The indirect costs and benefits of greenhouse gas limitations[1]

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1 Introduction

There has been a considerable amount of work on the appraisal of different projects and programmes that reduce greenhouse gases (GHGs) (Haites and Rose, 1996; IPCC, 1996, UNEP, 1997 and UNEP, 1998). The focus of these studies has been on the proper methodologies for the estimation of the costs of GHG limitation, and on the correct methods for measuring the amount of GHGs reduced. Clearly, these are some of the central issues that need to be addressed in arriving at a policy for GHG mitigation; ideally one would choose those actions that reduce GHGs at least cost, and a measure of that is the cost per ton of carbon (or carbon equivalent) eliminated.

Although the cost (correctly measured) is one key component of the decision on which policies to select, it is not the only consideration. Other factors will enter the decision, such as the impacts of the policies on different social groups in society, particularly the vulnerable groups, the benefits of the GHG limitation in other spheres, such as reduced air pollution, and the impacts of the policies on broader concerns such as sustainability. In developing countries these other factors are even more important than they are in the industrialised countries. GHG limitation does not have as high a priority relative to other goals, such as poverty alleviation, reductions in employment, etc. as it does in the wealthier countries. Indeed, one can argue that the major focus of policy will be development, poverty alleviation etc. and that GHG limitation will be an *addendum* to a programme designed to meet those needs. Taking account of the GHG component may change the detailed design of a policy or programme, rather than being the main issue that determines the policy.[2]

The purpose of this report is to evaluate GHG limitation issues in a broader context. This includes the impacts of projects on vulnerable groups, the impacts on the environment more generally and the impacts on sustainability in a wider sense. It also offers some advice on how a decision-making framework can bring together these different dimensions. The structure of the guidelines is as follows. Section 2 introduces essential cost concepts and discusses the adjustments needed to the financial costs of different components, to arrive at the true economic costs. Section 3 looks at the macroeconomic impacts of different GHG limitation projects / policies. Section 4 discusses the way in which the sustainability concerns of such projects / policies can be monitored. Section 5 brings these different components together and looks at different methods of project selection. Section 6 provides a basic framework of impacts that are likely to arise in different GHG-related projects / policies, and what kind of method of estimation is available for these different impacts. Sections 7 to 9 go into greater depth on specific impacts. Sections 7 and 8 look at the employment and distributional effects respectively, and how they might be estimated. Section 9 evaluates the benefits in terms of changes in environmental damage resulting from GHG projects / policies. Section 10 provides three case studies in which the methods outlined in the report are applied. These case studies consider a biogas plant in Tanzania, a forestry project in the Russian Federation, and an energy efficiency project in Thailand. Section 11 concludes the report.

The report contains a number of examples of GHG limitation measures. Some of these are taken from actual projects and some are examples. They are intended to

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[2] The World Bank recognises this different focus in many developing countries and has prepared guidelines for the valuation of GHG 'overlays' to projects in the energy and forestry sector (World Bank, 1997). Although useful in terms of putting GHG projects in a wider context, it does not address the kind of broader social and environmental issues that arise in such projects. It is these that are central to this paper.

demonstrate a method and should not be regarded as numerically correct estimates of the relevant impacts in the countries concerned. Where estimates of broader impacts can be used in any applications of this methodology, this is explicitly stated.

2 Adjustment to Financial Costs

2.1 General Conceptual Issues

Financial costs are based on actual payments for goods and services. In evaluating GHG projects, however, it is not enough to know what the financial costs are. It is the true economic value of the resources used in the mitigation project that is of interest. Financial costs will reflect this true economic value when market prices are based on competitive conditions, when there are no taxes or subsidies, and when households, firms and other agents have perfect information. This will not always, or even typically be the case. In this section, a discussion of the economic cost concept is provided. This is then employed to show the kind of adjustments that need to be made to financial costs, in order to derive the economic costs.

2.2 Economic Opportunity Cost or Economic Cost

The key idea behind an economic cost of something (call it X) is the value of the scarce resources that have been used in producing X. That, in turn, is measured in terms of the value of the next best thing which could have been produced with the same resources and is called *economic opportunity cost*.[3]

This notion of cost may differ greatly from the common notion of cost. For example, take the case of sequestering carbon by growing trees on a tract of public land. In estimating the costs of such a programme, what should be taken as the cost of the land? In some cases no ‘cost’ is attached, because the land is not rented out and no money actually flows from the project implementor to the owner (the State in this case). This, however, is incorrect in economic terms.

The cost of the land is to be measured in terms of the value of the output that would have been received from that land had it not been used for forestry. Such values may be direct (e.g. agricultural output), and / or indirect (e.g. recreational use).

Often a resource is used and there is a financial flow associated with it. Working with the same example, the government may have leased the land to a farmer, who keeps livestock on it. If it is used for forestry the government often does not demand payment from the forestry authority. In that situation the ‘opportunity cost’ might be interpreted as a loss of revenue to the government. Although that is an opportunity cost to the government it is incorrect to take it as the *economic opportunity cost.* The reason is that the price of the original lease may not be equal to the opportunity cost of that land. Even assuming that the highest value use is livestock, the value of the land is the *net income* from livestock grazing, after deducting all expenses. Frequently the

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[3] In UNEP(1998) a definition of opportunity cost is offered. The modified term economic opportunity cost is used here because there is a distinction between such a cost measured in terms of the true scarcity value of the economic activities forgone and the opportunity cost measured, for example, in terms of the financial value of the activities forgone. The text provides examples of this distinction.

leases are for much less than that, so the opportunity cost is not equal to the financial flow to the government.[4]

The key points of note with regard to opportunity cost are the following:

a) there may be an *economic opportunity cost* to the use of a resource even if there are no financial flows associated with that use; and

b) if there are any financial flows, the *economic opportunity cost* may or may not be equal to the value of those flows.

In designing mitigation and adaptation cost strategies the objective is to minimise the *economic opportunity cost* of the programme. *Economic opportunity cost* is sometimes called just the *economic cost* and is closely related to *social cost.* It is also related to the concept of *shadow price,* both of which are discussed below. For a more complete discussion of these concepts see Markandya, Halsnaes and Milborrow, (1997).

2.3 External Cost, Private Cost and Social Cost

The term *external cost* is used to define the costs arising from any human activity that are not accounted for in the market system. For example, emissions of particulates from a power station affect the health of people in the vicinity but there is no market for such impacts. Hence, such a phenomenon is referred to as an *externality,* and the costs it imposes are referred to as the *external costs.* These external costs are distinct from the costs that the emitters of the particulates do take into account when determining their outputs (e.g. prices of fuel, labour, transportation and energy). Categories of costs influencing an individual's decision-making are referred to as *private costs.* The total cost to society is made up of both the *external cost* and the *private cost*, and together they are defined as *social cost.*

Social Cost = External Cost + Private Cost

Estimation of mitigation and adaptation costs necessitates working with social costs.[5] Often, however, the data will only provide information on the private cost. In these situations a correction has to be made for the missing costs. For further material on external costs the reader is referred to Baumol and Oates (1988), and Tietenberg (1996).

In this report, the external costs of GHG projects have been looked at in Section 9 (and to some extent in Section 7). The focus here, therefore, is on the adjustment necessary to private costs. This is done using shadow prices which are discussed below.

2.4 Shadow Prices

The above discussion concluded that the proper cost to consider in GHG projects is one based on *economic opportunity cost.* As noted above, where markets operate competitively and efficiently, the prices will reflect the opportunity costs and can be used to estimate the correct costs. In many instances, however, this will not be the case, and some correction will need to be made. The corrected market price, which should be equal to the *economic opportunity cost* of the resource, is called the *shadow price.* One important case of this is analysed in Section 7 with respect to unemployment. In that

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4 It can be shown that, under competitive markets with no taxes, the market price-based costs will be equal to the economic opportunity costs. This is important in the estimation of opportunity costs from market data.

5 Where the pricing of commercial goods is such that it includes both the *private cost* and the *external cost* (i.e. it is based *social cost*) it is referred to as *full cost pricing.*

section the benefits of employment are calculated, based on the money value of the change in status from 'unemployed' to 'employed'. The true opportunity cost of employment is then the difference between the two. For example, if a project uses labour that is paid a wage of $20 a day but the benefits of employment are $8, then the true *economic opportunity cost* of that labour is only $12, and the *shadow price* of labour is $12.[6] Adjustments to market prices to obtain shadow prices will be needed when:

- there are distortionary taxes and subsidies, so market prices deviate from economic opportunity costs; and
- there are monopolies and other market imperfections making the market price higher or lower than the shadow price.

The simplest way to correct for such distortions, *where the resources are tradable*, is to take the international prices of the resources. Assuming well functioning markets, these prices are seen to be 'optimal'. If a good is exported, for example, the export price can be taken, or where it is imported the import price can be taken. These prices should then be corrected for taxes and subsidies (i.e. the former should be deducted and the latter added).

Where the good is not traded, the shadow price should be calculated on the basis of the cost of producing the good with the inputs being valued at their economic opportunity cost. A method for doing this has been developed by Little and Mirrlees (1974), Ray (1984) and Squire and van der Tak (1975), and subsequently used by several researchers to estimate shadow prices in a number of developing countries.

When applying this framework to a project (e.g. wind powered irrigation for increased agricultural yields) three important shadow prices are typically required. They are the prices of capital, labour and foreign exchange. For these, detailed analysis of the relevant sectors is required. The prices of labour is dealt with in Section 7. For capital and foreign exchange, the analyst carrying out a GHG estimation is advised to obtain the relevant values from economists who have worked on the sectors concerned. The World Bank and other bodies involved with Global Environment Facility (GEF) projects appraise projects in most developing countries and would have a set of values that are used; these can presumably be accessed from their databases (as can the shadow prices for many inputs and outputs). For example, in the case of India, the Institute of Economic Growth in New Delhi has recommended a coefficient value of 1.4 for capital, materials and equipment, but a value of one for foreign exchange. The value of 1.4 indicates that capital is 40 percent more scarce than its market price would suggest, so that when estimating the costs of the project the capital value should be increased by that amount. A value of one for foreign exchange implies that the exchange rate is in market equilibrium and there is no need to make any other adjustments in going from domestic to foreign prices and vice-versa.

Another important economic cost that does not have an adequate financial counterpart is the cost of time. Individuals often perform economic tasks that take time but for which they are not paid. Such time has an important value. In the context of GHG limitation projects an important time component is that of (typically women) collecting fuel wood or managing energy supplies for the home. A project that changes the energy source to a commercial one for which payment is made in money terms will release the energy manager's labour. This should be valued. In accordance with the

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[6] Some textbooks call the shadow price the **ratio** of the true cost to the market price. In the above case the ratio would be 0.6 and all market data would be multiplied by this to obtain the economic opportunity cost.

idea of opportunity cost this cost is the value of the alternative activities that can be performed with the same time. An analysis of the use of time in the community is necessary to establish this value but, as a first approximation one can take the wage paid to the person concerned, adjusted for any taxes / subsidies.

