equilibrium (CGE) model of the world economy. General equilibrium provides a comprehensive framework for studying price-dependent interactions between all markets of an economy. Its main virtue is the micro-consistent representation of the direct effects and indirect feedback or spillover effects induced by exogenous policy changes. The simultaneous explanation of income origination and income spending of economic agents allows the model user to address both economy-wide efficiency as well as equity implications of policy interference. Therefore, computable general equilibrium (CGE) models have become the standard tool for the analysis of the economy-wide impacts of policy interference on resource allocation and the associated implications for incomes of economic agents.

The CCGT model is designed to assess the economic and environmental impacts of trade policies as well as of greenhouse gas (GHG) abatement policies. The main data source underlying the model is the GTAP-E version 5 database which reconciles economic production, consumption and trade data with OECD/IEA energy statistics for 50 countries and 23 commodities (sectors). Apart from a detailed representation of GHG substitution possibilities in production and consumption, the model accounts for (static) allocation and (dynamic) accumulation effects of trade liberalisation. While the former relate to the reallocation of resources and expenditures in response to relative price changes, the latter are associated with changes in the amount of resources available, i.e. the accumulation of the human and physical capital. The static allocation effects include perfect competition effects emphasised by the classical trade theory and the so-called pro-competitive effects, stemming from the interactions of different market structures and trade policies under conditions of scale economies and imperfect competition. These effects may be enforced by demand side effects due to the greater substitutability of varieties after trade integration. In addition, the model features imperfect competition on GHG permit markets accounting for risk and transaction costs as well as technology spillovers associated with the use of the so-called flexible instruments (emission trading, joint implementation and the clean development mechanism) in GHG abatement strategies.

Policy Applications

So far, the CCGT model has been used for the policy impact analysis of (i) current and future trade treaties, (ii) GHG abatement strategies under the Kyoto Protocol, and (iii) the combination (interference) of trade and environmental policies. Apart from policy-induced changes in key macroeconomic indicators such as GDP, consumption, or investment, the analysis provided detailed information on changes in competitiveness, production, employment, imports and exports at the sectoral level.

Publications and Web-site

Project web-site: http://ccgt.zew.de/

Böhringer, C. (2002), Climate Politics From Kyoto to Bonn: From Little to Nothing?, *The Energy Journal* 23(2), 51-71.

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Model Characteristics

General Characteristics:

Multi-region, multi-sector CGE model of the world economy and global energy use, imperfect competition in good markets (including emission permit markets), incorporation of risk and transaction costs associated with the use of flexible instruments in GHG abatement strategies.

Purpose of the model:

Quantitative impact analysis of economic and environmental effects induced by trade, environment and energy policies, decision support tool for rational policy making.

Software used:

Model formulated as a system of non-linear inequalities (mixed complementarity problem - MCP) and solved using GAMS.

Input variables:

Consolidated input-output tables for 50 regions and 23 sectors (base year 1997) with bilateral trade flows (GTAP), substitution elasticities, tax and tariff data, baseline data on future economic growth and emission trajectories, policy scenario settings such as emission abatement requirements, energy technology constraints (e.g. nuclear phase-out), etc.

Output variables:

Macroeconomic indicators such as GDP, consumption, employment, investment etc.; prices and quantities (production, factor demand, exports/imports) at the sectoral level; environmental indicators (e.g. GHG emissions).

3.6 NEMESIS - New Econometric Model for Environment and Strategies Implementation for Sustainable Development

by Paul Zagamé

Summary

NEMESIS - New Econometric Model for Environment and Strategies Implementation for Sustainable Development - is a detailed econometric model including 30 production sectors and 16 European countries.

The final purpose of this model is to provide a framework for evaluating different policies aimed at achieving sustainable energy use over the long term, as well as structural policies, such as environmental policies, R&D policies, fiscal policies, etc.

The economic evaluation of environmental policies is generally made with general equilibrium models well suited for long term analysis but less adapted to forecasts and scenarios, less efficient for describing the short-medium-term consequences of policies and more oriented to normative aspects of behaviour. Econometric models, on the other hand, respond more appropropriately to these needs and NEMESIS performs particularly well, thanks to its level of detail.

