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GREENHOUSE GAS EMISSION PROJECTIONS AND ESTIMATES OF THE EFFECTS OF MEASURES: MOVING TOWARDS GOOD PRACTICE

OECD Information Paper

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FOREWORD

This paper has been prepared by the OECD Secretariat for the Annex I Expert Group. It addresses approaches used by countries in producing their projections of national greenhouse gas (GHG) emissions and their estimates of effects of policies and measures on those emissions. The aim of the project is to support Annex I countries in identifying and adopting good practice in their choice, use, and communication of methods. It may be of use in the revision of UNFCCC national communication guidelines and as background information for UNFCCC in-depth reviews of national communications. In this project, only a cursory investigation into Parties' use of methods has been possible, but the findings may provide an input to more substantive work on projections and effects of measures carried out by the UNFCCC secretariat.

The paper reflects discussions held at the OECD/IEA Workshop on Methods for Producing GHG Emission Projections and Estimating Effects of Measures, held in Paris, 29-30 October 1997. It draws and builds on the background paper prepared for the workshop, as well as earlier papers on energy and non-energy emissions prepared under this project by the OECD Secretariat, with input from the IEA Secretariat and a steering group of national experts. The background paper was based on a sample of first and second national communications from Annex I Parties, information from in-depth reviews of those countries, and additional background information provided by the countries. The information contained in that paper is included in Chapters 2 and 3 of this report.

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EXECUTIVE SUMMARY

Parties in Annex I of the UN Framework Convention on Climate Change (UN FCCC) are required to produce national communications to the Conference of the Parties (CoP). In those national communications they are required to provide:

- A projection of their GHG emissions and sinks, with measures;
- The effects of the individual policies and measures on their emissions and sinks.
- A baseline, or without-measures projection of emissions and sinks;
- Estimates of the overall effect of their policies and measures on their emissions and sinks;

The main purpose of the projections and assessments of measures is to allow the CoP and others to assess progress in the implementation of the Convention. To serve this purpose, data reported in national communications need to be accurate, complete, transparent, and internationally comparable. The most important of these criteria is accuracy, or its converse, uncertainty. In monitoring progress in emission reduction by Annex I Parties, accuracy in trends (i.e. differences from the base year) is more important than accuracy in absolute levels of emissions.

Existing communications vary considerably in their completeness. Although most provide with-measures projections of CO_2 from energy, coverage of other gases and sources is variable. Parties have also adopted quite divergent approaches to defining policies and measures to be included in their communications, and hence to their inclusion in with-measures projections and their exclusion from baseline projections. As a result of this divergence, neither the projections nor the estimated effects of measures are comparable among Annex I Parties. A major step towards improving the comparability of analysis in national communications would be to develop a clear and generally understood definition of “policies and measures”.

One reason for the divergence in approaches is that most Parties have had limited resources to produce their national communications. They have, therefore, used projections that were already available. Those countries that developed new projections mostly derived them from existing energy, forestry and agriculture outlooks that were designed for a domestic audience. Such projections are not necessarily designed to provide a “best estimate” of future emissions, but may be intended as challenges to policy-makers, or to show that current policies are adequate to meet policy objectives.

Good practice in quality management and treatment of uncertainty

Quality management applies to several aspects of data collection and analysis which are necessary to develop projections or to estimate the effects of measures. These are:

1. Estimating emission factors for particular technologies and activities.

2. Assessing historical data on fuel use and other activities.
3. Assessing the evolution of economic and other drivers, and their effects, along with existing and planned government policies, on activity levels, behaviour patterns and technology.

Information resulting from the first two of these stages is necessary for producing national GHG emission inventories, as well as projections and effects of measures. The third stage is necessary for producing both emission projections and estimating effects of measures. Any uncertainty associated with historical emission factors and activity data propagates into the emission projections and estimated effects of measures, regardless of the quality or sophistication of the models used.

Good practice for developing GHG emission projections and estimates of the effects of measures might involve:

1. Using and reporting information following the source/sink categories in the IPCC guidelines for national GHG inventories;
2. Ensuring complete transparency of data and methods used for the national communication, so that an international reader can trace the origin of the information and any assumptions made;
3. Using public or stakeholder consultation processes to discuss and establish whether the assumptions and results are generally considered reasonable;
4. Where possible, using two or more methods or data sources to establish a range of possible values for each data point or analytical result;
5. Where possible, drawing on independent analysis to corroborate government data and results;
6. Where possible, estimating the statistical confidence limits or ranges for data points and results, and reporting them in the national communication;
7. Establishing the history of emissions from each source, or of proxy indicators for those emissions, over a considerable period, ideally longer than the period of the projection;
8. Introducing a procedure for ex-post evaluation of the projection, to establish the extent to which differences between projected and actual emissions can be explained and, if possible, to improve the projection method;
9. Identification in the national communication of indicators and milestones with which the effects of measures can later be verified.
10. Undertaking a national research effort and exchanging information with other Parties to ensure that all Parties have access to the best possible methods and scientific information;

CHAPTER 1. INTRODUCTION

1 Background

The UN Framework Convention on Climate Change (UN FCCC) requires each Annex I Party to produce regular national communications containing:

- "detailed information on its policies and measures...as well as on its resulting projected anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol..." (Article 4.2(b)) and
- "a specific estimate of the effects that the policies and measures...will have on anthropogenic emissions by its sources and removals by its sinks of greenhouse gases..." (Article 12.2(b)).

The Convention also requires the Conference of the Parties to:

- "promote and guide ... the development and periodic refinement of comparable methodologies... for evaluating the effectiveness of measures to limit the emissions and enhance the removal of these gases" (Article 7.2(d)) and to
- "Assess...the overall effects of the measures taken pursuant to the Convention, in particular environmental, economic and social effects as well as their cumulative impacts" (Article 7.2(e)).

A subsequent decision by CoP 1 on national communications (UNFCCC, 1996c) clarifies the requirements for development and reporting of projections and estimates of effects of measures. Parties are expected to report on several pieces of analysis in their national communications:

1. Projections of their GHG emissions and sinks, with measures;
2. The effects of the individual policies and measures on their emissions and sinks.
3. A baseline, or without-measures projection of emissions and sinks;
4. The overall effect of their policies and measures on their emissions and sinks;

Of the four pieces of analysis to be included in national communications, only the first is unambiguously defined in the national communications guidelines. The with-measures projection or set of projections[1] should be the Party's assessment of its future emissions and removals taking into account policies and measures whose implementation is assured. Hence, in principle, it should be verifiable ex-post against the national GHG emission inventory. As the inventory can only become available after emissions take place, the projection is the most important element in any forward assessment of progress in the implementation of the Convention. Unfortunately, as some Parties' projections include measures that they would like to

[1] Parties are encouraged to test their projections for sensitivity to variation in key assumptions.

introduce, rather than measures that they have introduced, their with-measures projections do not reflect their expected future emissions.

The other three pieces of analysis are closely interlinked and are also linked to the with-measures projection. In particular, the overall effect of policies and measures should be equal to the difference between the with-measures projection and the without-measures projection. The overall effects of policies and measures should amount to the total of the effects of individual measures after correcting for any interactions or redundancy among them.

There are several purposes in communicating the effects, including costs, of policies and measures. One is to demonstrate the extent of the effort each Party is making to reduce its emissions: this purpose is probably only relevant in the context of discussions on burden sharing. Another purpose is to provide the CoP with information on the extent to which Parties are able to reduce their emissions. It has been said that the first step in bringing GHG emissions under control is to "try out the brakes". Parties and the CoP need information on the cost and effectiveness of current policies to enable them to design policies for deeper cuts if these are needed later. A further purpose is to provide other Parties with information on the design, implementation and cost-effectiveness of policies and measures that they might wish to replicate or adapt to their own circumstances.

The UNFCCC guidelines for national communications encourage Parties to include actions taken by local governments or the private sector, as well as policies introduced for reasons other than GHG mitigation. There is thus no guidance on which technical and behavioural changes should form part of the baseline projection, and which should be considered the effects of policies and measures. This lack of guidance is not a problem in producing with-measures projections, which should take account of the effects of all government and other measures expected to be implemented. Nevertheless, a major step towards improving the comparability of analysis in national communications would be to develop a clear and generally understood definition of the "policies and measures" to be excluded from the baseline, and those to be included in the with-measures projection.

Parties have taken widely varying approaches in deciding what to include in their national communication as a policy or measure, and in estimating the effects of measures. This means that the estimates of effects of individual measures, the estimates of overall effects of measures, and the without-measures projections, are not comparable among Parties.

Annex I Parties' first national communications varied considerably in the level of detail provided on the methods used for projections and estimated effects of measures, and in the interpretation of the UNFCCC communication guidelines. The reporting tables suggested in the guidelines for second communications are intended to lead to a much more uniform approach and increase the detail of reporting both of the projections and estimates of effects of measures, and of the assumptions underlying them. However, second communications submitted to date vary in style, layout and level of detail. Most communications provide very little information on the methods used to estimate the effects of individual policies and measures, although some Parties cite literature that gives further details.

2 Quality criteria for projections and estimates of effects of measures

The emphasis in this report is on *quality assurance* in the production of GHG emission projections, in estimating the effects of policies and measures, and in reporting the analysis and results in national communications. Quality assurance is not just about the use of the best possible model for any analysis. There are many criteria for high quality analysis, such as the four emphasised in this paper: *accuracy*, *consistency, comparability* and *transparency*. The weight placed on these criteria and others depends on the purpose of the analysis, but these are essentially the criteria emphasised in the UNFCCC guidelines for national communications.

The only explanation in the UN FCCC of the purpose of GHG emission projections is that at the beginning of Article 4.2(b): “In order to promote progress to this end”. “This end” is implicitly the commitment in Article 4.2(a) to adopt policies and measures to mitigate climate change with the aim of returning emissions to 1990 levels by 2000. Simply reporting information on future emission trends puts pressure on Parties to act in line with their obligations. Through the reporting process, they make public information on how well they believe they are doing. Information sharing on projections and inventories leads to more open dialogue on performance, and helps to ensure compliance.

Parties have different views on the type of projection that would best promote progress, and this has almost certainly contributed to the diversity in their chosen methods and approaches. Nevertheless, the most important of the criteria listed above is probably *accuracy*. Other criteria such as transparency, repeatability and comparability are important in ensuring that other Parties can assure their own confidence in a given Party’s analysis.