2.5 Hidden or Implementation Costs

Although not directly associated with *financial* versus *economic* costs, an important category of costs is that related to changes in institutional and other arrangements, so that the GHG limitation projects can in fact be implemented. In the literature there is reference to so-called 'no regret policies'. These are policies for which reductions in GHGs can be achieved at a *net savings in costs* (i.e. at negative costs). The standard response from economists is that if such options exist why are they not already being implemented? There are often perfectly good reasons for the failure to adopt such policies, such as institutional barriers or an inefficient capital market. The key point to note, however, is that these barriers are not going to disappear of their own accord. If 'no regrets' policies are to be implemented, allowance needs to be made for the costs of removing these barriers. One way the cost estimates should be extended is by including costs such as those of institutional reform and capacity building. A second is to place a shadow price on the resources that are scarce and that act as an impediment to the adoption of 'no-regrets' policies. Prime among these is capital, which should have a shadow price of greater than one in many developing countries, as discussed above.[7] Overall, the need to take account of such 'hidden' costs is very important to a realistic appraisal of the different projects and policies. It is a grave mistake to assume that certain projects and policies can be implemented without incurring significant institutional and transitional costs related to changing practices and customs.

Issues arising in the estimation of such 'hidden' or 'implementation' costs are discussed further in Marakandya, Halsnaes and Milborrow (1997). In estimating such costs it is important to distinguish between projects that can be implemented by one (or few) actors, like the government or a private company, and projects that involve many individual agents. A example of the first sort of project is a large scale power plant, while an example of the latter is a Demand Side Management (DSM) programme. It is generally more complicated to design and estimate the costs of implementation programmes targeted to many individual actors than one with centralised project planning.

Implementation policies can also be separated into policies that can be described as small "marginal" efforts that create an incentive for changing specific behaviour or introducing new technologies, and more "general" policy efforts like economic instruments or general educational programmes that work through changing the general market conditions and the capability of the actors.

Whether an implementation policy is "marginal" or "general" depends on market conditions, as well as on the overall set of policy instruments targeted towards climate change mitigation. Given a "general" environment in which energy and financial markets are efficient, competitive and have little government intervention, and where the institutional context is perceived as favourable for climate change mitigation programmes, the implementation policies need only take the form of information programmes, energy auditing and other specific regulation efforts. On the contrary, if

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[7] It should be recognised, however, that *implementation costs* assessed using shadow prices will not pick up factors such as quantitative or physical constraints on the use and allocation of some resources, particularly financial ones.

energy prices are heavily subsidised and financial markets are very limited, the implementation policy may require general price reforms, specific grants and other institutional changes.

Implementation policies of the specified “marginal” sort can be relatively easily integrated in project or sector level mitigation assessment. Implementation assessment will include the costs of different kinds of programmes for information, training, institution-strengthening, and the introduction of technical standards. The most difficult part of such an assessment relates to the behaviour of the target groups. A detailed amount of information is needed on the behaviour of specific actors including households and private companies in order to design the most effective policy options.

It is difficult to integrate “general” implementation policies like price changes in specific project and sector assessments. Returning to the example of DSM projects, implementation costs would include information and training programmes, institutional capacity building, financial costs, and sometimes also “costs” of changing market conditions (prices and taxes). The costs of “general” changes in market prices and tax systems can only be assessed at the economy-wide level. The introduction of energy or carbon taxes or removal of subsidies can cause significant structural effects, which again will change energy demand and technology choice. Thus the proper full analysis of the implementation costs will necessitate an economy-wide analysis involving, for example, the use of computable general equilibrium models.

A framework for assessing implementation costs will then include: costs of project or policy design; institutional and human capacity costs (management and training); information costs; and monitoring costs. The costs of resources involved should, in each case, be based on economic opportunity costs.

2.6 An Example of Shadow Prices

The following example (Table 1) shows how the financial costs can be modified to take account of shadow pricing along the lines suggested above. The project concerned incurs costs over 5 years under the categories of unskilled labour, skilled labour, capital (domestic) and capital (foreign). The corresponding shadow price coefficients are 0.5, 1.2, 1.4 and 1.6. The values of 0.5 and 1.2 for labour imply that there are employment benefits for unskilled labour (for reasons given in Section 7), but skilled labour is paid less than its scarcity wage. The values for capital imply that both domestic and foreign capital are more scarce than their market prices would suggest, with foreign capital being relatively more scarce than domestic capital.

Table 1 shows how the costs will vary once shadow pricing has been taken into account. The overall cost has risen by 30 percent but the changes in individual costs are as important because they will influence the design of the project (e.g. substituting unskilled labour for capital where possible).

Table 1 An Example of Shadow Price Adjustments to Costs[1]

Year	Unskilled labour		Skilled Labour		Domestic Capital		Foreign Capital		Total	
	F[2]	E[3]	F[2]	E[3]	F[2]	E[3]	F[2]	E[3]	F[2]	E[3]
1	100	50	20	24	100	280	100	160	320	514
2	100	50	20	24	60	140	60	96	240	310
3	50	25	10	12	0	0	0	0	60	37
4	50	25	10	12	0	0	0	0	60	37
5	20	10	5	6	0	0	0	0	25	16
Total	320	160	65	78	160	420	160	256	705	914

Notes:
[1] All figures are hypothetical and can be assumed to be thousands of dollars.
[2] F denotes Financial Cost.
[3] E denotes Economic Cost.

2.7 Conclusions

A clear understanding of the term *economic cost* and its role in the analysis is critical to the correct and consistent estimation of the costs of mitigation and adaptation to climate change. The main points to note are:

I. The key concept of cost in evaluating mitigation / adaptation programmes is the *economic opportunity cost.* This may not be equal to the financial flows arising from the programmes.

II. To estimate the *economic opportunity cost* of a programme it is necessary to adjust the data received from market transactions. One set of adjustments is to add any *external costs or benefits* that arise.

III. A second set of adjustments is to correct for distortions in the market prices. Such distortions arise because of government taxes and subsidies, because markets do not always clear, or function with money transactions, and because of monopoly or other factors.

IV. The full set of corrections described above can provide an estimate of the *social cost* of the programme.

V. An example of the corrections is given above for the non-external cost corrections. External costs corrections were dealt with in Section 9.

3 Macroeconomic Impacts

Certain categories of GHG limitation projects will have macroeconomic impacts, by which is meant impacts on GDP, the regional and sectoral breakdown of that GDP, employment and trade. Most likely candidates for such impacts are: projects that involve wholesale changes in fossil fuel use; the implementation of market based instruments, which raise the prices of energy based on its carbon content; and projects that entail large modifications to land use.

The assessment of such impacts is carried out through macroeconomic models that estimate impacts across sectors, allowing for important inter-sectoral linkages. There are many approaches to the modelling of macroeconomic impacts with the key differences being the assumptions about how the economy operates, and in particular how efficient it is at clearing markets, especially the labour market.[8] The costs of containing GHGs will in large part depend on which kind of model is taken, and on the assumed values for key parameters. In particular, since GHG models have long horizons (often more than 20 years) the rates of technological change will be crucial in determining the costs. The evidence that results can vary a great deal across models is amply provided by the IPCC (1996). It should also be noted that, even if agreement could be reached on the underlying model to be used, differences would arise because many of the parameters on which the answers depend are not ones for which we have adequate empirical estimates. This implies that one needs to carry out some sensitivity analysis of the impacts and report a range of results.

Some of the key issues that need to be addressed in the macroeconomic modelling are:

a) measurement of impacts in the models;

b) baseline selection; and

c) treatment of double dividend and multiple objectives.

3.1 Measurement Of Impacts In The Macroeconomic Models

Most macroeconomic models use changes in GDP as a measure of the economic cost. Although this is useful, it is perhaps not the most important macroeconomic impact that needs to be addressed. Also important are the effects of the GHG policies on employment, on the trade balance and on the sectoral composition of GDP. The last is particularly relevant because it will determine the response of many sections of society and could signal important regional and distributional impacts.

A further point to note is that GDP is not a correct measure of welfare, in the same way as economic opportunity costs are a measure of welfare. The reasons why GDP changes may not reflect changes in welfare are primarily the presence of non-market benefits and costs. So, for example, a policy that reduced GDP, but improved air quality, would have a measured loss in GDP terms but could have a net welfare gain when account is taken of the benefits of the improved environment. The same applies, to changes in income distribution, poverty, etc. that will affect welfare, but will not be picked up in the crude macroeconomic measures of GDP change. For these reasons the macroeconomic analysis can only provide a partial picture of the impacts of climate change measures.

In view of the above, the analysis of the macroeconomic impacts should look at multiple objectives, not just GDP objective. Most models are capable of providing at least some of the additional information.

3.2 Baseline Selection

The baseline for the macroeconomic analysis is the set of values of the key variables that would exist over the planning horizon in the absence of the GHG limitation policy. For the typical macroeconomic ('top down') models this will generally be rather crude as far as emissions are concerned, given the higher level of aggregation of these models. In most cases these are not checked for consistency with the more disaggregated sectoral models. This is due to the fact that the work is frequently done

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8 Examples of macroeconomic studies include: Barker *et al.* (1994) and Ekins (1994) for the UK; Jorgensen and Wilcoxen (1993), Nordhaus and Popp (1997) for the US; and Capros *et al.* (1996) for the EU. Also, IPCC (1996) cites more than two hundred such studies.

by different researchers who do not communicate on the setting of the baseline. Ideally the baseline assumptions for the macroeconomic evolution of the economy should be made by the macroeconomic analysts and those for the emissions should be the domain of the sectoral modellers, but this is not how the models have been developed or evolved. In view of this, care needs to be taken to ensure consistency in the baseline assumptions used in the macroeconomic analysis and those used in the more detailed estimation of projects for GHG reduction. In both cases the baseline should be, as far as possible, a representation of what would happen in the absence of the GHG reduction policy. Given the uncertainties about future trends it has been suggested that a number of baselines be used (the multiple baseline assumption). This will allow the analyst to provide a range of estimates of the impacts, all with some prospect of being realised. Issues of baseline selection are discussed in greater detail in UNEP(1998).

3.3 Treatment Of Double Dividend And Multiple Objectives

Some macroeconomic models have looked at the issue of climate change by imposing carbon taxes to encourage the reduction of GHGs. In such models the issue of what is done with the revenues arises. The revenue can be used to reduce other taxes, or can be recycled in some other way. The overall impacts, however, will not be indifferent to the method of recycling. Much is made in some studies of a possible ‘double dividend’, in that reducing the more distortionary taxes can increase economic efficiency and provide economic gains in addition to reductions in environmental impacts. The view taken here is that the modelling of policy instruments for climate change should not confuse the issue by seeking multiple objectives. If a carbon tax is introduced, the costs of achieving a given target reduction in emissions should be based on the policies most likely to be adopted for revenue recycling, not on the basis of possible tax shifts that *may* be desirable.