NEMESIS general characteristics are the following:

- *It is an econometric model*: all behavioural equations are econometrically estimated with methods using recent progress in time series econometrics, and with specification of dynamic relationships in terms of Error Correction Mechanisms. The multi-country approach allows the use of pooled panel methodology.
- *It includes a detailed energy-environment module*: in NEMESIS an energy-environment module describes the effects of different environmental and energy policies on EU economies and on the state of the environment. It consists of two sub-modules: a behavioural one which represents the effects of different policy instruments on the behaviour of agents (end of pipe or integrated abatement); and a state of environment module which uses activity indicators (sectoral added value, consumption etc.) and transforms them into energy-related indicators, such as prices, volumes and pollutant emissions (CO_2, SO_2, NO_X, etc…), differenciated by sector, country, fuel and durable goods. These are eventually translated into depositions, air concentrations and damage data.
- *It integrates new mechanisms for production*: in a first version, production is described by a production function that determines production factor demands (energy, capital and labour). The second version includes an endogenous decision of R&D and knowledge externalities (spillovers effects) between sectors and countries. These supply-side mechanisms are at the basis of the new theories of growth (endogenous growth). The equation for factor demands and prices are obtained using an assumption of optimising behaviour, according to which R&D decisions have consequences in terms of innovations. The inter-sectoral diffusion of innovations will be described with classical spillovers effect methods. This approach will be grounded on the monopolistic competition framework of the new macro-economic synthesis.

- *It represents sectoral interactions*: the NEMESIS model describes interactions between detailed sectors by four main channels :
  - the allocation of consumption between the different sectors,
  - the exchange of intermediary goods,
  - the exchange of capital goods,
  - technological transfers between sectors.

  The point of view adopted here is that medium-long term results are the result of a sectoral dynamics with strong interdependencies between activities which are described by matrices of exchange ("convert matrices") between sectors of intermediate goods, investment goods, and technology transfers.

Policy Applications

The model has a wide range of applications. First of all, as an econometric model, it can be used to run forecasts. Second, it can be used to assess the economic and environmental impacts of different economic policies. In particular, these are the targeted policies:

- energy and environmental policies (taxation, tradable permits, etc.);
- R&D policies (subsidies to R&D, search for the best actiivty for subsidising R&D, innovation etc).
- economic policies, taxation, subsidies, public expenditures, etc.

The new production module with the endogenous R&D decisions allows a new type of assessment of usual policies: the model describes a new behaviour of R&D decisions that follows a modification of prices, for instance a carbon penalty; the module also allows new policies based on R&D and innovation to be assessed.

All the results of simulations are available for individual countries or for 16 European Countries, and both at macro and sectoral level. Economic results are mainly: GDP or production and its counterpart in terms of investment, consumption, exports, imports, prices and competitiveness, employment and also internal and external financial balances. Environment-related results are: energy production and consumption, prices, pollutants emissions, etc.

Model Characteristics

The NEMESIS model provides macro-economic results, both at European and country level (GDP, exports, imports, factor demands, employment, R&D expenditures, state of the environment, etc.). As a detailed sectoral model, NEMESIS also provides some results at the sectoral level. These outputs of the model can easily be extended by using the highly customisable output function of the IODE software described below.

These are main characteristics of NEMESIS:

- Macro sectoral econometric detailed model (30 sectors) for 16 European countries.
- Annual, dynamic for the medium-long term (2-15 years).
- Supply side module with endogenous R&D decisions. Dual costs functions estimated by pooling methods.
- Energy-environment module using activity indicators from the economic part: pollutants, CO_2, SO_2, NO_X.
- Analysis of interdependencies by so-called "convert matrices" of investment goods, intermediate goods and technological transfers.

- Analysis of external exchanges.

Purpose of the Model:

The model is aimed at:

- forecasting scenarios on short-medium term (2-8 years) or coherent baseline scenarios up to 15 years, including Sustainable Devlopment scenarios;
- assessing environmental policies or energy policies and especially CO_2 mitigation policies;
- Assessing a wide scope of structural policies such as fiscal policies, R&D policies, technologies, etc.