While some Parties developed their GHG projections specifically for their national communications, most of the projections were derived from existing outlooks in the energy, transport, agriculture and forestry sectors. The philosophy behind these exercises varies from sector to sector and from country to country, and may affect the fitness of the resulting projections for international communication purposes:

- Projections may be designed as challenges to policy-makers, to show what might happen if they do not introduce new policies. In such cases, there may be a bias towards higher GHG emissions in the projections;
- They may be designed to show that current policies are sufficient to achieve government objectives. In these cases, the bias in GHG emissions may be downwards;
- Some countries have developed a range of projections or scenarios reflecting future uncertainties in the economy, world markets, technological development, and environmental concerns. These scenarios are used to test government strategies with the aim of ensuring that policies are robust, ensuring that essential goals are achieved under a range of circumstances;
- Other countries use their projections to provide a reference or target trajectory of GHG emissions, economic and other indicators, against which progress can be assessed.

The Kyoto Protocol introduces an additional purpose for projections. Parties may wish to trade emission allowances for any given year before their actual emissions for that year are known. They may have to rely on their own emission projections and those of their trading partners to assess the need for, and legitimacy of, a trade in any given year. Some have argued that Parties are a poor source for this information, since the results could be influenced by political concerns. An alternative would be for projections to be generated by independent market analysts.

The quality of analysis and communication of that analysis needs to be addressed at several stages in producing GHG emission projections:

1. Assessing historical data on fuel use and other activities.
2. Using emission factors or other methods to calculate emissions based on activity levels and the associated technologies and practices.

3. Assessing the evolution of economic and other drivers, and their effects, along with existing and planned government policies, on activity levels and technology, and hence on emissions.

Information resulting from the first two of these stages is necessary for producing national GHG emission inventories, as well as projections and effects of measures. The third stage is necessary for producing both emission projections and estimating effects of measures.

Any uncertainty associated with historical activity data and the associated emissions propagates into the emission projections and estimated effects of measures, regardless of the quality or sophistication of the models used. The Kyoto Protocol requires Annex I Parties to develop national programmes to improve the quality of such information.

3 Structure of this report

In Chapters 2 to 4, this report evaluates Annex I Parties' experience in analysing and communicating future GHG emissions and estimates of effects of measures, and considers the potential for better practice. It draws on a number of existing national communications, on material supplied directly by countries, and on the experience of those carrying out In-Depth Reviews under the Convention. The chapters consider, in turn, methods for projections, methods for estimating effects of measures, and methods for ex-post verification.

Chapter 5 draws conclusions from the review, identifying approaches that might be considered "good practice" in assuring the comparability, consistency, accuracy and transparency of analysis and communication.

CHAPTER 2. METHODS FOR BASELINE AND WITH-MEASURES PROJECTIONS

Countries have used a variety of methods and approaches for their projections, depending on the gas and source. The description of projections of CO_2 from energy differs considerably from that of other GHG. In particular, most countries provide a description of the models or assumptions used to project economic activity and hence CO_2 emissions from energy. Very few describe similar models for agriculture, forestry or waste. On the other hand, several countries provide descriptions of the carbon flow and other technical models used to estimate GHG emissions from agriculture, forestry and waste. Such a description is unnecessary for CO_2 from energy, because emissions can be calculated easily from projected fuel use. National communications allocate more space to explaining projections of CO_2 from energy than to those for other gases and sectors.

It is rarely clear from national communications whether agriculture, forestry and waste projections are based on economic models, trend extrapolation or expert judgement. When modelling approaches are used or referenced, such as economic models to project livestock numbers, little information is provided on the assumptions made or data requirements. In some cases projections have been produced using methods unknown to those producing the national communications.

This section reviews the methods used for projections on a gas-by-gas, source-by-source basis. It first considers projections for CO_2 and other gases from energy, industry and transport, and then turns to agriculture, forestry and waste.

1 Carbon Dioxide from Energy, Industry and Transport

Several conceptual and computational models have been used by countries to develop their energy projections or scenarios. Many models have an energy end-use component in which energy demand equations are estimated econometrically from historical price, income and energy demand data. Supply curves for fuels are often estimated based on national circumstances (expected cost and output of domestic sources, and projected prices for imports). The electricity sector is usually modelled more explicitly with some representation of dispatch cost for individual power stations or tranches of capacity, as well as construction costs for new capacity.

Some countries use models, or suites of models, that they have developed over a long period together with related national databases. Other countries, often those with less developed databases, or facing cost, time and staffing constraints, have used internationally available standard models.

Countries differ in their approach:

- some (e.g. Canada, Norway, the United States) have produced a single baseline projection, often with tests for sensitivity to GDP, oil price and other assumptions;
- others (e.g. United Kingdom, Latvia, Russia) have developed their sensitivity tests in more detail, including them as a range of scenarios in their national communications;

- still others (in particular the Netherlands, Bulgaria) have used a range of descriptive scenarios representing contrasting but self-consistent views of the future;
- a few (e.g. Australia, Germany) cite a range of projections and scenarios that have been developed by the government and others, using a variety of top-down and bottom-up models.

Many countries explicitly recognise the weakness of existing projection methods. These countries have generally adopted some form of scenario analysis or reviewed a range of model results.

Figure 1. Simplified Structure for Typical Energy Market Model

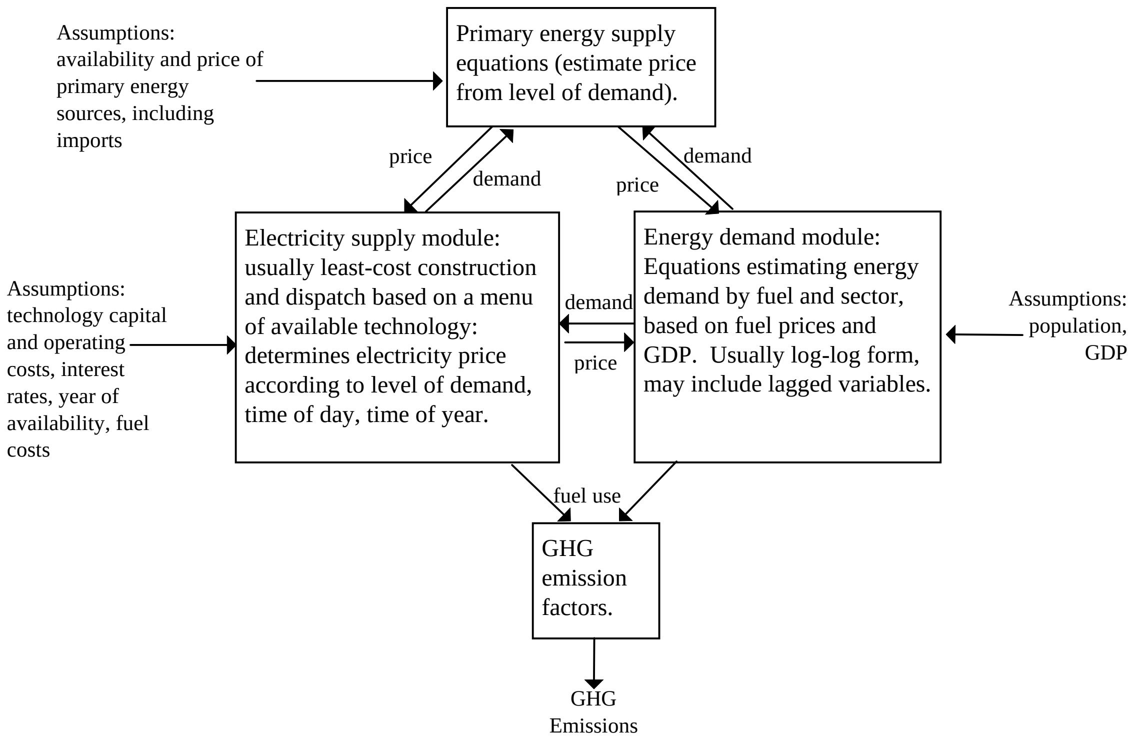

Figure 1 illustrates, in simplified form, the structure used for energy modelling in several countries. This type of energy model uses a combination of econometrically derived information on energy demand, with assumptions about technology and resources for energy supply. The two sections of the model iterate until a set of prices is found for which supply equals demand in each fuel or electricity market. While proprietary or standardised versions of this type of model exist (e.g. the European Commission's MIDAS), many governments have developed their own version. The simple model structure allows considerable flexibility in matching the level of disaggregation to the availability of data. Hence, the precise structure of the model and the level of disaggregation varies among countries. In particular, model results for energy supply depend heavily on the assumptions made about future availability and characteristics of resources and technology, and also about the investment and dispatch behaviour of electric utilities.

While the model structure in Figure 1 is common, it is by no means universal. Thus:

- Bulgaria and Norway have used macroeconomic simulation models to produce projections of sectoral activity from which energy use is calculated; in the case of Bulgaria, a demographic projection is used to estimate the number and size of households; expert judgement is used to derive energy demand from the macroeconomic sectoral activity projections, based on assumptions about the mix of technology.

- Several countries have developed separate projections of economic or other activity in energy-using sectors to estimate energy services demand, and then used models such as LEAP, MARKAL or ENPEP[2] to estimate energy sector emissions in 2000;
- Australia and Germany have drawn on existing projections from their national literature, produced by independent organisations or government agencies, using various types of model;
- the United States has used a simulation model which combines econometric and engineering or technical information in modules for fossil fuel supply, electricity generation, and a large number of categories of energy end-use.

Table 1 summarises the approaches taken in several countries to producing projections.

Only a few of the countries listed in Table 1 used a macroeconomic simulation model to estimate GDP and sectoral activity to 2000 for their projections. Some countries' national communications provided several GHG emission projections based on a range of assumptions about GDP growth (although these ranges may have reflected results from macroeconomic models that were not described in the communications). This approach can be more robust than depending on a single emission projection relying on a highly sophisticated macroeconomic model. Most countries made use of exogenous assumptions. In many cases, official government GDP projections were used.

Most of the economic models used to project GHG emissions are essentially sophisticated techniques for trend projection. They attempt to discern trends and relationships in historical data, which are then projected into the future. However, few of the parameters used in the models — price elasticities, constants in production functions, etc. — can be accurately estimated from empirical observations.

Modellers sometimes have to adjust these parameters to values that allow a computational solution to be found; thus, parameters may be fixed by computational convenience rather than by empirical observation. The more sophisticated the model, the larger the number of parameters required. This can result in greater uncertainty in the projections and less transparency in the methods used.

Trend-based projections are unlikely to be accurate when technologies, lifestyles or market institutions are changing rapidly. In such cases, expert judgement is usually essential to identify possible departures from the trend. This may apply to the many cases of sectoral reform under way in Annex I Parties, and especially to the more general economic reforms in countries with economies in transition. In some of the latter countries, a lack of data adds to the difficulties in trend extrapolation.

Energy system (engineering) models have the advantage that they can be used to track quite detailed physical changes in energy technology deployment and use. They do not simulate market developments in a realistic way, although they may give a reasonable picture of plant deployment in the electricity industry. Most such models require energy services demand to be exogenously specified either by a separate economic model or using expert judgement.

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2 See Sathaye and Meyers (1995) for descriptions of these models. MARKAL and ENPEP were both designed primarily as models of energy supply, although MARKAL-users have developed increasing sophistication in their representation of energy demand.