3.4 Conclusions on Macroeconomic Impacts

Macroeconomic impacts, i.e. impacts of GHG limitation policies on national output (GDP), employment, trade, and the sectoral / regional breakdown of output and employment, are important considerations for some policies. In particular they are important for the assessment of market based instruments, or limitation policies that affect a large number of individuals or require wholesale changes in energy sources and land use. For these policies some macroeconomic analysis is desirable. The problem is that the answers depend considerably on what assumptions one makes, and there is little guidance on what these assumptions should be. Consequently, it is important to provide a range of estimates of the macroeconomic impacts. The analysis should be carried out under the most realistic assumptions of what would be the case *without* the policy (the baseline) and what would be the case *with* the policy. Exploiting the opportunities of GHG policies to affect other changes such as changes in the tax structure, should not be built into the analysis unless there is clear evidence that these changes can in fact be implemented. The macroeconomic impacts will have to be evaluated in a multi-dimensional framework, such as that discussed in Section 5.

4 Sustainability

4.1 Basic Concepts

The issue of sustainability arises here because environmentalists are concerned that the policies followed should contribute to the longer-term resolution of the conflicts between protection of the natural environment and economic development. This issue, which was first brought into the public domain in a significant way by the Bruntland Report (World Commission, 1987), was posed as a search for a path of development that meets the needs of present generations without compromising the abilities of future generations to meet their needs. Subsequent developments of the idea refer to the concepts of 'weak' and 'strong' sustainability (Pearce, 1993). The notion of 'weak' sustainability is that society should develop its resources in such a way as to ensure the passing on of a stock of wealth (including natural capital) to future generations at least as great as the one inherited by present generations. This stock is measured in money terms. The notion of 'strong' sustainability is to ensure that critical parts of the natural capital are not degraded and that renewable resources are used in a manner that is as sustainability as possible, given other constraints on resource use and economic development. The appeal of 'weak' sustainability depends on the degree of substitution between natural and man-made capital in the production process. There are significant difference of opinion about that among environmentalists and economists.

4.2 Sustainability and GHG Mitigation

In the context of GHG limitation projects it is the 'strong' sustainability notion that is the important one. In developing policies for this area, importance should be given to the achievement of the goals of sustainable resource use and protection of critical natural capital. In addition greater importance should be paid to the long-term implications of any policies introduced today.

Table 2 provides a list of the main sustainability indicators that should be provided for GHG limitation projects in each of the following key areas: energy, forestry, transport and land use / agriculture.

A key indicator of sustainability in Table 2 is the impact the project or policy has for the share of total energy that will come from renewable sources at the beginning and at the end of the planning period. This applies to almost all interventions that are likely to be considered, and could, in fact, be reported for *all* interventions, even those that will not impact on the use of renewable resources.

For fossil fuel policies it is important to look at how long such policies will last. This is not mainly a physical consideration, but an economic one. At some time the fossil energy source may be so depleted that the costs of extraction will rise above those of the renewable source. That is the point at which the fossil fuel is effectively depleted. An idea of when that is likely to happen will provide useful information on the length of time for which the present project (and its successors) can last.

For projects that impact on the natural resource base directly, e.g. forestry and biomass production, an assessment of the impacts on key forms of natural capital, particularly biodiversity related, should be provided. This information will probably not be quantitative, but rather a qualitative description of what impacts are expected. In some cases, however, it is possible that quantitative data on species impacts or increased measures of eco-system stress may be available. For a further discussion of such measures see ExternE (1997).

For biomass projects it is important to monitor how agricultural land use will affect yields in the medium to long term. Placing a reporting requirement on this will ensure that estimates are prepared. A range will typically need to be reported to allow for the uncertainty arising from the estimation procedures.

Table 2 Sustainability Indicators for GHG Limitation Projects

Policy Intervention	Sustainable Use of Renewable Resources	Key Natural Capital	Other
Switches in fossil energy use	Period for which new regime of fossil fuel use will be economically feasible.		Cost / unit of energy from renewable energy source at end of period when fossil fuel will be economically feasible.
Renewable energy/ Energy Conservation/ Market Based Instruments	Change in share of total energy from renewable sources at beginning and at end of planning period.	Any impacts on key biodiversity or other natural assets of developing renewable sources.	
Forestry	Change in share of total energy from renewable sources at beginning and at end of planning period. Will programme include replanting at end of each cutting period?	Any impacts on key biodiversity or other natural assets of forestry resource development.	
Transport	Change in share of total energy from renewable sources at beginning and at end of planning period.		Impact of policies on share of total land for urban / suburban use.
Land Use/ Agriculture	Change in share of total energy from renewable sources at beginning and at end of planning period.	Any impacts on key biodiversity or other natural assets of developing renewable sources.	Change in yields from land devoted to biomass etc. at end of planning period.

Finally, some projects involving transport will have impacts on urbanisation and on land available for agriculture. One sustainability concern is that the trends in land use are not sustainable; that as more and more land is taken into urban and suburban use, there is a loss of amenity and of biodiversity. A proxy for that is the change in the percentage of urban / suburban land. Polices in the transport sector that reduce energy use could reverse present trends and cause a fall in the areas of suburban land (or at least arrest the rate of growth of such land).

The above measures of sustainability are useful complements to the monetary measures of the costs of GHG limitation projects. The next section discusses how the two kinds of information may be integrated into a framework for decision-making.

5 Selection Criteria

The information collected on the impacts of a GHG limitation project or programme needs to be summarised so that different projects and programmes can be compared. There are three kinds of information to be summarised. These are:

a) quantitative information in money terms;

b) quantitative information in physical units; and

c) qualitative information.

The same impacts can, of course, be classified in all three categories, so that data on reductions in fossil fuel emissions can be quantified in money terms, reported in terms of tonnes of pollutants, and in terms of quantitative impacts on eco-systems, etc. In preparing summary indicators it is important not to count the same information twice, so that it is unduly weighted in the final selection criteria.

5.1 Quantitative Monetary Data on the Project

5.1.1 The Cost Effectiveness Criterion

For programmes that estimate the cost of achieving a certain reduction in GHGs the main criterion is normally the net present value cost per ton of GHG removed. If the net cost in period *i* is C_i and the reduction in emissions in period *i* relative to the baseline is E_i then the appropriate criteria for project *P* is FUCOSTEF_p where:

$$\text{FUCOSTEF}_p = \frac{\sum_{i=0}^{i=T} C_i (1+r)^i}{\sum_{i=0}^{i=T} E_i (1+d)^i}$$

The cost C_i is the net cost of the project after any associated benefits have been subtracted from the direct costs in time period *i*. The term E_i is the carbon weighted reduction in emissions in period *i* relative to the baseline. FUCOSTEF refers to the fact that the costs are the full (FU) *economic costs* of the project (in so far as they can be monetised) and not just the direct financial costs, measuring the cost effectiveness (hence COSTEF). It is to distinguish it from FICOSTEF, which represents the direct *financial costs* (hence FI) of the project and which will be discussed below. Note that for FUCOSTEF, all net costs are economic costs, as described in Section 2. The term *r* is the rate of discount for costs and *d* is the rate of discount for emissions. It is rare, however, for programmes to be evaluated in this way. Frequently annual emissions are compared with levelised costs. This is not as accurate as using the above formula.

The values of FUCOSTEF_p will depend on the precise value attached to the different components of costs and, as noted earlier, these costs are uncertain, with ranges of values rather than a single value. In view of this, it is important to present a range of such values and to indicate the impacts from which the uncertainty arises. Related to that, it will be useful to present a more detailed table of the components of the costs by time period, so that the policy-maker can draw on this information should it be considered necessary.

5.1.2 Choice of Discount Rates

The debate on discount rates is a long-standing one (see IPCC, 1996). As that report notes, there are two approaches to discounting; an ethical approach based on what rates of discount *should* be applied, and a *descriptive* approach based on what rates of discount people actually apply in their day-to-day decisions. The former leads to relatively low rates of discount (around 3 percent in real terms[9]) and the latter to relatively higher rates (in some cases very high rates of 20 percent and above). The arguments for either approach are unlikely to be resolved, given that they have been going on since well before climate change was an issue. Normally the COSTEF values are calculated for more than one rate and the results presented to provide the policy-maker with some guidance on how sensitive the results are to the choice of discount rate. The sensitivity is certainly there; at high rates energy projects with long gestation periods become unattractive compared to those with a shorter period. For the purposes

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9 The real rate of discount is the market rate net of inflation. Thus if a market has a discount rate of 12% and inflation is 8% then the real rate is 4%.

of the broader analysis, it is recommended that a central real rate of 3 percent be applied and a sensitivity carried out for real rates of 1 percent and 10 percent.

In addition to discounting future costs and benefits there is the further issue of whether or not future emission reductions should be discounted when compared to present reductions. The justification for discounting them is that future reductions are worth less than present reductions in terms of reduced impacts. The choice of the appropriate rate, however, remains an unresolved issue and, again, taking a range of plausible values is the only solution. It is recommended that the same rate of discount be applied to them as to the costs, with sensitivity to rates of 1 percent and 3 percent being used.

One point perhaps which should be noted relates to the use of low discount rates for appraising GHG programmes in developing countries, where capital is scarce and market rates of discount are very high. This low real rate for mitigation programmes can be justified on the ethical grounds mentioned above. The scarcity of capital, on the other hand, can be dealt with by having a shadow price for capital that is greater than one, as discussed in Section 2.

5.2 Quantitative Non-monetary Information

Quantitative information in non-monetary units will be available for:

a) employment impacts;

b) income gains and losses of different groups;

c) associated environmental changes;

d) macroeconomic impacts on GDP, trade and sectoral changes in GDP; and

e) sustainability indicators of the share of energy derived from renewable sources, now and at the end of the planning period.

In addition, some of the other sustainability indicators may be quantified, although that is not certain.

Some of this information will have been converted into monetary units, namely (a) to (c). There are two ways of integrating this information with the monetary information. One is to calculate the FICOSTEF value, which excludes the costs associated with (a) to (c) and then present the cost information as well as the information on (a) to (e) in table form. As with the values of FUCOSTEF, there will be ranges of values for FICOSTEF and the items (a) to (e).