Quantitative Characteristics and Disaggregation of Data:

- Model of about 90000 equations
- 30 productive sectors
- 27 consumption categories of households (i.e. allowing for a differentiation of taxation)
- Energy products detailed in 15 categories
- European countries

Software Used:

IODE is an econometric tool-kit with all these functions: time series construction and analysis, estimation, simulation. The simulation module implements the Gauss-Seidel method and includes a “goal seeking” algorithm, which allows the status of variables to be exchanged and an endogenous variable to be transformed into an exogenous one.

Input Variables:

Exogenous variables on international (extra European) data: world demand, prices of oil, prices of commodities, rates of exchanges of Euro, etc.

Exogenous variables on intra European countries data: rate of interest, budgetary and fiscal policy, demography, etc.

Output Variables:

Outputs at the macro level for each European country and Europe as a whole: GDP, investment, consumption, imports, exports, internal and external financial balances, prices by category, wages, employment, terms of trade, price of energies, energy consumption by category, pollutants emissions, direct energy and environmental costs.

Outputs at the sectoral level for each European country and Europe as a whole: production, value added, prices, employment, investment, intermediary consumption, sectoral exports and imports, allocation of sectoral productions between investment, intermediary consumption and final consumption.

Output from the Energy-environment module : energy consumption, price of energy, pollutants emissions, investment in plants, direct energy and environmental costs.

3.7 The SAFIRE Energy Model

by Mark Whiteley

Summary

SAFIRE is an engineering-economic bottom-up supply and demand model for the assessment of first-order impacts of rational (i.e. renewable and new non-renewable) energy technologies on a national, regional or local level against a background of different policy instruments and scenario assumptions. SAFIRE is a framework that consists of a database and a computer model that provides decision-makers with a tool to evaluate the markets and impact of new energy technologies and policies. SAFIRE is currently being updated to take into account the calculation of baselines within the Kyoto framework and for the implementation of local energy planning for municipalities.

SAFIRE can be applied to assess the impact of energy technology and associated policies on a number of economic indicators:

- market penetration
- net employment creation
- pollutant emissions (6 types)
- value added
- import dependency
- capital expenditure
- external costs
- government expenditure

These indicators are calculated as *net* effects, taking into account the impact of the new technology on the one hand and the impact caused by the displaced conventional technology on the other.

The SAFIRE database is divided into two areas, which is the base year data (based upon actual statistics) and the scenario data (a view of the future). In the main SAFIRE calculation, priority is given to *decentralised* heat and electricity generation and, in a second stage, to *centralised* heat and electricity generation (district heating & electricity). Decentralised is defined as the output being primarily generated for on-site consumption. For a given location and scenario, the primary SAFIRE calculation uses two main methodologies. The first, for *decentralised* supply, is a substitution methodology to assess the potential future supply of rational energy, matching a demand matrix defined by the user. Centralised supply is calculated on a least cost dispatching basis. If the demand side management module is activated, this is calculated first as it directly affects domestic sector demand.

Policy Applications

SAFIRE has been used for a large number of applications, ranging from micro-level local planning to market assessment for companies and international agencies, from cost benefit analyses for public institutions to local, regional, national and EU policy and planning. Some key projects include supporting the European Commission in developing renewable electricity targets for the EU15 and for 12 Accession States, helping set the national renewable target for Poland, and integrating local energy planning into municipalities in Central and Eastern Europe.

Publications & Website

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Renewable energy technologies and the European industry, M.H. Whiteley & D.M. Bess, International Journal of Global Energy Issues, Vol. 14, Nos. 1-4, 2000

The energy, environment, technology nexus, D.M. Bess & M.H. Whiteley, International Journal of Global Energy Issues, Vol. 14, Nos. 1-4, 2000

Energy for the Future: Meeting the Challenge – TERES II (The Second European Renewable Energy Study), CD-ROM, 1997

SAFIRE, European Commission, DG XII, EUR 16785 EN, Brussels, 1995

http://www.esd.co.uk

Model Characteristics

Regions: 33 European countries (15 EU Member States, 12 Central & Eastern European countries, 6 other European States), 8 other major countries worldwide (Brazil, Canada, China, India, Indonesia, Japan, Mexico, USA). Local municipalities in Austria, Bulgaria, Denmark, Germany, Ireland, Netherlands, Poland, Portugal, United Kingdom.