Table 1. Methods used for Energy-Related Emissions

Country	Approach	Models Used for Projections
Australia	Projection adopted lies within a range of scenarios developed by the government and in the national literature	Energy market (mixed econometric and bottom-up) model, and MENSA (bottom-up L-P model)
Bulgaria	Range of scenarios and projections	Macroeconomic model for sectoral activities, bottom-up approach for final energy demand and ENPEP for projections of energy sector development and emissions
Canada	Single baseline with sensitivity testing for GDP, oil price.	Energy sector model (mixed econometric and bottom-up)
Czech Republic	Two scenarios developed: "Favourable development" and "Most unfavourable development", Differences partly attributed to policies and measures.	Off-model projections of population and economic activity. Energy emissions estimated in LEAP and MARKAL.
France	No without-measures projection	Energy emissions estimated in MEDEE (energy accounting model)
Germany	The first communication gives a range of scenarios/projections from literature. A supplement to the first communication and the second communication add to this information No projection is formally adopted by the government.	Various economic models
Italy	Single baseline based on projections in literature	Bottom-up estimates corresponding to macroeconomic projections
Japan	Single baseline	None: based on government plan
Latvia	Three scenarios	
Netherlands	Two descriptive scenarios (drawn from existing national foresight exercise)	CO_2 calculated from energy use in bottom-up sector models
New Zealand	Single projection	Energy sector model (mixed econometric and bottom-up)
Norway	Single projection	Macroeconomic model
Russia	Three scenarios (drawn from existing national energy projections)	Not specified
United Kingdom	Baseline presented as one of a range of projections (drawn from routine national energy projections)	Energy sector model (mixed econometric and bottom-up)
United States	Single baseline (drawn from routine national energy projections).	IDEAS (bottom-up energy sector simulation model) was fitted to this projection and the assumptions slightly modified to produce the Administration Baseline.

2 Estimating Overall Effects of Energy Measures

In principle, the ideal way to estimate the overall effects of measures on GHG emissions might be to:

1. establish a "without measures" emission scenario or "baseline";
2. establish a "with measures scenario", using the same methods;
3. subtract the "with measures" emissions from the baseline to obtain the effect of measures.

In practice, few countries have employed the same model to produce their emission projection and to estimate the overall effects of measures.

Some countries (e.g. France, Germany) have expressed doubt about the usefulness of the baseline concept because of the difficulty in defining a "without-measures" scenario. Most countries' baselines exclude measures implemented before 1990, but France notes in its national communication that its nuclear energy programme, resulting from policies introduced from the 1970s, has resulted in its GHG emissions being much lower than they would otherwise be. Germany, in a supplementary report to its first national communication (Germany, 1996), cites a “without measures” scenario which excludes any effects of structural and technical change to 2000. This scenario leads to a 14% increase in energy-related CO_2 emissions relative to 1990 levels. These two cases illustrate the point that, without a careful and detailed definition of “without measures”, the provision of “without-measures scenarios” by countries may not aid transparency and comparability. Major challenges remain:

- to establish whose measures the scenarios exclude: countries differ in their boundaries between national and regional government responsibilities and in their levels of public sector involvement in industry and the economy in general;
- to establish how to define “what would have happened anyway”: technical change occurs routinely but it does involve measures by private and public sector actors;
- to establish the cut-off point between historical and/or previously committed action, and action undertaken as part of a country’s response under the UNFCCC.

As the last section noted, several countries have produced a suite of scenarios representing different possible futures, including different policies. However, in these cases it is rarely possible to ascribe the differences in GHG emissions entirely to climate change mitigation policies. Other factors — foreign investment, industrial development, market reform, etc. — also affect emissions.

Whereas most countries use macroeconomic models or econometric trend projection to produce their without-measures projections, they generally use bottom-up simulation or engineering models to estimate the effects of sector-specific measures. Such models account for the effects of individual measures and their interactions.

Estimating the overall effect of a national programme in a single model is a challenging task, as different types of model are best suited to assessing different types of measure (see Section 4). The model used by the United States, IDEAS, is possibly an exception: it combines econometric and engineering information to simulate the technology stock and activity levels, and is designed to estimate the effects of policies via price changes, technology availability and technology deployment.

Linear optimising models such as MARKAL can also produce estimates of the effects of many types of measure, but these estimates may be very inaccurate as such models cannot easily capture behavioural responses to changes in price or technology. Most existing versions of MARKAL have exogenously determined demand for energy services, and technology: the model cannot estimate the effects of measures on energy services demand. MARKAL does estimate the effects of measures on the mix of energy end-use technology, but most existing versions use a single investment decision rule (minimise expected costs, discounted at a uniform rate) to test all technology choices. These shortcomings have been overcome in some versions of MARKAL, which have been modified to incorporate differences in discount rate among sectors and subsectors, or to simulate elastic demand for energy services.

3 Non-CO_2 GHG Emission from Energy, Industry and Transport

Major energy-related emissions of non-CO_2 GHG include:

- methane from coal, oil and gas production and from gas transmission and distribution

- nitrous oxide from fuel combustion, in particular from gasoline engines fitted with catalytic converters, and from fluidised bed coal combustion
- emissions of tropospheric ozone precursors: NMVOCs, NO_x and CO
- emissions of NO_x and water vapour from aircraft at high altitude

Other than CO_2, GHG emissions from industry not controlled under the Montreal Protocol include HFCs, PFCs, SF_6, N_2O, and NMVOCs from solvent evaporation. Cement-making is also an important non-energy source of CO_2.

Few countries give details in their national communications of the methods used to project emissions of these gases. Projections usually derive from sectoral activity projections or from energy projections. In most cases, it is necessary to rely on a bottom-up approach using expert judgement because emission factors depend heavily on the specific technology or fuel source involved. For example:

- Methane emissions from coal production vary from mine to mine: deep-mining produces much more methane than surface mining. Emissions from gas supply depend on the size and quality (including maintenance level) of the pipe network, rather than on the quantity of gas supplied.
- Nitrous oxide and ozone precursor emissions from fuel combustion depend on the combustion technology and its state of repair. For example, cars emit increasing amounts of N_2O as their catalytic converters age.
- Industrial emissions of gases such as PFCs from aluminium smelting and N_2O from adipic acid manufacture are estimated on a plant-by-plant basis and depend on the technology used.

Projections for some gases, such as PFCs and N_2O from industry, usually derive from industry plans or projections, often linked to voluntary agreements to limit their emission. Others, such as N_2O and ozone precursors from cars, can be estimated from energy projections but are ideally projected using sectoral models that account for changes in technology and activity levels. Detailed transport air pollution models in some countries account for the vehicle stocks using different fuel types, engine technologies, and patterns of vehicle use and maintenance.

4 Carbon Dioxide from Land-Use Change and Forestry

In their national communications, most Annex I Parties provided projections of *removals* of CO_2 by sinks. Some presented separate projections for CO_2 removals and CO_2 emissions, while others (Australia, Bulgaria, New Zealand the United Kingdom) projected *net* emissions of CO_2. Few countries provided both a “baseline” and a “with measures” scenario of CO_2 emissions and removals. The United States was one of the exceptions and described the different methods for the baseline and “with measures” projections (see Box 1). Some parties provided no estimate of removals because of high uncertainty in data, poor quality or lack of availability of data or because of the low overall importance of sequestration to their national emission totals. Uncertainties in land-use change and forestry fluxes have been cited at 20-25%.

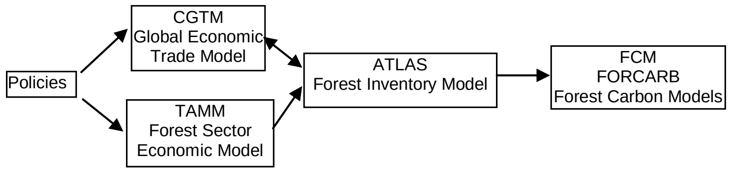
Projections of CO_2 sinks mostly focus on carbon sequestration by forests. In some cases carbon fluxes from other sources/sinks such as soils and land use change are included (see Table 8). The discussion below considers these categories of source and sink.

Box 1. The US baseline projection for carbon sequestration

The US baseline projection for carbon sequestration was developed using two US Department of Agriculture (USDA) Forest Service Models:

- The Timberland Assessment Market Model (TAMM) - an economic model; and
- The Aggregate Timberland Assessment System (ATLAS) a biological model.

TAMM provides long term projections of prices, consumption, and production trends and simulates the effects of policies. Projections of forest product trade and fuelwood demand are derived in other models and feed into TAMM. Demand is driven by GNP and by exogenous assumptions for some products. TAMM does not account for management changes in response to price signals. The ATLAS model tracks forest age distribution by forest type and production class. Inputs to the model include estimates of harvest, acreage shifts, management alternatives and growth parameters. The rate of harvest is based on exogenous assumptions for public lands and an econometric model for harvest on private lands. The two models are linked through stumpage (standing timber) markets.
The resulting forest inventory at any point in time is run through two alternative carbon models (FCM and FORCARB) to estimate forest carbon. The linkages between these models are illustrated below.



The results of this sequence of modelling are fed into a model of post harvest carbon (HARVCARB), which traces the flows of carbon in processing, use and disposal.

Some source and sink categories remain poorly defined, contributing to the diversity in approaches used for both inventories and projections. In Canada there has been some debate over whether to consider all emissions from forests as “anthropogenic”, or to define emissions as “anthropogenic” or “natural” depending on the extent to which the forest area is judged to be “managed”. This issue arises less in European countries where most forests are clearly managed. In Australia, a similar question arises with regard to biomass burning, which is intended to reduce the rate of runaway bush and forest fires. These issues have been the subject of ongoing discussion in the context of the development and clarification of the IPCC/OECD/IEA guidelines for national GHG emission inventories.

Methods to project CO_2 removal by forests generally start by projecting changes in forest cover. Carbon storage may be estimated using technical models of carbon sequestration (e.g. Netherlands, New Zealand, the United Kingdom, the United States), or using the IPCC default methodology.

A wide range of methods have been used to project the future area of forested land and the mix of forest activities (see Table 2). Although extensive detail is not available, it is apparent that some countries, particularly those with extensive managed forests, have used very sophisticated models. The models are generally designed for forest management, rather than for calculating carbon sequestration.

A critical factor in modelling CO_2 emissions from forestry or land use change is the need for a long time series of information on land use activities. For example, rates of growth can be influenced by planting 50 years earlier. Long time series of data on land use are required to estimate current or future emissions and removals with any accuracy. Data requirements are also higher for sophisticated models that discriminate between regions, tree species, rates of growth, etc. Countries differ in many details of their projections: the inclusion of carbon sequestration in harvested wood products; the impact of international trade; the influences on the rate of tree felling.