The second is to report the FUCOSTEF value, which include the costs attached to (a) to (c), and then add the information from (d) and (e) in a new table. Both are important and should be carried out. Once the data have been presented, a further summary statistic can be developed based on weights for the different components of the project, both monetary and non-monetary. This method is called a *multi-criteria* (or *multi-attribute*) analysis, further details of which are available in Pϑtry (1993), Keeney and Raiffa (1993), and Meier and Munasinghe (1994). The weights can be derived through discussions with policy makers, or through reviews of related policy decisions. An evaluation of the project will then constitute a single value (or a range of values, each associated with different estimates of the impacts) summarising its overall impact. This will enable comparison with other projects in the same and related GHG fields.

Perhaps more useful than the summary indicator is a guide to what weights are critical to decisions about the rankings of different projects. This will assist the policy maker to see how much something like “sustainability” or “GDP” must matter if a cost based ranking is to be reversed. It is difficult to give more detailed advice on this, as the use of the technique is very much a matter of practice. An example is given in Section 10 where some case studies are presented.

5.3 Qualitative Information

Qualitative information on impacts is important and should not be ignored. It cannot be integrated into the summary COSTEF values or the multi-criteria number, but it is relevant to the selection of the project and, more crucially, to the design of the project. Once a GHG-related project has been identified, a preliminary screening should generate important qualitative information. This should then be used to modify the design of the project so that the key negative impacts are mitigated wherever justified. The revised project will still have some impacts but these will have been passed as ‘acceptable’. This preliminary screening of projects will avoid serious environmental damages, as well as serious political blunders where projects that seem technically acceptable have such negative impacts on key stakeholders that they are bound to fail on political grounds.

5.4 Conclusions on Selection Criteria

Ultimately the decisions on which projects to undertake is a political one. The screening rules discussed above are a guide to those decisions. As has been noted, these rules will not provide unique guidance on which policies or projects to choose. Nevertheless, they will provide a range of indicators on financial costs (FICOSTEF), full economic costs (FUCOSTEF), and on the other quantitative and qualitative impacts that are inputs to the decision-making process.

In Section 10 some summary statistics are provided for three GEF ‘projects’.

6 A Framework for All Impacts of GHG Limitation Projects

Greenhouse gas limitation projects may be implemented in many sectors of the economy and may have a wide range of impacts. A partial but my no means exhaustive list of possible projects, applicable to four key source sectors (energy, forestry, transport, agriculture / land use), is shown in Table 3. A qualitative indication of the main impacts that need to be considered when assessing limitation projects in each of these sectors is provided in Table 4. Discussed below[10] are some of the reasons for the judgements made in Table 4.

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[10] This discussion is only intended to point to the directions where impacts are likely to be important. A more full discussion of the effects and their measurement is given in Sections 7 to 9.

Table 3 Examples of GHG Limitation Projects in Different Sectors

Sector	Mitigation Option
Energy	• End-use energy efficiency improvements in domestic, commercial, or industrial premises • Transmission systems • Fuel switching • Renewable technologies (decentralised) • Supply technologies (centralised): fossil fuel, nuclear, renewables
Forestry	• Afforestation projects • Increasing the carbon sequestration capability of growing forests • Recycling or permanent storage of carbon sequestered in harvested biomass • Reforestation
Transportation	• Efficiency improvements for vehicles • Switch to fuel systems with lower emissions • Improve transport system efficiency • Modal shifts • Manage transport demand
Agriculture / Land use	• Fertiliser control systems • Introduction of crops with large carbon sequestration capability • Livestock management • Use of agricultural products as a fuel source • Cultivation of rice paddies

Source: UNEP (1997).

Table 4 Impacts of GHG Projects Relevant to a Broader Analysis

Project	Employ-ment	Income Distribu-tion / Poverty	Associated Environ-mental Benefits	Adjust-ment to Financial Costs	Macro - economic Impacts	Sustaina-bility
Energy Fossil Fuels (Efficiency / fuel switching)	++V	+V	+++	+++	++	++
Renewable Energy	++	+++V	+++	+	+	++
Energy Conservation	+	+	+V	++	++	++
Market Based Instruments	+V	++V	++V	+++	+++	++
Forestry	++V	++	++V	++	+	+++
Transport	+	+++V	+++	++	++	++
Land Use / Agriculture	++	++V	+++V	++	++	+++

Key:
+ Not considered important.
++ Of some significance.
+++ Of considerable significance.
A 'V' indicates that the impact will vary according to local circumstances.

6.1 Energy

6.1.1 Fossil Fuels

There are many projects that deal with measures to reduce emissions from fossil fuel use through increased efficiency (e.g. repowering of electric generating units), or though fuel switching (e.g. conversion from coal to gas), etc. The employment effects of such projects are not likely to be large in general, although there could be major impacts if a country followed a policy of switching from domestic coal to gas, for example. Likewise, the income distribution and poverty impacts of fossil fuel efficiency / switching policies will not be significant, in most cases. The associated environmental benefits will, however, be important as there will be implied changes in emissions of SO_x, particulates and other pollutants. These can be quantified. Adjustments to financial costs will be required when prices of capital goods are out of line with the true economic costs of these goods, and when fossil fuel inputs carry significant taxes and subsidies. Macroeconomic impacts of fuel switching will arise when there are trade effects from the switching policy, or when the substitute fuels are more expensive for industry and households than the original fuels. Finally, the sustainability concerns relate to how long the new fuel regime can last and whether adequate substitutes can be developed in the time period before it becomes too costly to use an alternative fossil fuel (or more generally how the costs of the substitutes will evolve over time).

6.1.2 Renewable Energy

There is a wide range of renewable energy projects that can be introduced to limit GHG emissions. For example, the use of biomass, solar, wind, hydro and nuclear as a substitute for fossil fuels will result in reduced GHG emissions. In developing countries, increased efficiency in the use of fuel wood, the development of biogas and other rural energy sources could also result in reduced GHG emissions. In this case the employment impacts are potentially important and should be analysed, as should the impacts on the poor and the vulnerable income groups. There will be associated environmental benefits in the form of reduced polluting emissions as well as reduced damage to the natural environment (if biogas replaces open access fuel wood collection, for example).

With renewable energy in developing countries the financial costs will diverge significantly from the economic costs. For example, the provision of regular energy supplies to rural consumers will reduce the time spent collecting fuel wood. This time has a value, although there is no direct financial flow associated with it, and it should therefore be priced and included in the analysis as a benefit or reduction in cost.

Macroeconomic impacts from renewable energy programmes are likely to be small. Sustainability issues, on the other hand, will be important in that the move from the existing use of energy to a more sustainable renewable source will entail a benefit in terms of sustainability. These effects also need to be accounted for.

6.1.3 Energy Conservation

Energy conservation programmes are envisaged here as 'end-use' energy efficiency programmes, such as improved insulation, improved heating and refrigeration, lighting equipment that allows for more efficient energy use, waste heat recovery, etc. These measures have an impact on firms and households and can generate some impacts outside the area of main concern to them. These are unlikely, however, to include significant effects on employment and income distribution, although the acceptability of household schemes for energy conservation will depend on there not being any adverse income effects.

The main associated benefits/costs of energy conservation programmes will arise in relation to the pollution saving, which results from the increased efficiency, and from the sustainability implications of the increased levels of conservation.

6.2 Forestry

In the case of forestry projects, employment effects could be important, as could the impacts of using land for re-plantation on peasants and other potential users. These effects have to be estimated and reported in the broader analysis.

Associated environmental benefits of forestry projects could be changes in the conservation of biodiversity, reduced soil erosion, etc. There could be associated benefits from secondary forest products that result from any re-plantation programme. On the other hand, large mono-cultural plantations have often had negative environmental impacts, which have to be accounted for. The design of the forestry programme should be such as to minimise these costs (Hall and House, 1994).

The adjustment to financial costs arises primarily because of a limited market in land that is used for the purpose of reforestation and for the secondary forest products. These items do not have adequate market values that can be used in the analysis, and hence an alternative method of valuation has to be used. Details were discussed in Section 2.

From the experience so far, reforestation programmes are not expected to have significant macroeconomic impacts.

Sustainability issues that arise from forestry projects relate to the long-term plans for the areas replanted. If the expectation is that the forest will be managed sustainably (i.e. replanted after harvesting), the impact will be different compared to a situation where the planting is a ‘one-off’ exercise.

6.3 Transport

As indicated in Table 3, a number of options are available that will reduce GHG emissions from the transport sector.

The employment effects of most of the practical options in these areas are not likely to be large, although one should check carefully for each option proposed.[11] The income distribution effects are potentially significant. Some measures to reduce emissions will require increased strict controls on older vehicles, two-wheel vehicles, etc. Others will raise the cost of transport in general. The costs of these options are likely to fall on urban groups, which, while not at the bottom of the income distribution, are among the lower middle income earners. The impacts on these groups are, however, of considerable significance both in social and political terms. From the practical viewpoint of the implementation of the policies, it is not enough to have an idea of the impacts by broad income category. Much more details are needed on the key groups impacted and on the spatial and other dimensions of the impacts. This is still lacking, both in developing countries, and industrialised countries. In the latter it has been argued that the distributional impacts of most environmental polices are not large; as a

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11 The exception relates to mitigation policies that may require significant investment in the transport infrastructure, in which case there might be some short-term employment effects.

percentage of income the gains and losses are indeed small. But that is misleading in relation to the possible objections that can arise over such measures, as recent attempts to increase energy prices in the US and UK have shown. A better understanding of the distributional effects of different measures is required across a wide range of environmental policies.

The associated environmental benefits of transport policies are of considerable importance. Reductions in emissions will generate benefits in terms of health, reduced materials damage, reduced damage to ecosystems and amenities, as is discussed in Section 9. These secondary benefits in themselves could justify many of the GHG mitigation measures proposed for this sector.

The financial costs of transport are often a poor guide to the true economic costs because many transport services are not priced. In particular, the use of roads is not subject to direct pricing, so that the effects of changes in traffic flows on travel time have to be estimated separately and included in the costs of the measures. Taxes on fuels and on vehicles also result in financial costs diverging from economic costs.

There are some potentially important macroeconomic impacts of transport policies. Unlike market based instruments, where the effects are more on GDP, trade, etc., in the case of transport the effects will be more spatial and sectoral. These include changes in the value of land, the relocation of economic activity, etc. Modelling these is difficult and, to date, there is very little empirical work available, particularly for developing countries. In most cases one will have to rely on *ad hoc* discussions of potential macroeconomic impacts of this kind.

The sustainability issues concerning transport relate to how the policies will influence the long-term use of resources and land. A policy of reduced transport investment could, for example, reduce the conversion of non-urban land to urban land, thereby maintaining the stock of natural capital in a better state than it would be with present policies. This is a potentially important impact that needs to be looked at, although, as with the macroeconomic impacts, there are few tools available for doing so.