Fuel types: 10 biomass/waste fuels: forest residues, energy crops – wood & biofuels, solid agricultural wastes, liquid agricultural wastes, municipal solid wastes, sewage gas, landfill gas, solid industrial wastes, liquid industrial wastes and 11 conventional fuels: Electricity - peak & off-peak, natural gas, derived gas, coal, lignite/peat, heavy fuel oil, light fuel oil, petrol, diesel, nuclear fuel.

Energy Demand Sectors:

- Residential: The residential sector has a single average category of dwelling. Specific energy consumption is divided into 3 categories: space heating (thermal/electric), water heating (thermal/electric) and electricity. The DSM module further divides electricity consumption into cooling, lighting, insulation and other electrical appliances.
- Commercial: The commercial sector is divided into 7 sectors. Within each sector, there are four sizes of sub-sector – small, medium, large and very large, based upon floor area. Specific energy consumptions can be defined for electricity, space heating and water heating.

- Industry: The industrial sector is divided into 43 predefined NACE categories. Alternatively, the user can choose to specify up to 30 industrial sectors of their own choice. Specific energy consumptions can be entered for process heating (both high and low temperature), water heating, space heating, electricity and cooling.
- Agriculture: Agriculture is divided into 6 predefined sectors, or the user can define 10 agricultural sectors of their own choice. Specific energy consumptions can be entered for process heating (low temperature onlyter heating, space heating, electricity and cooling
- Transport: The transport sector calculates the potential for bio-ethanol and biodiesel as substitutes for petrol and diesel.

Energy Supply Sectors:

- SAFIRE includes an extensive database for 22 renewable energy technologies and eight new non-renewable electricity generating options, seven fuelling options for cogeneration plant including fuel cells, and a domestic sector demand side management option. All of these technologies, where relevant, can be applied as electricity only plant, thermal plant or as cogeneration. In addition to these technological options, they can be applied as decentralised or centralised (both electricity and district heating) generation.
- SAFIRE also includes two transport biofuels: Bio-ethanol, biodiesel.

Time Horizon

SAFIRE runs for a 35-40 year period from a flexible starting year specified by the user. Outputs are saved at 5-year intervals.

Output (Dynamic Annual Projections in Specific Units)

- Energy demand (heat, electricity, transport) by sector (GWh)
- Technical potential (by renewable technology) (GWh)
- Decentralised renewable market potential (by technology, sector, location, heat/electricity) (GWh, Mtoe)
- Market penetration (by technology, sector, location, heat/electricity, centralised/decentralised) (GWh, Mtoe)
- Net Employment (by technology, sector, location) (net jobs/year)
- Net emissions – CO_2, NO_x, SO_2, CO, VOCs, particulates (by technology, sector, location) (net change in tonnes of emission/year)
- Value added (by technology, sector, location) (Euro/year)
- Import dependency (by technology, sector, location) (GWh/year, Euro/year)
- Capital investment (by technology, sector, location) (Euro/year)
- External costs (by technology, sector, location) (Euro/year)
- Government expenditure (by technology, sector, location) (Euro/year)

Software: FoxPro 2.5b for PC. It is currently being redeveloped in new software (to be determined in October 2002).

3.8 EXTERNE and EXTERNE Transport

by Rainer Friedrich

Summary

The 'EXTERNE' methodology aims at assessing the impacts of energy and transport systems and technologies. The impacts of operation and life cycle of the analysed technologies on human health, materials, plants and ecosystem are quantified as far as possible and then converted into monetary units by using contingent valuation, i.e. by assessing the willingness to pay of the population to avoid the quantified damages. As damages are site-specific, a bottom-up methodology, the 'impact pathway approach' has been developed. This assessment procedure follows the impact pathway starting with the emissions of pollutants and then calculating the changes in ambient concentrations and depositions caused by these emissions. In a next step, exposure-response relationships are used to quantify the physical impacts on human health (mortality, morbidity such as non-fatal cancer, heart failure, asthma, bronchitis and so on), crops, building materials, and. In the last step, physical impacts are valued in monetary terms. As damage occurs on the local, European and global scale, all these scales are considered in the analysis.