Soil carbon stocks and fluxes are more uncertain than those for above-ground biomass. Nevertheless, some countries have attempted to model these fluxes. For example, the United Kingdom calculates and projects soil carbon fluxes due to land use change using a soil carbon model and scenarios of future land use change activities. Scenarios of land use change are based on a continuation of historical trends. The model uses a simple exponential decay function to estimate changes in soil carbon following any disturbance (Milne et al., 1997).

Table 2. Projections of CO_2 emissions/removals from non-energy sources

	Sources:	Methods for projecting removal of CO_2
Australia	Land use change	Bottom-up economic models of agriculture and wood flow.
Bulgaria	Agriculture, Forestry	No information provided
Canada	Agricultural soils	No information provided
Japan	Forestry	Projections taken from targets for area of “managed forest”.
Latvia	Agriculture, Forestry	Expert judgements of growth in forest area and tree felling
Netherlands	Forestry	Projections of land area to be forested taken from policy targets.
New Zealand	Forestry	Projections of forest area based on planting trends, policy effects, land availability.
Norway	Forestry	No information provided
Russia	Forestry	Based on estimates of forest growth, timber volume and carbon storage
Sweden	Forestry	Expert judgement of forest growth, felling, timber volume and carbon storage
United Kingdom	Soils, Forestry	Scenarios include modelled CO_2 fluxes from soil carbon and forestry changes.
United States	Soils, Forestry	Baseline: Combined economic and biological models (TAMM/ATLAS) (see box 1)

To evaluate the economic and carbon impacts of changes in land use, the United States combines economic models of agricultural production, such as RAMS, with soil carbon models (DNDC and CENTURY). RAMS is a regional model of agricultural production practice (crop rotation, soil tillage, contour management and irrigation practices). This model is linked with soil carbon models to assess the effects on carbon of changes in agricultural practice (US EPA, 1995). The CENTURY model simulates the dynamics of soil organic matter over time periods as long as 100 to 10,000 years.

4.1 Methane from Livestock, Agriculture and Waste

In Annex I Parties, waste disposal accounts for 34% of anthropogenic methane emissions while ruminant livestock accounts for 38% (UNFCCC, 1996). Methane emissions from paddy rice cultivation, although an important source in some European and Asian Pacific countries, represent only 1% of total CH_4 emissions from the agriculture sector in Annex I Parties (UNFCCC, 1996). Uncertainties in inventory figures are high, in some cases exceeding ±50%.

Some Annex I Parties provide separate projections for emissions from **livestock** waste and from digestive processes in ruminant livestock. Most assume constant emissions per animal and base their GHG projections directly on livestock projections. Many Annex I Parties project livestock numbers using econometric models developed by their agriculture ministries or agricultural research institutes. In other cases projections are based on expert judgement. Country examples are listed below with a brief overview of methods in Table 3.

Some countries have used models to estimate emission factors depending on livestock type, diet and husbandry. Most countries assume a constant emission factor, although many countries identify technical means of reducing (e.g. through nutrition management or genetic engineering).

Japan is the only Annex I Party with significant **wetland rice production**. Methane emissions from this source are highly uncertain. There is some debate over the treatment of methane emissions from rice paddy fields as “anthropogenic”, where the fields have been converted from natural wetland which would have emitted methane naturally. Although CH_4 emissions from rice production depend on management of water and organic matter, these variables are not incorporated into emission factors because of limited knowledge of their effects. Japan’s emission estimate is calculated as the sum of the emissions in five different soil types . The projection assumes a constant emission factor. Projections of rice production are based on long-term outlooks for supply and demand of agricultural products.

Table 3: Projections of CH_4 emissions from non-energy sources

	Methods:
Australia	Livestock: Economic model (EMABA) calculates livestock numbers based on trends in Asia/Pacific markets, population, GDP etc. Emission factors take account of feed quality. Waste: Baseline projection based on population projections.
Bulgaria	Agriculture: Expert judgement Waste: Based on projected population, assumes a slight increase in waste per capita.
France	Livestock: Projections of animal production levels made using the MAGALI simulation model for French agriculture supplemented by expert advice. Two scenarios take account of uncertainty in effects of GATT.
Germany*	Livestock: Estimated effects of EC agricultural policy reform - no further information given. Waste: Estimated effects of waste management measures - limited information on how these projections are derived
Japan	Agriculture: Emission scenarios derived from projections of the demand for agricultural products - limited information on how these projections are derived. Waste: Scenarios analysis incorporating assumptions on the quantity of waste
Latvia	Agriculture: Expert judgement of future livestock numbers Waste: Based on population estimates
Netherlands	Agriculture: Scenario analysis Waste: Scenario analysis incorporating assumptions on rates of gas recovery
New Zealand	Agriculture: Estimates derived from projected livestock numbers, which are estimated by expert opinion
Norway*	Waste: two scenarios were developed based on expert judgement of the expected effect of measures and assumptions as the amount of gas extraction.
United Kingdom	Livestock: Baseline projection assumes CH_4 emission would remain constant at 1990 levels to 2000. "With measures" projections for agriculture based on trends in productivity and livestock numbers. Waste: Landfill emissions based on decay model taking account of amount and age of waste in place, also accounting for gas extraction or flaring. Model is calibrated against field measurements.
United States	Livestock: Two scenarios of population, constant GHG emission factors. One based on trend projection, the other on an economic model of demand and supply of major commodities, including effects of trade and agricultural policies. Waste: scenario analysis on future waste composition, landfill management and gas recovery.

Future CH_4 emissions from landfills are influenced by the composition and age of waste in the landfills, landfill management practices and regulatory requirements (EPA, 1993, Van Amstel *et al* 1994). The quantity and composition of waste deposited in landfills depends on the extent of waste generation, recycling and incineration. Data requirements for models are significant, and include information on generation, collection, transport and disposal. Countries frequently used an adapted version of the IPCC default inventory methodology.

4.2 Nitrous Oxide

Anthropogenic sources of N_2O emissions include fuel combustion, the chemical industry, and agriculture. On a *global* scale it has been estimated that agriculture contributes 70% of anthropogenic N_2O emissions (IPCC 1996). The main agricultural source of emissions globally as well as in Annex I Parties (90%) is from the application of synthetic and organic nitrogenous fertilisers to agricultural soils. Scientific uncertainties are very high for emission of N_2O (national communications cite uncertainty varying from 25-100%). For most Annex I Parties emissions of N_2O from agricultural sources are projected to be fairly stable.

Most countries only include N_2O emissions from fertiliser use, although a few (e.g. Australia, Germany**)** also include soil disturbance and animal waste (see Table 4). In general the analysis assumes no efficiency gains in fertiliser use through conservation or other practices, an assumption which has been questioned (Gallaby, unpublished). Fertiliser use projections themselves are often based on a range of variables including producer prices, input prices and measures that influence these prices.

Table 4. Projections of N_2O emissions from non-energy sources

	Sources	**Methods**
Australia	Agriculture (soil disturbance, fertiliser use, animal waste) Biomass burning Land use change	Agriculture: Mainly using EMABA model of agricultural activity and fertiliser industry projections. Animal waste: derived from livestock projections (EMABA model)
Bulgaria	Agriculture & forestry	Not specified.
Canada	No projection	
France	Agriculture, fertiliser use	Not specified.
Germany	Agriculture (animal wastes, fertiliser use) Waste	Agricultural and waste: No information on methods used
Japan	Agriculture Waste	
Latvia	Agriculture (soils)	Expert assessment
Netherlands	Agriculture (soils)	
New Zealand	No projection	
Norway	Agriculture	No information provided on methods used
Russia	No projection	
Sweden	Agriculture	
United Kingdom	Agriculture (fertiliser use)	Expert judgements of future trends by sector
United States	Agriculture (fertiliser use)	Based on projections of fertiliser use, animal numbers and area of legumes.

CHAPTER 3. METHODS FOR ESTIMATING EFFECTS OF INDIVIDUAL MEASURES

1 General Principles[3]

Countries have used widely differing definitions of "measures", ranging from clearly implemented government policies to desirable technical changes. Even if measures are defined as "fully implemented government policies", their effects are difficult to assess objectively because: it is impossible to verify the baseline; and there is insufficient understanding of the many influences on emissions, and hence of the specific effects of policies.

Of the countries reviewed for this study, most describe measures in the non-energy sectors, but only a few quantify the effects of individual measures. The assessments that have been made are often based on estimates of the economic or technical potential for GHG reduction rather than on the effects of the measure itself. There are several reasons for the lack of quantification. First, emissions from these sources are subject to a high degree of scientific uncertainty. Second, many of the measures are based on voluntary approaches or information dissemination, which have highly uncertain outcomes. Third, policies in the agriculture, forestry and waste sectors are generally motivated by objectives other than GHG mitigation. As a result, there is generally limited analysis of the policies' impacts on GHG emissions, and it is difficult to establish a realistic "without-measures" projection.

This section reviews some of the main types of measures described in the national communications and methods used to estimate their impact.

1.1 Taxes and Subsidies

The effects of price increases for energy, fertiliser or other goods are usually estimated using econometric techniques assuming that demand responds to price changes with a constant elasticity, although many models incorporate elasticity lag structures. Price elasticities can be estimated wherever historical data exists on commodity prices and consumption. However, such techniques have little validity in markets where consumption or supply has been constrained by influences other than price (e.g. quotas, constraints on market access, queuing, etc.). Thus, in countries with economies in transition, expert judgement is crucial in assessing the effects of pricing measures. Even in liberal or near-ideal markets, parameters such as price elasticities are often very uncertain because the data are not sufficiently detailed, because price effects are superimposed on other influences and because the behavioural response to price changes does not necessarily correspond to a constant elasticity. This means that price elasticities can be estimated, but the confidence intervals may be very wide and the values obtained may have little validity for estimating the future effects of measures.

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[3] This section is based on IEA (1994b).

Price effects can also be estimated in technology-rich models of energy, agriculture and forestry. Technology models have the advantage that they can, in principle, explicitly capture the effects of price changes on technology investment which results in an asymmetric price elasticity (when prices rise, they provide a stimulus for technology changes which may not be reversed if prices subsequently fall).

A better understanding of the effects of fiscal measures on consumer decision-making is likely to depend partly on improved collection of data including very detailed survey information. The most important statistics are those relating to energy consumption in different end uses by different consumers, and to possible influences on that energy consumption other than price and income. There is a growing body of research attempting to improve understanding in this area but there is no real alternative to econometric analysis.