6.4 Land Use and Agriculture

In practice, policies aimed at changing land use and agricultural practices to limit GHGs are few. Of the options listed in Table 3, examples of the following have been identified: the use of agricultural residues for energy generation (co-generation); the production of ethanol for use in existing fleets of motor vehicles; and reductions of methane emissions from livestock (Karekezi, 1994, and Hall and House, 1994). These examples all show how the agricultural/land use issues are linked to energy, transport and other categories of GHG mitigation considered in this report.

The employment effects of programmes that use agricultural land to generate raw materials for energy could be significant. The impact of interest is, of course, the net effect of changing from one form of land use to another. In addition, the processing of the agricultural products will also have an employment effect, which has to be accounted for. The same measures will often generate income among low-income households and thereby contribute to the reduction in poverty. This also needs to be taken into account.

There are a number of associated environmental impacts that need to be looked at. Increased use of agricultural inputs, water resource implications and soil mining are all factors that have impacts that need to be evaluated. The planting of areas with mono-cultures may have impacts on biodiversity that will also need to be estimated. In some cases, such as the agro-forestry planting of trees, the projects may actually enhance food production and reduce run-off, which may have significant positive impacts.

As with the case of forestry, financial costs will not always reflect the economic costs of the land used for planting, or the agricultural residues, which may have alternative uses that are not valued through the market place.

The macroeconomic impacts of agricultural projects are mainly through their effects on food production. If the land used for biomass production is degraded or surplus, then the impact on food should be small, but account should be taken of the use of water and other inputs for the biomass and its knock-on effects on food production.

The contribution of agricultural projects to sustainability will depend on how the new pattern of land use can be maintained over time, compared to previous uses of the same land. A sustainability index of land use based on the maintenance of land productivity over time can be used to estimate this. Details were provided in Section 4.

6.5 Overview of Impacts

This section has provided a preliminary screening of the major impacts of different GHG limitation projects. The aim was to identify the kind of impacts and the type of quantification that is needed. In some cases this quantification will be only in physical terms; in others it will be in physical and monetary terms; and in a few others no quantification will be possible. Furthermore, the degree to which adjustments to financial costs and the assessment of macroeconomic impacts is required, and the significance of sustainability issues, varies from case to case.

Sections 7 and 8 respectively consider employment and distributional effects in greater depth; specifically looking at how these effects might be estimated. Section 9 evaluates the benefits of reduced environmental impacts resulting from secondary emission reductions.

7 Evaluating Employment Effects of GHG Projects and Policies

If a project creates a job, this has a benefit to society, to the extent that the person employed would otherwise not have been employed. In other words, the benefits of employment are equal to the social costs of the unemployment avoided as a result of the project. These benefits will depend primarily on the period that a person is employed, what state support is offered during any period of unemployment, and what opportunities there are for informal activities that generate income in cash or kind. In addition, unemployment is known to create health problems, which have to be considered as part of the social cost.

A physical measure of the extent of the employment created is therefore the first task of any project assessment. The data that have to be estimated include:

- the number of persons to be employed in the projects;
- the duration of time for which they will be employed;
- the present occupations of the individuals (including no formal occupation); and
- the gender and age (if available).

This physical information should be reported in a summary table for the project, to be used in the selection criteria discussed in Section 2. In addition, it is possible to place some money value on the employment.

Before setting out the framework for such an evaluation, it is important to set out the theoretical reasons for arguing that unemployment reduction has a social value. In neo-classical economic analysis, no social cost is normally associated with unemployment. The presumption is that the economy is effectively fully employed, and that any measured unemployment is the result of matching the changing demand for labor to a changing supply. In a well functioning and stable market, individuals can anticipate periods when they will be out of work, as they leave one job and move to another. Consequently, the terms of labor employment contracts, as well as the terms of unemployment insurance, will reflect the presence of such periods, and there will be no cost to society from the existence of a pool of such unemployed workers.

These conditions are, however, far from the reality in many of the countries in which the GHG projects will be undertaken. Many of those presently unemployed have bleak prospects of finding stable employment. In general, unemployment is a primary worry among those who are presently employed, and the political pressure not to take measures that will further increase this level is very high.

In these circumstances, therefore, it seems entirely appropriate, to treat the welfare gain of those made employed as a social gain. Traditionally this welfare gain is defined as:

(a) The gain of net income to the individual as a result of the new job, after allowing for any unemployment benefit, informal employment, work-related expenses, etc.; *minus*

(b) the value of the time that the person had at his or her disposal as a result of being unemployed and that is lost as a result of being employed, *plus*

(c) the value of any health related consequences of being unemployed that are no longer incurred.

To calculate the social benefits (the unemployment avoided as a result of the project), one has to multiply the welfare cost (a) minus (b) plus (c) by the period of employment created by the project.

7.1 Gain of Income

The gain of income will depend on the new net of tax wage, and how much unemployment and other benefits are available. Data on average earnings by occupation are available for many countries and have to be used for this calculation. Adjustment for personal taxes should be made, and this is often complicated. For those working in large enterprises, tax deductions are relatively clear, but for the informal sector there is very little information available on what taxes are paid.

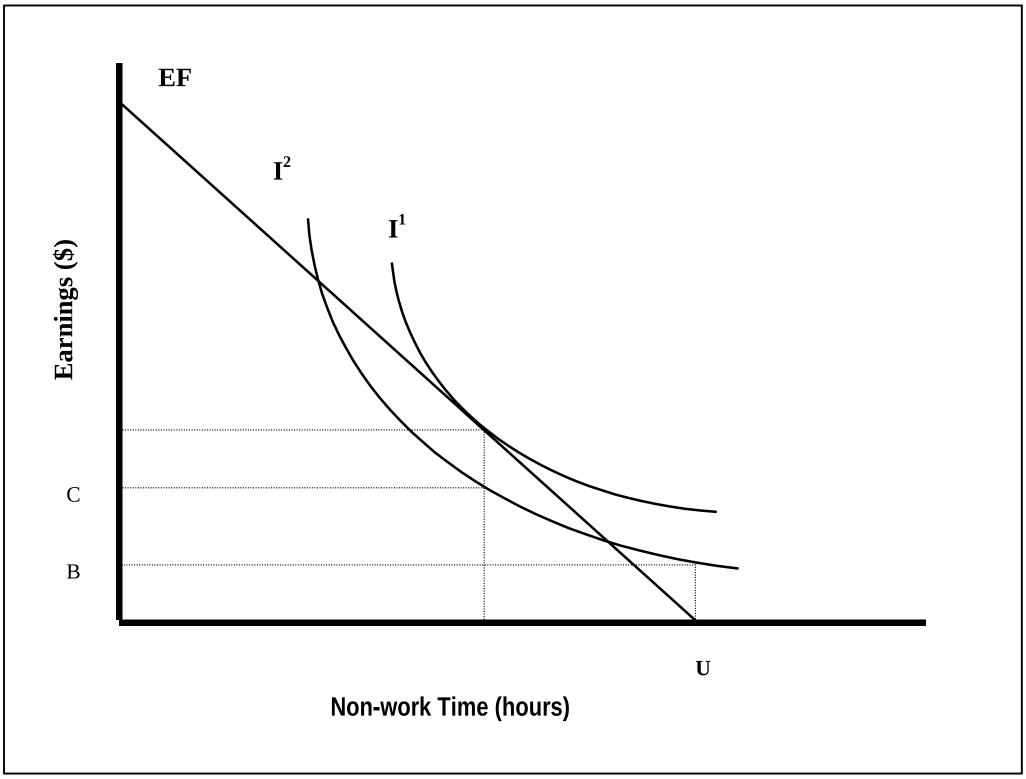
7.2 Replacement Earnings

Replacement earnings are the earnings received during the period of unemployment, in the form of unemployment benefit and other forms of support. The structure of these benefits is complex. Some countries have no benefits; others have a limited amount; and others a more complex system, with benefits falling after some period. In addition the unemployed receive some social benefits, depending on their previous work history and their qualifications. They are also permitted some part time earnings while claiming unemployment.

7.3 Value of Any Lost Leisure

In moving from unemployment to employment, an individual faces a loss of leisure, which has some value. Diagrammatically, this is shown in Figure 1 below. On the horizontal axis is the amount of 'leisure' time, measured in hours.[12] On the vertical axis is the level of earnings, net of any taxes. The line EF is a simplified representation of the choice between earnings and leisure, given a constant hourly wage.[13] The curve I^1 represents all combinations of earnings and leisure that give a constant level of welfare. In the employed situation, the person chooses point A. When s/he is made unemployed, and receives unemployment income of U, s/he is placed on a lower level of welfare, represented by the line I^2. The 'true' difference in welfare between being employed and being unemployed is given by the distance AC, whereas the gain in income is given by AB. Hence AB is an overestimate of the gain in welfare from employment, and the difference BC is the value of the additional leisure that the person has as a result of the unemployment.

Figure 1 Earnings, Non-work Time and the Cost of Employment



12 "Leisure" (the standard term in the literature) is perhaps not the best word of for such time, as it will often be used for various activities, such as home repairs, household work etc., although it is standard. Non-working time is, therefore, a better phrase.

13 In reality the wage rate may vary according to the hours worked, choices between labor and leisure may be restricted and taxes/subsidies could render the budget line EF quite non-linear (see Atkinson and Stiglitz, 1980). However, the principles of what is being discussed are unchanged.

The value of such non-working time will depend on the elasticity of labor supply. The more elastic is the supply, the greater, other things being equal, will the value be. For economies in transition such elasticities are not available; the situation since the collapse of the command economy having been characterized by excess supply of labor, in which estimation of the supply elasticity is extremely difficult. Nevertheless, from other industrialized market economies, it is concluded that, with the exception of some classes of women workers, notably married women, the elasticity of supply is very low (Atkinson and Stiglitz, 1980).

Another source of estimates of non-working time is from the transport literature, where savings in travel time are valued at approximately 30-50 percent of the gross wage. This estimate is derived from considerations of tax rates as well limited work opportunities for any time saved. However, for large scale enforced non-working, such as that associated with unemployment, it is almost certainly too high.

This issue is being investigated further, but for the initial calculations of the benefits of employment it is proposed that the value of the non-working time be taken at 15 percent of the gross wage, reflecting *some* limited alternative earning opportunities. This is illustrated in the calculations reported below.

7.4 Health Related Impacts

It has long been known that, on average, people in employment are healthier and have greater life expectancy than those who are unemployed. This is despite the fact that many jobs involve work-related hazards, both accidents and occupational diseases (for example long-term exposure to carcinogens at work). The generally better health of people in employment was known in occupational epidemiology as the "healthy worker effect" (HWE). It arises at least in part because the selection of persons for employment, and the continued employment thereafter, depends on being healthy (Fox and Collier, 1976). Thus, it is not unusual to find mortality studies of industrial workers which show standardized mortality ratios (SMRs) of 80 or thereabouts; meaning that they have age-specific death rates 20 percent less than the general population.