The method has been applied to assess external costs of a large number of energy technologies (including the use of renewable energies) and transport technologies for all modes (rail, road, waterways, air) operated at numerous locations in Europe. Furthermore, versions for Asia and South America have been developed and applied.

Policy applications

The EXTERNE methodology can be used (and in fact is already used) for supporting environmental, energy and transport policies:

Special areas for application are:

- The provision of marginal external costs for policies aiming at internaliseing external costs, that means at 'getting the prices right' (as requested by the Göteborg European Council in June 2001).
- The comparison of costs and benefits e.g. for measures and directives to protect human health and the environment (as demanded by the Amsterdam treaty, Art. 175).
- The assessment of technologies, especially the identification of advantages and weak points.
- The use of monetised values of damage as sustainability and welfare indicators.

Among others, the methodology has been applied for economic evaluations of the:

- Draft directive on non-hazardous waste incineration.
- Large combustion plant directive.
- EU strategy to combat acidification.
- Costs and benefits of the UN-ECE Multi-pollutant, Multi-effect protocol
- Costs and benefits for the emission ceilings directive.

- Air quality limits for PAHs.
- Diversion of PVC from incineration to landfill and recycling.
- Costs and benefits of acidification and ground level ozone (as input to negotiation on the ozone directive 1998).
- Air quality guidelines on CO and benzene.
- Second NO_x Protocol (for the UNECE Task Force on economic aspects of abatement strategies).

Publications and Web-page

http://www.ExternE.info

European Commission, EXTERNE: Externalities of Energy, volumes 1-10, Brussels 1995/1999.

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Characteristics of the Tool used

To apply the methodology, the software tool ECOSENSE has been developed. ECOSENSE is a user-friendly modular MS-Windows based software system, running on a 32-bit Windows-PC with at least 8 MB RAM and 60 MB space available on the hard disk. The program system consists of a database holding the data needed for the Impact Assessment and several modules which are designed to manage the data and to calculate, aggregate, and present the results. By changing the contents of the database with help of the database management tools of ECOSENSE the user has the possibility to change and adapt the implemented assessment procedure.

Impacts of air pollutants (primary and secondary particles, SO_2, CO, benzene, BaP, O_3 and others) are considered for the following objects at risk:

1. human population:
   - reduction in life expectancy due to long and short term exposure to pollutants;
   - morbidity effects such as chronic bronchitis, non-fatal cancer, congestive heart failure, asthma attacks, respiratory hospital admissions, cough for different parts of the population, e.g. asthmatics, children, adults, population above 65 years, and for the total population,
2. building materials:
   - ageing of galvanised steel, limestone, mortar, sandstone, paint, rendering, and zinc for utilitarian buildings,
3. crops:
   - yield change for wheat, barley, rye, oats, potato, sugar beet, rice, tobacco, sunflower seed,
   - increased need for liming,
   - fertilising effects,
4. ecosystems:

- exceedance of critical loads for acidification and eutrophication for terrestrial as well as acidification for aquatic ecosystems.

To cover pollutant dispersion and chemical transformation on different scales, ECOSENSE provides three air transport models (for local and regional scales). For the local scale, one model calculates the dispersion of emissions from point sources (e.g. power plants); the other the transport from line sources (e.g. a car on a street). The regional model (covering the whole of Europe) simulates as well transport as chemical transformation of pollutants (into secondary pollutants like ozone, acid substances and secondary aerosols).

Input data on receptor distribution (e.g. population density), meteorology (precipitation, wind speed and wind direction), background emissions for SO_2, NO_X, NMVOC, PM_{10} and NH_3, exposure-response functions, as well as monetary values is included in the ECOSENSE database. All geographical information is organised using the EMEP co-ordinate system, which defines grid cells of 50x50 km2 covering all EU and European non-EU countries. The only missing information for performing an assessment is the pollutant emissions in question, which is defined by the user with supporting information (e.g. emission factors) provided by ECOSENSE.