1.2 Technology standards

It is often harder to make quantitative predictions of the GHG effects of standards and regulations than fiscal measures. This may seem counterintuitive. The key point is that historical information on commodity prices and demand are usually readily available, and this is all that is needed to produce a first-order econometric estimate of the effect of a tax. It is much harder to obtain detailed information on technology stocks and the level of GHG emission by specific technologies, and to understand exactly how firms and consumers will respond to regulated changes in the technology. For example, energy efficiency standards may lead to increased appliance costs and reduced sales in the short term, but reduced operating costs, increased disposable household budgets, and increased sales in the long run. Energy efficiency standards can also affect the performance or aesthetics of appliances. These effects depend not only on the impact of new technology standards on the average performance of the total stock of equipment (requiring models of stock turnover) but also on the impact on the way the technology is used.

A full assessment of the effects of regulations and standards often requires both detailed technology information, and detailed information about markets and behaviour. Detailed surveys may be the only way to obtain such information. In practice, analysts generally use expert judgement to estimate the effects of regulations and standards, based on percentages of assumed compliance, and assumptions about any “take-back” or other secondary effects. For some countries, this expert judgement may be supported by historical experience with similar measures, which can be assessed through information from manufacturers on the sale of technology, and from follow-up surveys to find out how the technology is being used.

1.3 Planning policies

Where governments exercise direct and non-controversial control on energy system, transport, forestry and waste planning it may be quite straightforward to predict the effects of planning policy. Where planning measures are more indirect, relying on licensing or other laws, the effects are much less predictable.

1.4 Education and Information Measures

Researchers have studied the effects of education and information on the attitudes and choices of the community at large, and developed qualitative theories describing the mechanisms for these effects. For example, marketing specialists have developed techniques for market segment estimation, based on household or consumer clustering according to attitudes and lifestyles. These techniques are used to estimate the proportion of the population that would respond to particular types of information, or information provided through particular channels. Others (Wilk, 1997; Stern, 1986) have analysed the effects of information through advertising, press and the media on consumer attitudes and preferences. However, there is no single accepted framework for assessing the effects of education and information.

1.5 Encouraging Technological Innovation

Scenarios of future GHG emissions depend heavily on assumptions regarding the rate of improvement in the GHG performance of technologies and practices, and the rate of change of the mix of technologies and activities in the economy. These developments depend on the availability of different types of technology, as well as the choices made by individuals and firms. Both technical progress and consumer preferences are extremely complex and unpredictable. Governments play a role in technology development in a variety of ways, ranging from legislation on patents, provision of R&D funding and facilitation of information sharing, through to the full suite of policies that affect market incentives. At present, no reliable quantitative techniques exist for assessing the effects of government policies on technological innovation.

1.6 Summary

Table 5 summarises the methods used by a few countries in estimating the effects of energy sector measures.

Table 5. Overview of Methods used to Estimate Effects of Measures

	Methods Used for Effects of Measures		
Country	**Taxes/Subsidies**	**Regulations/Standards/Planning**	**Information/Education/Training/ Voluntary measures**
Australia	Each measure assessed by relevant experts using a variety of models and approaches, with assumptions and information based on past experience/monitoring of existing measures, technical and economic studies, and market survey information.		
Bulgaria	Expert judgement	Bottom-up modelling and off-model calculations (econometric and techno-economic estimates by sector experts)	Expert judgement
Canada	Not reported	Bottom-up modelling and off-model calculations (techno-economic estimates by sector experts)	Expert judgement, company commitments
France	Off-model calculations based on econometric studies, techno-economic information and expert judgement	Off-model calculations based on techno-economic information and expert judgement	Expert judgement, company commitments
Germany	Bottom-up modelling and off-model calculations (econometric and techno-economic analysis by relevant experts)		
Japan	Estimates by sector experts using techno-economic information		
Netherlands	Bottom-up sector models		
Norway	Carbon tax assessed in economic models	Not reported	Not reported
United Kingdom	Econometric equations based on those in national energy (projection) model	Bottom-up models, off-model estimates. UK has made particular efforts to reconcile bottom-up and top-down projections.	Survey data, expert judgement, previous programme experience, company commitments
United States	Each measure assessed by relevant experts using a variety of models and approaches, with assumptions and information based on past experience/monitoring of existing measures, technical and economic studies, market survey information, trials with measures etc.		

2 Measures in the Energy Supply Sectors

Most countries' national communications mention measures aimed at reducing GHG emissions from electricity generation. The UNFCCC's compilation and synthesis of national communications (UNFCCC, 1996a) lists some of the most common measures: regulatory reform to promote competition in energy supply and distribution; removing subsidies to coal; extending natural gas and district heating networks; introducing time-of-day or seasonal electricity pricing; building nuclear power plants; and research into renewables. Other important measures include voluntary agreements; consumer taxes; and measures to develop markets for non-fossil energy sources, including landfill gas.

Some electricity sector measures (e.g. consumer taxes, removing direct subsidies, removing trade barriers, building new generating capacity, compulsory purchase of renewables) can be represented easily in the models typically used to produce GHG emission projections. The GHG effects of other measures — increased competition; renewables R&D — can only be modelled by making assumptions (using expert judgement) about their effectiveness in reducing costs, improving efficiency, etc. With such assumptions, the effects of the measures can often be modelled using typical projection models. However, it must be emphasised that the restructuring of many national electricity industries is leading to a radical change in the decision-making processes of industry actors. Some of the possible outcomes (e.g. strategic rather than "optimal" investments made by new companies in a competitive industry) may be very hard to foresee.

In most cases, off-model calculations using expert judgement form an essential component of the assessment of measures. Models are used to account for the feedback or system effects of changes in individual markets or technologies. Different types of measure require different types of assumptions as shown in Table 6 below.

Table 6. Methods used to estimate effects of energy supply measures

Type of measure	Typical assumptions (in some cases these can be endogenous model results but they are often based on expert judgement)	Modelling method (if modelled: in many cases effects are estimated by expert judgement using off-model calculations)
Regulatory reform, subsidy removal, network extension, time-of-day pricing, other pricing measures	Effects of reforms on prices Effects of price changes on demand Trade effects Generating technology characteristics (costs, efficiencies, emission factors)	Price or demand changes incorporated in bottom-up electricity or other energy supply model
Electricity supply planning decisions	Capital stock turnover rate/timing of deployment of new technology Availability/load factor of new technology	New capacity introduced in bottom-up electricity sector model
Voluntary agreements	Based on industry commitments and assumptions about extent to which VA targets are met	Efficiency, fuel or emission factor changes introduced in bottom-up models
Research, development and demonstration	Market share of new technology over time Cost and performance of new technology	New technology made available in bottom-up electricity sector model

3 Measures in the Industry Sector

A wide range of industry sector policies and measures are reported in national communications (UNFCCC, 1996a). Most aim to reduce CO_2 emissions through energy efficiency improvements. Measures include: voluntary agreements; legislation, regulations and standards; financial incentives including grants, tax relief, third-party financing, direct subsidies; energy market liberalisation and energy subsidy removal; information, education and training; and new technology demonstration projects.

Measures in the industry sector are mostly assessed through expert judgement combined with off-model calculations. Of the energy end-use sectors, industry is probably the hardest to treat realistically in an energy model because industrial energy use is very heterogeneous.

- Some energy consumption, especially for chemical and physical processing of materials, is closely linked with production processes. That is, the choice of production process determines the energy use, but energy is often a secondary concern relative to other priorities such as product quality and minimising labour inputs.
- Certain energy-using technologies, such as boilers and electric motors, are generic to a wide range of industries.
- A large part of industrial energy use, especially for heating and lighting buildings, form part of overhead costs and thus may be minimised almost independently of the choice of production process.

Ideally, these different areas of energy use would be modelled separately as the decision-making processes associated with technology choice and management practices differ significantly among them. There will also be large differences among industrial subsectors. However, without comprehensive and on-going industrial energy audits, there is insufficient data in most countries to allow for such disaggregated modelling. Hence, industry is often modelled using econometric equations for energy demand in a small number of subsectors. More detailed, bottom-up models do exist — for example, Germany's IKARUS, the Netherlands' ICARUS and various countries' versions of MARKAL. Linear programming models such as MARKAL and IKARUS can be used to simulate the effects of policies in the industry sector, on the assumption that decisions on energy technology investment aim to minimise costs on a discounted cash flow basis. Different required rates of return or payback times among subsectors can be simulated, but it is hard to represent differences in the non-energy, non-cost attributes of technologies (e.g. quality of manufactured product). Hence, users of these models generally constrain the mix of technology based on expert judgement, so that the models are being used as accounting tools rather than to simulate the effects of measures on technology or industrial behaviour.

Table 7. Methods used to estimate effects of industry sector measures

Type of measure	Typical assumptions (in some cases these can be endogenous model results but they are often based on expert judgement)	Modelling method (if modelled: in many cases effects are estimated by expert judgement using off-model calculations)
Voluntary agreement	Based on industry commitments and assumptions about extent to which VA targets are met	Emission reductions usually calculated off-model but assumed effects on energy use may be incorporated in bottom-up models for energy accounting purposes
Regulations/standards for new equipment	Based on assumptions of capital stock turnover and level of compliance with standards	Usually estimated off-model. Results may then be incorporated in bottom-up models for energy accounting purposes.
Subsidies and other incentives for uptake of new technology	Based on assumptions of capital stock turnover and industry response to incentives (e.g. through reduction in payback period)	Usually estimated off-model but can be estimated in bottom-up, linear programming or simulation models.
Fuel price increases (taxes, charges, subsidy removal, energy market deregulation)	Calculated using assumed price elasticities	Econometric-based models or off-model calculations
Information, demonstration programmes etc.	Uptake of new technology and practices based on past experience with similar measures	Usually estimated off-model. Results may then be incorporated in bottom-up models for energy accounting purposes.

4 Measures in the Transport Sector

Transport sector policies mentioned in national communications fall in three main classes (UNFCCC, 1996a):

1. economic instruments and incentives to influence vehicle design, purchase and use — most countries already levy vehicle and fuel taxes, and in many instances vehicle taxes vary according to vehicle size, weight, engine size or fuel economy;
2. regulations, standards and voluntary agreements for vehicle fuel economy — government targets and voluntary agreements with manufacturers are the most common approach;
3. local measures to influence behaviour such as traffic control measures and the promotion of public transport and cycling.

As in the case of GHG emission projections, countries have been more likely to use models in the transport sector than in other sectors because:

- A few major categories of transport account for most of the sector's energy consumption. In most OECD countries, road transport accounts for about 80% of domestic transport energy use, with cars, light trucks and heavy duty trucks accounting for well over 90% of road energy use. Trains and buses account for a more significant share in EIT countries.

- Energy demand is closely related to activities that are usually recorded in national statistics — car and other vehicle-km and freight tonne-km. Meanwhile, these activity levels are usually modelled for transport planning purposes and the results are easily adapted to estimate energy use and GHG emissions.
- The ease of availability of fuel price, fuel demand and activity level data in the sector has made it easy territory for econometric analysis. Price and income elasticities of vehicle and fuel demand are better known in the transport sector than in other sectors.