Recently, however, some real evidence has been collected which shows that health-related selection for work only explains part of the difference between employed and unemployed people; and that unemployment *per se* is also detrimental to health. To investigate this, it is necessary to separate out the effects of unemployment as such from the effects of health related selection, and that in turn requires longitudinal (cohort) studies. Three such studies are from the United Kingdom: see Moser *et al* (1984); Moser *et al* (1987); and Morris *et al* (1994). Three other studies are from Scandinavian countries: Iversen *et al* (1987) for Denmark; Martikainen (1990) for Finland; and Stefansson (1991) for Sweden.

The main findings relate to mortality and focus on male employment in industrialised countries. All six studies report a statistically significant excess mortality among unemployed men. The main conclusions are:

a) Age adjusted mortality is higher for unemployed men by an amount ranging from 21 percent to 95 per cent. In some studies "unemployed" referred to status at the start of the study (the OPCS and Danish studies). In the Finnish and Swedish studies, various levels of duration of unemployment were considered. Morris *et al* studied becoming unemployed in later life after a period (at least 5 years) of stable employment, and found almost double the mortality compared to those remaining in employment.

b) The excess is not principally attributable to the "healthy worker effect". For example, Morris *et al* find that, among healthy individuals who became unemployed for reasons other than illness, there was an excess mortality of 87 percent (the 95 per cent confidence interval was 35 to 160 per cent).

c) Consistently across studies, there is a particularly high excess mortality from suicides and from "external" causes such as accidents, as opposed to "internal" causes such as disease or illness.

d) Most studies show a greater impact in terms of percentage increase in mortality among younger men. The percentage increase also appears to be positively related to the duration of unemployment.

From the present studies, and taking account of the different power of the different estimates, we conclude that the excess mortality from unemployment in men of employable age may be taken as 75 per cent, with a range from 45 to 110 per cent.[14]

Unfortunately, these data are only available for developed countries and their applicability to developing and industrialising countries has not been confirmed. However, as a first step it is worth taking the values of increased life expectancy during the period of employment from the industrialising countries and applying them to the countries in which the projects are being evaluated. Hence if the mean estimated death rate in the country for men from 15-64 is 6 deaths per 1,000 of population (about two times the US rate), the excess death rate among the unemployed is 4.5 deaths per 1,000 men.[15]

7.5 Valuing the Health Effects

In the environmental economics literature, mortality impacts are valued by multiplying the change in risk of death by a "Value of Statistical Life" (VOSL). This methodology has been extensively surveyed (for a recent review see Markandya, 1996). Although there are good reasons for thinking that alternative methods of valuation may be preferable (for example based on the value of life years lost), the VOSL method of valuation has been widely used and has some general acceptance. For the EU countries Markandya (1996) estimated a central VOSL at ECU 2.6mn ($3.1mn), which is broadly consistent with figures used for the US. This was in 1990 prices. Converting to 1995 prices gives a VOSL of ECU 3.14mn ($3.9mn). PACE (1992) used a VOSL for the US of $4.0mn and Krupnick *et al* (1996) used a value of $3.6mn. For non-OECD countries, such a value is almost certainly too high; it broadly measures individual willingness-to-pay to reduce the risk of death by a small amount. One adjustment that has been proposed for lower income countries is to adjust the VOSL by the ratio of the real *per capita* GDP in the country concerned, to the GDP in the US or EU (Markandya, 1994). By real GDP is meant taking account of differences in purchasing power (PP) in converting GDP to dollar or ECU terms. This implicitly assumes an "elasticity" of willingness to pay to reduce mortality risks of one. A different value for this elasticity is cited in Krupnick *et al* (1996), who, referring to the work of Mitchell and Carson (1986), argue that a case can be made for a value of 0.35

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14 This conclusion was based on an unpublished review of the literature by Dr. F.Hurley of the Institute of Occupational Medicine, Edinburgh (Hurley, *pers. comm.*).

15 It is unclear to what extent the excess depends on socio-economic or cultural factors, such a background levels of unemployment, social cohesion and welfare provision. However, it is interesting to note that the excess mortality was found in the UK pre and post 1979, when a number of changes in welfare provision were initiated. It should also be noted that the above only looks at the mortality impacts of unemployment. There will be morbidity impacts but there are no studies that quantify these.

(meaning that a one percent increase / decrease in real income should result in a 0.35 percent increase / decrease in the damages).

In order to assist researchers in estimating the health benefits of employment, Table 5 provides the VOSL for different countries based on an income elasticity of 1 and Table 6 the VOSL for an elasticity of 0.35. Both sets of figures use a VOSL for the US of $4.0mn. The PPP GDP per capita for the US is $25,880 based on data from the World Bank Development Report.[16]

Although this section has provided a method of estimating the health consequences of unemployment, it is by no means clear that such valuations will be accepted by policy-makers. The 'transfer' of method and values from the OECD countries may not be appropriate. Further research is needed to establish whether or not this is the case. Until such research has been carried out, analysts may prefer simply to report the health consequences qualitatively.

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[16] In order to facilitate the comparison of economic activity between countries, the UN's International Comparison Programme (ICP) developed internationally comparable measures of GNP, known as purchasing power parity (PPP) estimates of GNP; these are derived using purchasing power parities as opposed to exchange rates as conversion factors. The PPP conversion factor is defined as the number of units of a country's currency required to buy the same amounts of goods in the domestic market as one dollar would buy in the United States (World Bank, 1996). Data on the average domestic prices of a representative basket of goods and services are collected by the ICP, and PPPs are derived in relation to the average international prices that are implicitly derived from the prices of all participating countries (World Bank, 1996).

No data are available for the following countries: Albania, Algeria, Costa Rica, Croatia, Gabon, Georgia, Guinea, Hong Kong, Iran, Lao PDR, Macedonia, Moldova, Mongolia, Slovak Republic, Turkmenistan, United Arab Emirates, Vietnam and Yemen Republic.

TABLE 5 Value of Statistical Life for Various Countries

Notes: Countries are arranged alphabetically.
Elasticity is assumed to be 1.00
VOSL is assumed to be US $4.0 mn (1995)

Country	PPP GNP US$ 1994	VSL US $ '000 1995	Country	PPP GNP US$ 1994	VSL US $ '000 1995
ARGENTINA	8,720	1,348	MALAWI	650	100
ARMENIA	2,160	334	MALAYSIA	8,440	1,304
AUSTRALIA	18,120	2,801	MALI	520	80
AZERBAIJAN	1,510	233	MAURITANIA	1,570	243
BANGLADESH	1,330	206	MAURITIUS	12,720	1,966
BELARUS	4,320	668	MEXICO	7,040	1,088
BENIN	1,630	252	MOROCCO	3,470	536
BOLIVIA	2,400	371	MOZAMBIQUE	860	133
BOTSWANA	5,210	805	NAMIBIA	4,320	668
BRAZIL	5,400	835	NEPAL	1,230	190
BULGARIA	4,380	677	NEW ZEALAND	15,870	2,453
BURKINA FASO	800	124	NICARAGUA	1,800	278
BURUNDI	700	108	NIGER	770	119
CAMEROON	1,950	301	NIGERIA	1,190	184
CANADA	19,960	3,085	NORWAY	20,210	3,124
CENTRAL AFR. REP.	1,160	179	OMAN	8,590	1,328
CHAD	720	111	PAKISTAN	2,130	329
CHILE	8,890	1,374	PANAMA	5,730	886
CHINA	2,510	388	PAPUA NEW GUINEA	2,680	414
COLOMBIA	5,330	824	PARAGUAY	3,550	549
CZECH REPUBLIC	8,900	1,376	PERU	3,610	558
DOMINICAN REP.	3,760	581	PHILIPPINES	2,740	423
ECUADOR	4,190	648	POLAND	5,480	847
EGYPT	3,720	575	ROMANIA	4,090	632
EL SALVADOR	2,410	372	RUSSIAN FED	4,610	713
ESTONIA	4,510	697	RWANDA	330	51
ETHIOPIA	430	66	SAUDI ARABIA	9,480	1,465
GAMBIA	1,100	170	SENEGAL	1,580	244
GHANA	2,050	317	SIERRA LEONE	700	108
GUATEMALA	3,440	532	SINGAPORE	21,900	3,385
GUINEA-BISSAU	820	127	SLOVENIA	6,230	963
HAITI	930	144	SOUTH AFRICA	5,130	793
HONDURAS	1,940	300	SRI LANKA	3,160	488
HUNGARY	6,080	940	SWITZERLAND	25,150	3,887
INDIA	1,280	198	TAJIKISTAN	970	150
INDONESIA	3,600	556	TANZANIA	620	96
ISRAEL	15,300	2,365	THAILAND	6,970	1,077
JAMAICA	3,400	526	TOGO	1,130	175
JAPAN	21,140	3,267	TRINIDAD & TOBAGO	8,670	1,340
JORDAN	4,100	634	TUNISIA	5,020	776
KAZAKSTAN	2,810	434	TURKEY	4,710	728
KENYA	1,310	202	UGANDA	1,410	218
KOREA	10,330	1,597	UKRAINE	2,620	405
KUWAIT	24,730	3,822	URUGUAY	7,710	1,192
KYRGYZ REPUBLIC	1,730	267	USA	25,880	4,000
LATVIA	3,220	498	UZBEKISTAN	2,370	366
LESOTHO	1,730	267	VENEZUELA	7,770	1,201
LITHUANIA	3,290	509	ZAMBIA	860	133
MADAGASCAR	640	99	ZIMBABWE	2,040	315

Source: World Bank (1996)

TABLE 6 **Value of Statistical Life for Various Countries**

Notes: Countries are arranged alphabetically.
Elasticity is assumed to be 0.35.
VOSL is assumed to be US $4.0 mn (1995)