Impacts from greenhouse gas emissions causing global warming are taken into account using a damage cost as well as an avoidance cost approach; that means that marginal damage costs of emitting CO_2 and other greenhouse gases are estimated in addition to the marginal avoidance costs of reaching the Kyoto targets.

For calculating impacts of noise, noise propagation models are used – one for road and rail noise and one for noise emitted by aeroplanes during the LTO (landing and take off) cycle. Damage caused by noise includes amenity losses, myocardial infarction, angina pectoris, hypertension and subjective sleep quality.

Impacts, where pollutants are transported through soil and water, before causing damage to human health, animals or plants, are analysed with a tool that simulates the path of the pollutants from the deposition of air pollutants to soil and water and from direct emissions to water and soil via ground water to agricultural plants, fish and drinking water and further to human beings.

The monetary values for assessing the different studies are derived from a thorough analysis of existing contingent valuation studies. For identifying results to monetise life years lost, surveys are currently underway within the project.

A detailed analysis of uncertainties in the applied impact pathway assessment has been carried out in the EXTERNE project series, including comparisons of modelled with measured concentration data and sensitivity analyses. With its user interfaces for changing all relevant input data, EcoSense supports sensitivity analyses by the user allowing for easy modification of assumptions. Uncertainties are still quite high. Despite these uncertainties, the use of the methods described here is seen to be useful, as the knowledge of a possible range of the external costs is obviously a better aid for policy decisions than the alternative – having no quantitative information at all. In fact, this tool will allow identification of the relative importance of different impact pathways (e.g. has benzene in street canyons a higher impact on human health than fine particles? The answer is no) and of the important parameters or key drivers, that cause high external costs, thereby facilitating a more transparent decision-making process. It also highlights promising future research strands.

The EcoSense program is a user-friendly modular MS-Windows based software system. The program system consists of a database system holding the data needed for the Impact Assessment and several modules designed to manage the data and to calculate, aggregate, and present the results.

Model specifications e. g. chemical equations, dose-response functions or monetary values are stored in a database and can be modified by the user. This concept allows an easy modification of model parameters, and at the same time the model does not necessarily appear as a black box, as the user can trace back what the system is actually doing and both intermediate and final results can be calculated.

3.9 GREENSENSE: An Applied Integrated Environmental Impact Assessment Framework in the European Union

by Pamela Mason

Summary

GREENSENSE is the latest in a series of projects dealing with 'green accounting', using the impact pathway analysis methodology developed under the EXTERNE project series. GREENSENSE aims to make two major contributions to environmental Impact Assessment and regulatory policy. These are: to improve the availability of data on the major impacts of environmental damage caused by economic activity to human health, wellbeing and the economy; and to develop and apply an environmental accounting framework that, unlike the standard green accounting framework, incorporates sustainability issues.

The project's scientific objectives are thus to:

- Develop a framework of economic and environmental reporting that accounts for both economic efficiency and sustainability. That is, the reporting framework will both report the realised effect of environmental damage on economic wellbeing, and estimate the net effect of proposed policies in terms of sustainability criteria.
- Extend the methodology by which physical environmental damage is measured. This involves updating and extending pollution databases, extending the ECOSENSE software for emissions Impact Assessment (see below: "Characteristics of the model used") and estimating the effects of biodiversity loss, resource extraction, noise and waste. The current and future effects of greenhouse gas emissions are estimated by incorporating recent research on climate change into the FUND model (see below).
- Estimate the reductions in impacts required in order to satisfy a definition of Sustainable Development.
- Attach economic costs to the environmental impacts and the actions required to meet sustainability standards (abatement costs), and use this data to apply the reporting framework.

The major advantages of this approach are that it incorporates the latest available data on emissions, analyses these to produce updated estimates of physical damage, and uses these together with an analysis of sustainability requirements to produce policy advice for both economic efficiency and sustainability. A further significant advantage is the development of a reporting framework that incorporates sustainability issues. Drawbacks are the fact that it is difficult to estimate precisely the required emissions reductions given complex interdependencies, and that abatement cost data is currently lacking.