Table 8. Methods used to estimate effects of transport sector measures

Type of measure	**Typical assumptions (in some cases these can be endogenous model results but they are often based on expert judgement)**	**Modelling method (if modelled: in many cases effects are estimated by expert judgement using off-model calculations)**
Fuel taxes	Underlying fuel prices, price elasticities	Effects on transport energy demand may be estimated directly in both national energy market (econometric) models and bottom-up (optimisation or econometric) models
Economic instruments (fuel economy incentives in new car taxes)	Based on assumed underlying vehicle prices, vehicle fleet, stock turnover and use.	Many countries have detailed transport activity models estimating energy demand. Results may then be incorporated into a national energy model to estimate energy system emissions. Bottom-up (MARKAL-type) models may also be able to estimate effects of this type of measure on technology but not on level of use. More sophisticated modelling takes account of the effect of vehicle technology on cost and level of use (e.g. in US' IDEAS model).
Regulations and standards	Based on vehicle fleet, stock turnover and use.	Effects on technology but not on level of use can be estimated in simple vehicle stock vintageing models, in MARKAL-type models and in some national energy market models. More sophisticated modelling takes account of the effect of vehicle technology on cost and level of use (e.g. in US' IDEAS model).
Local measures	National effects based on these local estimates plus expert judgement on likely success of measures.	Effects of measures often estimated in local transport network models or based on detailed studies and surveys of previous experience with measures.

5 Measures in the Residential and Commercial Sectors

The measures most often mentioned in the residential and commercial sectors are (UNFCCC, 1996a): regulations and standards to improve the thermal insulation of new buildings; standards and financial incentives (including tax expenditures) to improve the energy efficiency of heating systems and other appliances; fuel taxes; technical assistance and information for building design and construction; and public awareness campaigns.

Several countries have detailed accounting models of the technology stock in the residential and commercial sectors, based on regular surveys. These models tend to focus on a few major areas contributing to energy consumption: building age, type and fabric; types of heating and air conditioning system; hot water; refrigeration; and lighting. The turnover and use of technology in such models is usually set by the user — i.e. it is not determined endogenously by economic variables, as is often the case for transport sector models.

A very few countries have residential/commercial sector models that are able to estimate energy demand for specific uses based on econometric information: most econometrically-based energy models estimate energy demand by fuel for the sector as a whole.

Table 9. Methods used to estimate effects of residential/commercial sector measures

Type of measure	Typical assumptions (in some cases these can be endogenous model results but they are often based on expert judgement)	Modelling method (if modelled: in many cases effects are estimated by expert judgement using off-model calculations)
Regulations/standards for new buildings and equipment	Based on projections of capital stock turnover and level of compliance with standards	Usually estimated off-model. Results may then be incorporated in bottom-up models for energy accounting purposes. Effects can be estimated directly in national bottom-up (e.g. MARKAL-type) energy models.
Fuel taxes	Calculated using estimated or assumed price elasticities	Effects on residential/commercial energy demand may be estimated directly in both national energy market (econometric) models and bottom-up (MARKAL-type) models
Financial incentives for purchase of energy efficient equipment	Based on projections of stock turnover and response to incentives (can be based on assumed or econometrically derived responses to shorter payback periods for energy efficiency)	Usually estimated off-model. Results may then be incorporated in bottom-up models for energy accounting purposes. Effects can be estimated directly in bottom-up (MARKAL-type) models.
Information and training	Typically assume that energy savings for a given level of programme expenditure will be similar to those estimated from past experience	Usually estimated off-model. Results may then be incorporated in bottom-up models for energy accounting purposes.

6 Carbon Dioxide from non-Energy Sources

The most frequently referenced measures to reduce non-energy CO_2 emissions or to enhance removals include: measures to increase the area of forest; measures to improve carbon management in existing forests; and measures to improve carbon management in agricultural soils. Agricultural policy reforms (generally introduced to meet non-GHG-related objectives) have also been identified in several communications as contributing to reduced losses of CO_2 from soils and enhanced CO_2 sequestration.

Many Annex I countries described measures afforestation that increase the carbon sink capacity. Several of these countries (e.g. Australia, Japan, France, New Zealand, Sweden, the United Kingdom, the United States) provide estimates of the amount of carbon which will be sequestered as a result. The methods used to projects forestry plantation vary, some being based on economic models, others on trend analysis and on expert opinion.

The US uses an economic model to estimate the potential contribution of a large scale rural tree and forest management programme to reducing net CO_2 emissions. The model also estimates the direct social costs of such a programme (Moulton and Richards, 1990). The data requirements for this type of model are substantial. For each of the 10 USDA farm production regions, potential programme land areas were identified and classified according to soil, region, susceptibility to erosion, slope, current use and condition. Each land type was matched with an appropriate forestry treatment such as planting or natural regeneration with an appropriate mix of species.

Box 2: Measures to reduce conversion of native vegetation into agricultural land use

Australia is the only Annex I country where the conversion of native vegetation into agricultural land use has been reported as a major source of CO2 emissions, although this activity is also a major source for many non Annex I countries. Australia estimates measures to reduce this process as having the greatest potential for reducing CO2 emissions from the terrestrial biosphere. The estimation of this potential is based on a scenario analysis comparing a population based “business as usual” with a “rapid cessation” scenario and a gradual cessation scenario” (Lloyd, unpublished).

7 Methane

Several countries identify technological options to reduce methane emissions per unit of production through improved farm management practices; improved grazing management; production enhancing agents and genetic improvement techniques. In a few cases some technical assessment of the potential impacts of these measures on reducing GHG emissions is provided. The United States provides an assessment of the cost-effectiveness of these measure based on expert analysis**.** Australia also used expert analysis to estimate effects.

Some countries (Germany, France the Netherlands, New Zealand, the United Kingdom) identify agricultural policy reform measures as contributing to reducing CH_4 emissions from livestock production. The Netherlands for example, estimate that reforms to the CAP will result in a 10% reduction in methane emissions from the agricultural sector between 1990 and 2010. Little information is available on the methods used to calculate these effects.

Several countries also identify methane recovery from landfill programmes to mitigate against CH_4 and CO_2 emissions. The United States, for example, developed such estimates based on technical models to simulate the potential for methane recovery from landfills. For most other countries little information is provided on the methods used to calculate the effects of these programmes.

8 Nitrous Oxide

There are very few examples of estimates of the individual effects of measures to reduce N_2O from fertiliser use, as noted earlier, in part because of high uncertainties for emission of N_2O (limited scientific information about the processes underlying the emissions). Also, many of the measures which are identified have primary objectives which are not related to mitigating emission of N_2O (for example, many of the policies and measures which have been introduced to increase the efficiency of nitrogen fertiliser use have been introduced to address problems of high nitrate concentrations in water supplies). It is also difficult to model the effects of many policies affecting non-energy N_2O (such as the careful spreading of fertiliser including during times when crops have higher nitrogen uptake) these effects being more easily estimated by expert judgement.

CHAPTER 4. EX-POST VERIFICATION

Monitoring can assist policy makers to assess whether their projections are good approximations of reality as well as whether policies and measures are being implemented as planned. Reporting on such results not only acts as a self-check but also provides information to the international community. Ex-post verification of the overall effect of a national programme is, however, at least as challenging as producing an ex-ante estimate of the effect of the programme. GHG emissions are estimated in national inventories and several countries have now produced 1995 inventories which can be compared with their earlier projections for 1995. Such comparisons are most fruitful where inventories are disaggregated to the sectoral or sub-sectoral levels corresponding to the models used to produce the projections

While it is never possible to establish the precise causes of changes in emissions, it may be possible to identify major drivers: fluctuations in weather, the economy, prices of fuels, exchange rates and many other factors all make a contribution, along with government policies. Nevertheless, by monitoring indicators of activity levels and GHG intensity in sectors where measures are applied, it may be possible to isolate the effects of those measures. The United States developed an elaborate system of metrics (indicators) and milestones, against which to monitor progress in the implementation of the energy efficiency measures in its Climate Change Action Plan. Measuring progress towards an overall GHG emission target is easier than identifying the contribution of individual policies and measures to that progress.

Box 3. Ex-Post Verification in the United Kingdom

In 1995, the United Kingdom produced a year-by-year with-measures CO_2 projection. This allows it to monitor progress towards its aim of returning GHG emissions to 1990 levels in 2000 on a gas-by-gas basis. DoE (1995) compares actual emissions of CO_2 from the United Kingdom with the projection. DoE estimates the contribution to total changes in CO_2 emissions of changes in temperature, GDP and fuel mix, the residual being due to changes in the energy intensity of the economy, as shown in Table 10.

Table 10. Decomposition of CO_2 Emission Changes in UK

	1990	1991	1992	1993	1994
Projected CO_2 (MtC)	--	--			
Actual CO_2 (MtC)	158	159	155	151	148
Contributions to change in MtC relative to 1990					
Temperature effect		+6	+3	+2	+2
GDP change		-3	-4	-1	+5
Carbon intensity of fuel mix		-2	-3	-10	-13
Energy intensity of GDP		+1	+2	+1	-3
Overall change		+2	-3	-7	-9

Several countries have made some effort to develop indicators and introduce mechanisms to monitor the development of their GHG emissions. Many produce regular updates of their emission projections. Such monitoring can warn governments of the need to introduce additional measures, if this turns out to be necessary to meet national mitigation targets.

Several models give projection data only for every five or ten years, making monitoring on a year-by-year basis difficult. The United Kingdom has used a top-down decomposition approach (UK DoE, 1995), monitoring total national GHG emissions and influences on those emissions. This helps the government ensure that the GHG intensity of GDP is falling sufficiently rapidly to offset the expected effects on GHG emissions of GDP growth (or climate change) to 2000 (see Box 3).

Governments routinely monitor their programmes to make sure that they are working, to ensure cost-effectiveness, and to provide a feedback process that can lead to adjustments in programme design. International and non-governmental audiences use the existence and results of monitoring programmes as a measure of government commitment, and also as a useful source of information on experience with policies. Major monitoring programmes are often designed to serve domestic audiences.

Thorough assessment is expensive as it involves extensive surveys on the market penetration of technologies, interviews with firms or farmers to evaluate their responses to the programmes. However, it is an important element in improving programme design.

As mentioned earlier, it is often difficult to estimate the effect of a measure ex-post. For example:

- demand responses to fuel price are hard to distinguish from the effects of other influences, including exchange rate shifts and the effects of other policies and measures;
- the effects of information provision, technology standards, voluntary agreements and targets are hard to distinguish from "business-as-usual", or what would have happened anyway;

similarly, subsidies and other price incentives to adopt new technology or practices may be taken up by a large proportion of "free riders" - those who would have adopted the new technology anyway.