Country	PPP GNP US$ 1994	VSL US $ '000 1995	Country	PPP GNP US$ 1994	VSL US $ '000 1995
ARGENTINA	8,720	2,733	MALAWI	650	1,102
ARMENIA	2,160	1,677	MALAYSIA	8,440	2,702
AUSTRALIA	18,120	3,531	MALI	520	1,019
AZERBAIJAN	1,510	1,480	MAURITANIA	1,570	1,500
BANGLADESH	1,330	1,415	MAURITIUS	12,720	3,120
BELARUS	4,320	2,138	MEXICO	7,040	2,536
BENIN	1,630	1,520	MOROCCO	3,470	1,980
BOLIVIA	2,400	1,740	MOZAMBIQUE	860	1,215
BOTSWANA	5,210	2,283	NAMIBIA	4,320	2,138
BRAZIL	5,400	2,311	NEPAL	1,230	1,377
BULGARIA	4,380	2,148	NEW ZEALAND	15,870	3,371
BURKINA FASO	800	1,185	NICARAGUA	1,800	1,574
BURUNDI	700	1,131	NIGER	770	1,169
CAMEROON	1,950	1,618	NIGERIA	1,190	1,361
CANADA	19,960	3,652	NORWAY	20,210	3,668
CENTRAL AFR. REP.	1,160	1,349	OMAN	8,590	2,719
CHAD	720	1,142	PAKISTAN	2,130	1,669
CHILE	8,890	2,752	PANAMA	5,730	2,360
CHINA	2,510	1,768	PAPUA NEW GUINEA	2,680	1,809
COLOMBIA	5,330	2,301	PARAGUAY	3,550	1,996
CZECH REPUBLIC	8,900	2,753	PERU	3,610	2,007
DOMINICAN REP.	3,760	2,036	PHILIPPINES	2,740	1,823
ECUADOR	4,190	2,115	POLAND	5,480	2,323
EGYPT	3,720	2,029	ROMANIA	4,090	2,097
EL SALVADOR	2,410	1,743	RUSSIAN FED	4,610	2,187
ESTONIA	4,510	2,170	RWANDA	330	869
ETHIOPIA	430	953	SAUDI ARABIA	9,480	2,815
GAMBIA	1,100	1,324	SENEGAL	1,580	1,503
GHANA	2,050	1,647	SIERRA LEONE	700	1,131
GUATEMALA	3,440	1,974	SINGAPORE	21,900	3,773
GUINEA-BISSAU	820	1,195	SLOVENIA	6,230	2,430
HAITI	930	1,249	SOUTH AFRICA	5,130	2,270
HONDURAS	1,940	1,615	SRI LANKA	3,160	1,916
HUNGARY	6,080	2,409	SWITZERLAND	25,150	3,960
INDIA	1,280	1,397	TAJIKISTAN	970	1,267
INDONESIA	3,600	2,006	TANZANIA	620	1,084
ISRAEL	15,300	3,328	THAILAND	6,970	2,527
JAMAICA	3,400	1,966	TOGO	1,130	1,337
JAPAN	21,140	3,727	TRINIDAD & TOBAGO	8,670	2,728
JORDAN	4,100	2,099	TUNISIA	5,020	2,253
KAZAKSTAN	2,810	1,839	TURKEY	4,710	2,203
KENYA	1,310	1,408	UGANDA	1,410	1,445
KOREA	10,330	2,900	UKRAINE	2,620	1,794
KUWAIT	24,730	3,937	URUGUAY	7,710	2,618
KYRGYZ REPUBLIC	1,730	1,552	USA	25,880	4,000
LATVIA	3,220	1,929	UZBEKISTAN	2,370	1,733
LESOTHO	1,730	1,552	VENEZUELA	7,770	2,625
LITHUANIA	3,290	1,943	ZAMBIA	860	1,215
MADAGASCAR	640	1,096	ZIMBABWE	2,040	1,644

Source: World Bank (1996)

7.6 Applying the Methodology to Estimate the Benefits of Employment Creation in Money Terms

This sub-section demonstrates how the above method may be used to estimate the employment benefits of a project in money terms. The basic data on employment by category and by duration as a result of the project are provided in Part 1 of Table 7. The sample country is assumed to be Egypt, but the example is not intended to be realistic for that country. The project under consideration will employ 3,000 people (2,000 men, 600 women and 400 youths) for 36 months. The corresponding wages per day are E £120, E £70 and E £50. Some of those who will be employed on the project are currently unemployed; 1,600 men, 400 women and 400 youths are currently unemployed. If this project had not come along, the men would have been unemployed for 12 months, the women for 30 months, and the youths for 36 months.

Part 2 of Table 7 provides data on unemployment benefits and loss of non-work time. The unemployment benefits are of limited duration: 12 months for men, zero months for women and 6 months for youths. The level of benefits is E £20 per day for men and E £12 for youths. In addition one must add the value of non-work time, which is taken at 15% of the daily wage rate. These benefits are lost when a job is created and so the net economic value of a job is the earnings less the above benefits, *for the period that the person would have been unemployed.*

Apart from the direct economic benefits of the job to the individual, he or she also gains because the health costs of unemployment are avoided. These are given in Part 3 of Table 7. The valuation is based on the reduced risk of death among employed persons, at a rate of 4.5 persons per 1,000 males (i.e. 4.5 / 1,000 is the reduction in mortality among employed people). The VOSL is taken as E £2.86 million. Hence the health benefit per person per annum is:

E £2.86 *x* 4.5 / 1,000 = E £12,870.

This value is applied to men only, for the first 12 months, as after that period they would have been employed anyway.

The net benefits of employment are given in Part 4 of Table 7; subtracting from the daily earning, the unemployment benefits and the value of non-work time, as given in Part 2, and adding the health benefits, as given in Part 3.

To arrive at the economic costs of labour, the cost of employment has to be reduced by the amount of the benefit as given in Part 4. The aggregate figures for the project are given in Part 5, amounting to E £70.7 million. The aggregate financial costs are simply the daily wages times the numbers employed and are given in Part 6. They amount to E £235 million. This indicates that the economic cost is about one third the financial cost. It should be remembered that this is an illustrative example, however the basic structure could be used to make calculations for other countries.

Table 7 An Illustration of Estimating the Net Employment Costs of a GHG Project in Egypt

Part 1 Basic Employment Data

Group	Number Employed by Project (persons)	Number Previously Unemployed (persons)	Duration of Unemployment (months)	Daily Wage (E £/day)	Length of Project Employment (months)
Men[1]	2,000	1,600	12	120	36
Women	600	400	30	70	36
Youths[2]	400	400	36	50	36

Part 2 Unemployment Benefits and Value of Non-work Time

Group	Daily Benefit (E £/day)	Duration of Benefit (months)	Value of Non-work Time[3] (E £/day)	Total Daily Benefits (E £/day)		
				1-6 months	6-12 months	12-36 months
Men[1]	20	12	18.0	38.0	38.0	18.0
Women	-	-	10.5	10.5	10.5	10.5
Youths[2]	12	6	7.5	19.5	7.5	7.5

Part 3 Health Benefits of Employment[4]

Group	Annual Benefit[5] (E £/year)	Total Daily Benefits (E £/day)		
		1-6 months	6-12 months	12-36 months
Men[1]	12,870	35.3	35.3	-
women	n/a	n/a	n/a	n/a
Youths[2]	n/a	n/a	n/a	n/a

Part 4 Net Benefits of Employment (Previously Unemployed)

Group	Total Daily Net Benefit (E £/day/person)		
	1-6 months	6-12 months	12-36 months
Men[1]	117.3	117.3	102.0
Women	59.5	59.5	59.5
Youths[2]	30.5	42.5	42.5

Part 5 Economic Labour Cost of Project[6]

Group	Total Cost (E £)		
	1-6 months	6-12 months	12-36 months
Men[1]	6,809,863	6,809,863	39,936,000
Women	2,366,000	2,366,000	9,464,000
Youths[2]	1,014,000	390,000	1,560,000
Sub-total	10,189,863	9,565,863	50,960,000
Wage Bill	70,715,726		

Part 6 Financial Labour Cost of Project[6]

Group	Total Cost (E £)		
	1-6 months	6-12 months	12-36 months
Men[1]	31,200,000	31,200,000	124,800,000
Women	5,460,000	5,460,000	21,840,000
Youths[2]	2,600,000	2,600,000	10,400,000
Sub-total	39,260,000	39,260,000	157,040,000
Wage Bill	235,560,000		

Notes:

[1] Assumed to be between 21 and 64.
[2] Assumed to be under 21.
[3] Assumed to be 15 per cent of daily wage.
[4] Excess mortality is assumed to be 4.5 deaths per 1,000 persons per annum.
[5] The VOSL is taken from Table 5 at US $575,000, or E £2.86 million.
[6] Assumed to be 260 working days per annum.

8 Income Distribution and Poverty

8.1 Data on Income and Poverty Impacts of Policies

The impacts of GHG limitation projects on income distribution and poverty are of great importance and merit careful attention and treatment. The main effort has to be devoted to collecting information on which income groups and which sections of the population are affected by the measures proposed. The measures will impose costs as well as benefits and both are important. The breakdown of data on who is impacted need not take the form of household income alone, but could include, for example, rural and urban households, households classified by race, etc. A matrix of the distribution of gains and losses is required, classified in the categories that are believed to be important, both for a correct estimate of the true costs of the project, as well as for a successful implementation of the project. If the analysis fails to identify groups who would lose as a result of the project, but who have the power to block it or to thwart its effective implementation, the whole exercise will be a failure.

The inclusion of data on gainers and losers from the project provides a separate dimension by which the desirability of the project should be judged. This was discussed in Section 5. It is also possible, however, to incorporate distributional considerations into money measures of social costs by using weights. The method for doing this is discussed further below.

8.2 Estimates of Income Distribution Weights

The costs of different GHG programmes, as well as any related benefits, belong to individuals from different income classes. Economic theory has developed a method of weighting the benefits and costs according to who is impacted. This is based on converting changes in income into changes in welfare, and assuming that an addition to the welfare of a lower income persons is worth more that of a richer person.

More specifically, a special form can be taken for the social welfare function, and a common one that has been adopted is that of Atkinson (1970). He assumes that social welfare is given by the function:

$$W = \sum_{i=1}^{N} \frac{AY_i^{1-\varepsilon}}{1-\varepsilon}$$

where

W… social welfare function;
Y_i … income of individual *i*;
ε … elasticity of social marginal utility of income or inequality aversion parameter;
A… a constant.

The social marginal utility of income is defined as

$$\frac{\partial W}{\partial Y_i} = AY_i^{-\varepsilon}.$$

Taking per capita national income, $\bar{Y}$ as the numeraire, and giving it a value of one, we have

$$\frac{\partial W}{\partial Y_i} = A\overline{Y}_i^{-\varepsilon} = 1.$$

and

$$\frac{\partial W}{\partial Y_i} = SMU_i = \left[\frac{\overline{Y}}{Y_i}\right]^{\varepsilon}.$$

Where SMU_i is the social marginal utility of a small amount of income going to group *i* relative to income going to a person with the average *per capita income*. The values of SMU_i are therefore the weights to be attached to costs and benefits to groups *i* relative to costs and benefits to a person with average income.

In order to apply the method estimates of $\overline{\mathrm{Y}}$ and ε are required. The literature has estimates of the inequality aversion parameter (ε) in the range 1-2 (Stern, 1977; and Murty *et al*, 1992). A value of 1 would be implied if:

a) policy-makers decided to value environmental damages to all individuals at the value associated with the average income individual: and

b) the 'income elasticity' of environmental damage with respect to income was one.[17]

This has some appeal when governments are unwilling to attach higher costs of environmental damages to the rich relative to the poor. Some recent studies estimating the value of ε, for the Indian economy (Murty *et al*, 1992), have resulted in values in the range of 1.75-2.0.