Policy applications

The anticipated policy applications of the model include estimates of the reductions in pollution emissions, and of the other impacts outlined above, that are required (a) to achieve economic efficiency, and (b) to achieve sustainability. The reporting framework aims to highlight the economic, social and environmental benefits of proposed policies for sustainability, which may increase political support for costly measures.

Web-site

For further information see the website:

http://staff.bath.ac.uk/hssam/greensense/home.html

Characteristics of the tools used

The FUND model is a one-sector Solow-Swan model of economic growth, driven by scenarios of population and technology. Economic activity generates greenhouse gas emissions, which are fed into simple models of carbon cycle and climate. Climate change impacts include agriculture, water, energy, coastal zone, health and ecosystems. The model has nine major world-regions, namely OECD-America, OECD-Europe, OECD-Pacific, Central and Eastern Europe and the former Soviet Union, Middle East, Latin America, South and Southeast Asia, Centrally Planned Asia, and Africa. The model runs from 1950 to 2200, in time steps of a year. The model is used for the purposes of GreenSense to estimate a wide range of impacts of climate change in terms of changes (as %GDP) in:

- water resources
- cooling costs
- heating costs
- coastal protection
- land loss (km2)
- wetland loss (km2)
- ecosystems
- agricultural production and consumption
- forestry production and consumption
- forced migration (number of people)
- mortality and morbidity due to cardiovascular and respiratory diseases as well as malaria, dengue fever and schistosomiasis (number of deaths, years of life lost)

Impacts are functions of climate change as well as exposure and adaptive capacity, which in turn depend on population and economy. Impacts also affect population and economic growth. In terms of treatment of uncertainties, all parameters of the impact model have best guesses, standard deviations, and probability density functions that can be used to estimate probability density functions of the outputs. The model is programmed in TurboPascal 7.0.

The EcoSense model, developed during the EXTERNE project series, is explained in detail in the previous section. Within the GreenSense project, the EcoSense multi source version is used and further developed on a regional scale to assess environmental impacts and damage costs in whole countries and to attribute them to source sectors and countries of origin. Impacts of primary and secondary (nitrate and sulfate) particles, SO_2, CO, and O_3 on human population, building materials, crops, and ecosystems are considered. The multi source version of EcoSense will be extended as far as possible to cover also impacts from toxic substances, and a water and soil model is being developed.

A detailed analysis of uncertainties in the applied impact pathway assessment has been carried out, consisting in particular of sensitivity analyses. A comparison of modelled with measured concentration data is also included.

4. CONCLUDING REMARKS

The Communication on Impact Assessment is expected to modify the way in which European policy proposals are issued, so that the objectives of the EU Strategy for Sustainable Development are reached.

The tools presented in this booklet are not exhaustive but constitute a representative sample of some of the tools that have been developed at Community level and may serve the purposes of Impact Assessment. Their use is already well established, as we have highlighted in Part B, however it is hoped that their utilisation on a wider scale will improve sustainability in Europe.

It is also hoped that both other EU institutions and Member States will join this exercise. In some cases, Member States have already experience of policy appraisal and regulatory Impact Assessment and the Commission proposal is expected to reinforce this activity and, possibly, their experience will be shared with other EU countries. Also the contribution of European institutions other than the Commission can play an important role.

In fact, the Communication on Impact Assessment itself encourages other institutions to adopt similar new working methods. This should apply in particular to significant amendments of Commission proposals, but is also expected to have an impact on Member States, for example when transposing Directives that leave them broader margins for implementation.

This review of methodologies and tools has also highlighted their importance in the years to come and the need to carry on with research activities in the socio-economic field, and with modelling in particular.

Nowadays, the need is felt for the research community to go beyond energy and environment linkages and to develop integrated assessment models that look at impacts other than those caused by climate change. Other important aspects will be crucial for the EU policies of this century, such as water pollution, soil and groundwater pollution, and land-use issues.

Measurement methods and analytical tools need to be developed by the research community in order to prepare and shape a sustainable future for the enlarged EU.

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