Like projections of the effects of measures, ex-post evaluation of these effects requires expert assessment. Evaluation relies on the skilful use of indicators (e.g. energy intensity in a given sector) and milestones (e.g. a series of targets for introducing a specific new energy technology) along with market surveys to evaluate the extent to which policies and measures have played a role in bringing about changes. Even with these techniques, experts may argue intensely over the true effects of a policy.

Despite these difficulties, several countries (e.g. Norway, United Kingdom, United States) have established mechanisms to monitor the effects of measures. The UK national communication is unusual in that it briefly summarises approaches to monitoring. These include:

- carrying out econometric studies of the response of fuel consumption to changes in price;
- monitoring returns from businesses and other organisations which have committed themselves to voluntary emission reductions
- continuing existing research on the cost-effectiveness of carbon saving per unit of Government expenditure in information programmes
- monitoring the uptake of direct government supports for the use of low-emission technology
- monitoring the effect of standards on actual appliance uptake and rates of construction of new buildings.

Australia has identified a set of performance indicators to measure implementation of its National Greenhouse Response Strategy (NGRS) (Lumb et al., 1995) (see Box 4 below). The United Kingdom has been conducting atmospheric measurements of methane emissions from different types of landfill which help quantify the effects of measures such as gas collection and flaring, and soil oxidation. Canada has developed an indicator of CO_2 balance for Canadian agro-ecosystems.

Box 4: Examples of Indicators for Monitoring Non-Energy GHG Emissions

	Primary indicators	**Secondary indicators**
Agriculture, Forestry and Land-Use Change	• Sheep methane equivalents per animal • N_2O emissions index • CO_2 from land use change	• Area of cultivated land • Area of biomass burnt for protection and management • Area of conservation reserves
Waste	• Per capita methane emissions from landfills	• Quantity of organic waste to landfill per capita • Percentage of methane emissions captured

Source: Lumb et al., 1995

The time needed for ex-post evaluation of projections and measures for non-energy sources may be longer than for energy sources, because slower processes are involved. For example, measures for afforestation can take 30 years to achieve their projected effects on carbon uptake. This requires greater emphasis on intermediate indicators of progress, such as the area of forested land.

CHAPTER 5. MOVING TOWARDS QUALITY ASSURANCE

1 Assuring quality in historical activity data

Estimating national anthropogenic GHG emissions, whether in inventories or projections, depends on having accurate statistics on the human activities that result in those emissions. Estimation of fossil fuel CO_2 emissions from fossil fuel use is easier than that of most other GHG from most other sources, because fossil fuels are commodities whose sale is monitored in most countries, and CO_2 emissions are directly proportional to the quantity burned and carbon content of fuel of each type. Most other GHG emissions are much less directly related to variables for which good statistics exist. For example, the emissions of non-CO_2 GHG associated with fossil fuel use are heavily dependent on the technology used, its age, condition, and the way in which it is used. Similarly, emissions of GHG associated with industry, agriculture, forestry and waste depend strongly on conditions that are not carefully monitored.

National fuel supply data are reasonably accurate because of the small number of companies involved and because government duties are charged on some fuels. Some countries estimate national fuel use based on two or more different sources of data collected in different ways or at different points in the supply chain, increasing the confidence that can be placed in the data. The data are internationally comparable because of the well-developed reporting systems employed by the IEA and others. All OECD countries and many others already collect annual energy statistics in a standard format, broken down by fuels and sectors. However, national energy statistics may not be particularly transparent or traceable, partly because some of the data are collected from commercial sources which cannot be revealed.

To develop projections and estimate the effects of measures, countries also need data on trends in final energy use, broken down by fuels, technologies and activities. Such data are usually based on surveys rather than comprehensive accounts. The confidence that can be placed in the data varies widely among countries. Although there are international standards for data *reporting*, there are no such standards for data *collection*. Hence, the results are not internationally comparable. The quality of information on the breakdown of natural gas use in households or diesel use in vehicles, for example, is highly variable among countries. Some Annex I countries carry out detailed, extensive, regular surveys, while others have little or no information.

Emission factors for non-CO_2 GHG emissions are often highly variable depending on circumstances. This means that detailed activity data are essential to achieve any degree of accuracy in emission estimates. For many GHG emitting activities, however, it is necessary to estimate activity levels from proxy indicators. These are usually statistics that are readily available and collected regularly, such as population, number of households, number of vehicles, or consumption of fertiliser. The correlation between these indicators and more specific GHG emitting activities and processes may be estimated on a one-off basis from a detailed survey, or based on surveys carried out in other countries.

Good practice in monitoring and reporting activity levels and trends might involve:

- ensuring complete transparency of data used for the national communication, so that an international reader can trace the origin of the data, the survey techniques used, and any assumptions made; this would include identifying any information gaps
- making use of existing data collection processes to collect and regularly update activity data relevant to estimating GHG emissions
- exchanging information on data collection processes with other Parties to establish consistent methodologies
- ensuring that national data collection processes include statistical analysis to establish the accuracy of, and any bias in, the resulting data, and subjecting results to peer review
- using two or more approaches or data sources to estimate a given activity indicator or to establish a range of possible values for that indicator

2 Assuring quality in estimating emissions from activity levels

Emission factors for CO_2 from burning a given type of fuel do not vary by more than a few percent, regardless of the combustion technology or circumstances. Other emission factors (e.g. for methane per km of gas pipe, or for N_2O per kg of fertiliser applied) can vary in practice by factors of ten or more depending on local circumstances. Emissions of non-energy and non-CO_2 GHG given in national GHG inventories are thus highly uncertain unless they are based on detailed national measurements. Many countries identify uncertainty in emission factors in the inventory as the main source of uncertainty in their projections and estimates of effects of measures related to non-energy GHG sources and sinks. Changes in emissions from the base year may be less uncertain than their absolute levels, if that variation results mainly from changes in activity level rather than changes in emission factors.

In many instances, Parties have assumed changes in emission factors in their projections or in their estimated effects of measures. This applies, for example, where measures include the recovery of methane from landfill or voluntary agreements with industry to control N_2O emissions. In such cases, the absolute changes in emissions are usually reasonably well-known because the effects of the measures are closely monitored. However, the national inventory total for the source category may be very uncertain, as less monitoring is carried out at sites where no action is being taken.

Current GHG emissions are essentially knowable: they can be measured directly. However, in practice, especially for emissions related to land-use change, agriculture and forestry, direct measurement is not possible. Parties have to rely on small samples of data or literature sources to develop their inventory methods.

Good practice in producing, using and reporting emission factors and methods might involve:

- using inventory methods and emission factors following the IPCC guideline source/sink categories to ensure international comparability (this is a requirement in the inventory Reporting Instructions)
- ensuring that all assumptions and literature sources are easily traceable by international readers of the national communication (also required in the Reporting Instructions)
- reviewing scientific literature to establish the range of emission factors found under conditions similar to those being considered

- exchanging information with other Parties to ensure that all countries have the best available information, relevant to their national circumstances
- in addition to providing point estimates, either estimating the statistical confidence limits of the emissions and reporting them in the national communication, or citing the range of relevant emission factor estimates from the literature and any additional national research (this is requested in the Reporting Instructions)
- subjecting all assumptions to peer review
- undertaking a research effort to develop and regularly update GHG emission factors and methods relevant to national circumstances (this is a long-term and expensive commitment that may not be possible for all countries)
- monitoring changes in emission factors and processes due to policies and other influences

3 Assuring quality in projections

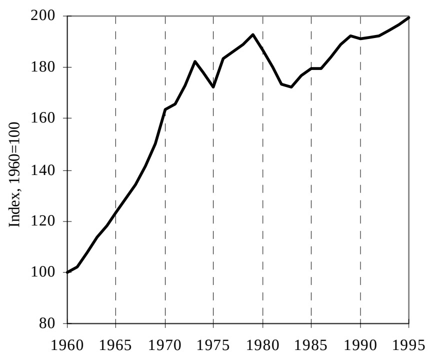
According to the UNFCCC guidelines for national communications, Parties should include both a "without-measures" (baseline) projection and a "with-measures" projection. This section briefly discusses the definitions of these two projections, and then goes on to consider approaches to assuring quality in both types of projection.

3.1 Defining the baseline projection

Not all Parties provided a without-measures or baseline projection in their first communication. Many Parties provided a without-measures projection for CO_2 from energy, but few provided one for other GHG emissions or for removals by sinks. Hence, baselines were neither complete nor comparable. The concept of a "baseline" remains rather ambiguous. In principle, it should be a projection of what a country's emissions would have been without the implementation of the mitigation policies identified in the national communication. In practice, as noted in the introduction, Parties differed widely in the way they defined and identified policies and measures to be included in their national communications. Hence, their definition of a "baseline" also differed.

In the absence of a clear definition of "without-measures", it may be simplest to develop the "baseline" as a "trends continued" or "business as usual" scenario. However, such a scenario has little meaning in a country that is undergoing, or has recently undergone, major economic reforms, or energy sector restructuring. Indeed, care is needed in extrapolating trends in general. It can easily be seen from Figure 2 that CO_2 emission projections based on trend extrapolation for the OECD as a whole would depend very heavily on the point at which the projection was made, and the length of the historical time series used to estimate the trend. Significant breaks in the trend, resulting mainly from events affecting the oil market, occurred in 1973, 1975, 1979, 1983 and 1990.

Figure 2. CO2 Emissions from fossil fuel use in OECD Member countries (pre-1994 Membership: 1960=100)



Source: IEA Statistics

3.2 Defining the "with-measures" projection

Just as "baselines" were defined in various ways by Parties, the philosophy behind "with-measures" projections also varies considerably. Countries also vary in their inclusion of GHG sources and sinks. Hence, with-measures projections are neither comparable nor, in many cases, complete.

Some Parties produced a "best-estimate" of future emissions, taking account of all policies that they knew would be implemented. Others produced a range of sensitivity tests or scenarios, reflecting uncertainty in economic growth, oil and agricultural markets, and other factors beyond the control of the government. Still others produced scenarios that reflected uncertainty in the policies to be introduced by the government.

Whereas it may never be possible to define exactly which measures should be excluded from a without measures projection (measures taken by whom, when, for what purpose), it should be possible to define what should be included in a with-measures projection. The current sense of the UNFCCC guidelines for national communications is that the with-measures projection should be what Parties expect to happen. Hence, it should include the effects of all measures taken, for whatever purpose, by national and local government and by the private sector. However, it should not include measures whose future implementation is uncertain. Further clarification may be needed in the guidelines.

3.3 Developing projections

There is no reliable model of the functioning of the economy, of the process of technological change, or of human behaviour in general. Emission projections and estimates of effects of measures rely heavily on expert judgement. Computer models are, at their best, a tool to aid that judgement. At their worst, they are used as bad substitutes for expert judgement, and they may obscure the many assumptions or estimates that have to be made in producing emission projections.

Short term developments in response to rising incomes, changing commodity prices and economic policies can be estimated using econometric techniques. However, these techniques are essentially sophisticated means of trend projection, assuming that technology and behaviour will continue to change at historical rates, and will respond to influences such as incomes and prices in the same way as they have in the past. Such assumptions are not valid for analysing longer term developments (over about 5 years) or for estimating responses to policies aiming for market reforms, improved information or accelerated technical change.

Longer term developments are often analysed using general equilibrium models or engineering optimisation models. Both types of model rely on assumptions about the behaviour of firms and individuals, and about the types of technology available. These assumptions are not always corroborated by observation, often being designed for ease of computation rather than accuracy.

Uncertainties associated with the technological and behavioural assumptions in models compound the uncertainties associated with measuring historical activity levels and GHG emissions. Several countries' national communications mention the various sources of uncertainty in GHG emission projections, and adopt a scenario approach as the most effective means of dealing with it. However, in many instances, the scenarios are essentially sensitivity tests, introducing different values for GDP or oil prices into econometrically-derived models. Such sensitivity tests address only a small portion of the overall uncertainty in emission projections.

A few countries have attempted to address the larger long-term uncertainties associated with changes in technology and behaviour. These include the Netherlands, which adopted an approach based on a set of descriptive scenarios, and countries such as Australia and Germany which draw on results from a variety of models. Many countries with economies in transition have also adopted a scenario approach, reflecting uncertainty in future political, economic and technical developments.

A few countries have begun to evaluate the differences between the projections in their first national communications and their subsequent emissions. This kind of ex-post monitoring allows them to check whether additional mitigation policies are needed to meet their targets, and to improve on their projection methods.

Good practice in developing projections might involve:

- establishing the history of emissions from each source, or of proxy indicators for those emissions, over a considerable period, ideally longer than the period of the projection;
- evaluating the extent to which the historical data fits any economic or other model used for the projections;
- carrying out sensitivity analysis to obtain model results with a range of input assumptions to reflect uncertainty;
- if possible, using more than one type of model, to test the effects of different assumptions about market, technology and other dynamics;
- if possible, comparing the projections with any independent national or regional projections;
- using public or stakeholder consultation processes to discuss establish whether the assumptions and results are generally considered reasonable;
- ensuring complete transparency of the projection exercise in the national communication, so that an international reader can trace full details of the methods and assumptions used;
- introducing a procedure for ex-post evaluation of the projection, to establish the extent to which differences between projected and actual emissions can be explained and, if possible, to improve the projection method.

4 Assuring quality in estimates of effects of measures

As mentioned in the introduction, the UNFCCC guidelines for national communications encourage Parties to adopt a very broad definition of “measures”. The definition includes government policies adopted for purposes other than GHG mitigation, and measures adopted by actors other than the government. The guidelines for first national communications required Parties to report only on measures implemented since 1990. However, in their first national communications, Parties used widely differing definitions of “measures”. For example:

- some Parties included only national policies, while others included both local and international measures, including technical changes adopted by the private sector
- some Parties only included measures introduced since 1990, while others included measures implemented before 1990

- some included only clearly implemented government policies, while others included policies that were still under discussion, or even desirable technical changes that were not being encouraged by any new policy.

A broad definition of "policies and measures" may be helpful to maximise the exchange of information through national communications. On the other hand, in the interests of international comparability there is a need for a tighter definition in the estimation of effects of measures. For the purposes of this report, policies and measures are taken to be national government policies that have been implemented since 1990, or whose future implementation is not in question.

Expert judgement is central to *all methods* for estimating the effects of measures, just as it is for producing inventories and projections. The integrity and transparency of the approach used may be as important as the choice of model. Some countries have adopted inter-ministerial or public consultation processes to review the assumptions and outcomes in the modelling exercise; a few have involved a variety of stakeholders.

Any method used to estimate the effects of policies and measures has to embody assumptions of one kind or another regarding the way measures will affect firm and consumer behaviour, equipment turnover, and the introduction of new technology. Engineering models are usually based on the assumption that technology is chosen and used to minimise system-wide discounted costs in meeting a given set of energy service demands. Input-output models are based on assumed or estimated production functions for each industry or process modelled. National energy models tend to have econometrically-derived energy demand equations rather than include explicit representations of industrial technology.

Good practice in estimating the effects of measures might include:

- using a wide range of data sources, taking care to ensure that the definitions used in collecting the data are consistent
- opening estimates and methods to peer review;
- explicit recognition of, and responses to, barriers to the changes encouraged by policies;
- recognition of the barriers to policy implementation;
- provision in the national communication of indicators and milestones with which the effects can later be verified.

5 Conclusions

This report has briefly reviewed various aspects of good practice in developing GHG emission projections and in estimating the effects of policies and measures on those emissions. The main purpose of providing with-measures emission projections in national communications under the UNFCCC is to allow Parties to assess progress in the implementation of the Convention. Projections may also be important in the future for Parties considering whether to trade GHG emission allowances.

There are several reasons for Parties to estimate and communicate the future (and historical) effects of policies and measures. These estimates give an impression of the effort each Party is making to reduce its emissions, and also give an indication of its ability to reduce its emissions. The requirement to report on effects of measures also encourages Parties to introduce monitoring systems, and to adjust their programmes to achieve their GHG mitigation objectives.

Baseline or without-measures emission projections have little purpose separate from the estimates of effects of measures.

Clearer guidance is probably needed for Parties on the types of policies and measures they should include in their with-measures projections, exclude from their without-measures projections, and include in their estimated effects of measures. Parties have interpreted the existing UNFCCC guidelines for national communications in a variety of ways, so that neither projections nor estimates of effects of measures are internationally comparable.

The national communication guidelines encourage Parties to move towards more detailed reporting on modelling assumptions. However, even where countries have provided quite comprehensive details of the assumptions made in the various models they have used, it is not possible for the reader to evaluate fully the robustness of the results.

A clear approach to monitoring, evaluation, and consequent programme adjustment may be more useful than detailed reporting on projection methods. While some countries' second communications have included a column on "monitoring" in the tables[4] describing the effects of individual measures, few have specified the indicators of progress that will be used.

There would be little value at present in harmonising of the modelling approach. Standardising models alone would contribute little to the comparability of the modelling results, which depend mainly on the inputs and the way the models are used. Standardisation of input data, however, is neither possible nor desirable. Countries should continue to use the best possible methods available to them.

There are many ways in which Parties could move towards better practice in developing and communicating their projections and estimates of effects of measures. Good practice would aim to improve the **comparability**, **consistency**, **accuracy** and **transparency** of national communications.

These four quality criteria need to be addressed at all stages in the development of projections and estimates of effects of measures:

- in the collection and analysis of historical data on activities
- in the measurement or estimation of the GHG emissions and absorptions linked to those activities
- and in the projection of future developments of technology and behaviour, and hence of activity levels and the associated GHG emissions and absorptions.

Comparability can be improved by following the existing guidelines for producing GHG emission inventories and national communications. It could be further improved by increasing the level of contact among the experts involved in the analysis for national communications in different countries.

Consistency could be improved by more contact among those involved in producing different sectoral assessments within countries. It could also be improved through the introduction of peer review processes for the analysis within countries.

Accuracy, or at least recognition of uncertainty, could be improved by ensuring that all assumptions or data used in producing projections and estimating effects of measures are based on literature review and national surveys or research, and are subject to peer review.

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4 This column is suggested in the template for the table provided in the guidelines for second communications.

Transparency could be improved by ensuring that all assumptions and data sources are fully documented, and that sources can be traced by an international user of the national communication. It could be further improved by conducting public and stakeholder review processes, and by including contact details in the national communication for those involved in the analysis.

Expert reviews have a particularly important role to play in improving the quality of national analysis and reporting. The UN FCCC In-Depth Reviews already provide one opportunity for expert scrutiny of national analysis, but there is rarely sufficient time during the reviews for a comprehensive evaluation. Annex I Parties might wish to consider some form of peer review process specifically designed to improve the quality of their projections and estimates of effects of measures.

6 Next Steps

In general, the current national communication guidelines provide an adequate framework for reporting on methods, but there is perhaps a need for clarification in some areas, in particular on the definition of policies and measures. One means of improving national communications would be through some form of good practice handbook. There is also clearly a need for more discussion among government analysts, at a more technical level and focused on some specific issues. One approach would be to establish more regular expert meetings to work towards a shared understanding of the purpose and approach to analysis for national communications.

This work could be pursued by the Annex I Expert Group or the UNFCCC Secretariat. If they wished to address inventory methods, they would need to do so in co-operation with the IPCC/OECD/IEA Programme on National GHG Emission Inventories.

ANNEX. ESTIMATING THE COST OF GHG MITIGATION

Some countries have placed particular emphasis on estimating the cost of their mitigation programmes. There are many possible indicators of mitigation cost:

1. visible costs of programmes and policy implementation in government budgets
2. private sector investment induced by government policies or recorded within a voluntary programme
3. net discounted public or private sector costs
4. effects on GDP
5. effects on trade, consumer surplus, inflation, employment, income distribution and other socio-economic indicators
6. effects on welfare based on a social cost accounting framework (e.g. “green” GDP)

Discussion of mitigation costs has tended to focus on indicators that are readily available as model results. These are net discounted costs (type 3), which are calculated for the energy sector by engineering models such as MARKAL, and effects on GDP (type 4), which are calculated by macroeconomic simulation models and general equilibrium models. In addition, macroeconomic simulation and general equilibrium models can usually calculate some costs of types 2 and 5.

A review of mitigation cost estimates in the United States has recently been published by the World Resources Institute (Repetto and Austin, 1997). This study examines model results of the effects of mitigation efforts on GDP and on “green” GDP. It finds that the models produce broadly consistent results, with differences being determined mainly by a list of six characteristics or assumptions.

- The extent to which substitution among energy sources, energy technologies, products and production methods is possible
- The extent to which market and policy distortions create opportunities for low-cost (or no-cost) improvements in energy efficiency
- The likely rate of technological innovation and the responsiveness of such change to price signals
- The availability and likely future cost of non-fossil, backstop energy sources
- The potential for international ‘joint implementation’ of emission reductions and
- The possibility that carbon tax revenues would be recycled through the reduction of economically burdensome tax rates.

Differences in assumptions explain why some studies find that GHG mitigation would decrease GDP, while others find that mitigation would increase GDP.

Azar (1996) has also carried out a detailed review of mitigation cost studies, focusing particularly on the underlying mechanisms for technical change assumed in the models. Several modellers, including

Dowlatabadi (1997), Grubb (1996) and Messner (1996) have experimented with models that incorporate endogenous technical change. That is, they assume that new technology becomes cheaper and more efficient the more it is used. This is consistent with historical experience (Nakicenovic, 1996). Such models tend to estimate much lower costs, or larger benefits, of mitigation than conventional economic models, which treat technical change as an exogenous process.

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