An application of the method of calculating weights is provided using data from India. The Economic Survey, 1995-96 (Government of India) provides an estimate of per capita Gross Domestic Product for the Indian economy of Rs. 9,321 at 1995-96 prices.

Using this estimate of $\overline{\mathrm{Y}}$ and values of ε of 1, 1.75 and 2, the estimated income distribution weights attributable to different income classes in the Indian economy are given in Table 8. For example, costs to someone with income level of Rs. 3,000 (around 30% of the average income) would be imputed at a level of 3 to 10 times the actual cost in the analysis, whereas costs to someone with an income of Rs. 185,000 (around 20 times the average) would have costs imputed of 0.3% to 5.0% of the actual values.

Although evidence exists for a value of ε of up to 2, the implied weights for that number are quite extreme and may be questionable. It is suggested that a figure of 1-1.75 be used in any GHG limitation exercise.

Similar weights can be constructed for any country in which GHG limitation costs are being estimated and applied in any analysis. The case studies give some examples of the application of income weights.

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17 This is the same adjustment that is made when the mortality costs of climate change are valued at a single figure for all deaths, based on average world income, irrespective of where they occur. See Fankhauser *et al* (1997).

Table 8 Income Distribution Weights for India

Income Class	Income Distribution Weights		
Rs. 1995	e=1.00	e=1.75	e=2.00
3.000	3,107	7,271	9,653
4.000	2,330	4,395	5,430
5.000	1,864	2,974	3,475
6.000	1,554	2,162	2,413
7.000	1,332	1,651	1,773
8.000	1,165	1,307	1,358
9.000	1,036	1,063	1,073
10.000	0,932	0,884	0,869
11.000	0,847	0,748	0,718
12.000	0,777	0,643	0,603
13.000	0,717	0,559	0,514
14.000	0,666	0,491	0,443
15.000	0,621	0,435	0,386
20.000	0,466	0,263	0,217
25.000	0,373	0,178	0,139
30.000	0,311	0,129	0,097
35.000	0,266	0,099	0,071
40.000	0,233	0,078	0,054
45.000	0,207	0,064	0,043
50.000	0,186	0,053	0,035
55.000	0,169	0,045	0,029
60.000	0,155	0,038	0,024
65.000	0,143	0,033	0,021
70.000	0,133	0,029	0,018
75.000	0,124	0,026	0,015
85.000	0,110	0,021	0,012
95.000	0,098	0,017	0,010
105.000	0,089	0,014	0,008
115.000	0,081	0,012	0,007
125.000	0,075	0,011	0,006
135.000	0,069	0,009	0,005
145.000	0,064	0,008	0,004
155.000	0,060	0,007	0,004
165.000	0,056	0,007	0,003
175.000	0,053	0,006	0,003
185.000	0,050	0,005	0,003

Notes:

[1] Average income is Rs. 9,321 per annum.

9 Environmental Impacts and their Assessment

9.1 Introduction

A large number of GHG limitation projects will have environmental impacts other than those related to climate change. Some of these can be valued in money terms; others cannot. It is proposed that all impacts be reported in physical terms and those that can be valued in monetary terms be so valued. Some guidelines to the values to be applied are provided here. The impacts are divided into changes in air quality, changes in natural and semi-natural eco-systems, and changes in amenity. Changes in air quality are considered in Sections 9.2 and 9.3. Other impacts are discussed in Section 9.4.

9.2 Changes in Air Quality

9.2.1 Health

The main airborne pollutants known to cause detrimental health effects are oxides of sulphur (SO_2), ozone (O_3) and particulate matter of various grades (e.g. PM_{10}); as well as secondary pollutants in the form of nitrates and sulphate aerosols from NO_x and SO_x. These can be emitted from both stationary and mobile sources. In analysing the effects of pollutants on health it is very important to distinguish between *acute* effects (which occur on the same day as increases in pollution, or very soon thereafter), and *chronic* effects (which are the delayed effects of long-term exposure).

With acute mortality, the mechanism here is the number of air pollution days contributing to a higher number of deaths on the same day or on immediately following days. In this case, the 'at-risk' population consists mainly of elderly people (>65 years of age) with existing (serious) cardio-respiratory problems. The expectation is that persons affected are already quite ill and have only a short life expectancy.

With chronic mortality, the mechanism here is long-term exposure to air pollution which leads to disease, which contributes to premature death. In this case, it is formally irrelevant whether death follows a higher pollution day. Cohort studies generally show increased mortality from cardio-respiratory disease, and from lung cancer.

The acute effects of various pollutants across a range of health endpoints are reasonably well established. These include respiratory infections, asthma attacks and restrictive activity days. Research has tried to establish reliable exposure-response functions for such effects. It is more difficult to establish relationships for chronic effects such as bronchitis or other longer term respiratory infections.

As will be seen below, health impacts are the main ones in value terms out of all environmental impacts.

9.2.2 Crops

Atmospheric pollution can also affect agricultural outputs, both in terms of yield and quality. There are two basic pathways through which pollutants act on plants. The first is via dry deposition of pollutants and foliar uptake, and the second via wet deposition and soil acidification, although the two processes are not mutually exclusive. Most studies have considered the effects of SO_2, NO_x, O_3 and acidic deposition, and there is a consensus that yield changes are more closely related to long term mean levels of pollution than to peak values.

In general, the research that has considered these impacts using an impact-pathway approach has concluded that the size of the impact will be quite small. Indeed, mild levels of fossil fuel related pollutants are thought to enhance yields (e.g. via nitrogen deposition). Ozone is thought to present the largest potential threat to crop production, but assessing the impact with any confidence has proved to be very difficult. Research in this area is still in its infancy and more comprehensive analyses are required that consider more crops and their interactions with other stressors.

9.2.3 Materials

Pollution related damage to materials includes discolouration, failure of protective coatings, loss of architectural detail and structural failure. Modern building materials such as concrete, polymers, galvanised steel, glass and paints are all just as susceptible to attack by atmospheric pollutants compared to traditional stone.

For a number of materials, the dry deposition of SO_2 exerts the strongest corrosive effect of atmospheric pollutants. Wet deposition (predominantly acid rain) does exert a corrosive effect but this is generally thought to be weaker. Ozone is known to affect polymeric materials such as paints, plastics and rubbers. This has resulted in the rubber industry being forced to develop anti-ozone products to mitigate damage at considerable expense.

Despite the reduction in urban smoke emissions, particulate air pollution, dispersed primarily from mobile sources now presents a major soiling problem. The black smoke from lorries and buses so frequently seen in cities and towns contains millions of tiny carbon particles of approximately 10 micrometer diameter or less. These stain stone and glass facades resulting in increased cleaning costs. Particulates are also thought to act as a catalyst to other pollutants. If mixed with organic pollutants photo-oxidation of polymers can be accelerated. It also affects the conversion of sulphur dioxides and nitrogen oxides into sulphuric and nitric acids. The presence of these acids on a surface leads to the initiation of decay processes, especially on calcareous stones.

It is the synergistic effects of pollutants, however, that now present the greatest problems. Stone will corrode much faster when exposed to sulphur dioxide and nitrogen dioxide together, compared to exposure to only one of these pollutants. Particulates deposited on a stone surface assist in the absorption of acidic gases such as nitrogen and sulphur oxides. The synergistic effect may be to act as a catalyst in the conversion of the acidic gases to their nitrate and sulphate forms respectively and also in the actual process of stone decay.

These issues could seriously affect the results of dose-response functions for individual pollutants, which, up till now, have not considered synergistic effects. The interaction of different atmospheric pollutants synergistically tends to multiply rather than add to the decay rate. This indicates that there is a need for a more holistic approach to the calculation of dose-response functions and their application. With the shift towards a more complex chemical cocktails of atmospheric pollutants in the urban environment, such as volatile organic compounds (VOC's) and nitrogen oxides leading to the formation of secondary pollutants, the synergistic effects of atmospheric pollutants are becoming more prominent and future dose-response functions will need to reflect this.

9.2.4 Forests

The problem of forest decline and its possible association with atmospheric pollution has been the subject of much debate in recent years. In making estimates of forest damage it is necessary to carefully separate out the effects of pollutants from other factors such as climate, pests, pathogens and the consequences of poor management. Pollution can affect forests in two main ways. Dry deposition induces direct foliar damage (loss of needles or leaves or discolouration), whereas wet deposition mediated through the soil causes more serious damage. Soil acidification disrupts nutrient cycling within forests by increasing leaching which causes root damage.

Models are available to assess forest response to airborne pollutants. These are subject to many problems and uncertainties including a lack of knowledge on key growth processes, lack of comprehensive data, and the difficulty in identifying appropriate endpoints. The alternative approach is to use *critical load exceedance*. This is done by identifying critical loads and levels for different types of forest ecosystem and mapping these over the area being considered. Pollution deposition maps for sulphates, nitrates and ammonium (accounting for both acidifying and neutralising inputs) are then superimposed and areas of exceedance are recorded. Research in this area is still at an evolutionary stage, although there is good reason to believe that pollution damage on forests could prove to be quite significant.

9.3 Estimates of Damages from Industrialised Countries

A great deal of work has now been undertaken to value the damages from the major pollutants associated with fossil fuels: SO_2, NO_x (and associated ozone) and particulates. Studies include ExternE (1995a and 1997a, b and c) for the EU, Rowe *et al* (1995) for the US (New York), Thayer *et al* (1994) for the US (California), CSERGE (1993) for the UK, and Pearce (1996) for developing counties. The estimates of damages can be reported in terms of $/kWh or in terms of $/tonne of emissions. Both values are, of course, site dependent; the closer an emission source is to the stock at risk and the greater the density of receptors, the greater will be the damages. Although the above local effects are important they should not be exaggerated. The ExternE work has, however, noted the importance of long distance impacts of most pollutants, so that, for most sources, less than 20% of the total effect is picked up in the impacts over the nearest 50 km (ExternE, 1995b). This implies that the total damages will be less site-dependent than was originally envisaged.

Table 9 provides a summary of damages in US $/tonne from the ExternE project, CSERGE Thayer *et al* and Rowe *et al* studies.[18] All figures are in 1996 prices. For all damages the ranges are very wide. For NO_x the estimates are also highly dependent on the source and on local conditions It should be noted that work is ongoing in these areas and some adjustment to the estimates can be expected over the next year or two.

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18 IPCC (1996, chapter 6) also quotes some studies with damages in US $/tonne. These are all relatively old studies and the state of the art has advanced since they were done. Hence in this report only the most recent studies are taken.

Table 9 Estimates of Damages from EU and US Studies

Study and Year	Study Area	Pollutant	Damage Costs (1996 US $ per tonne)		
CSERGE (1993)	UK	SO_2		2,530	
Rowe *et al* (1995)	New York	SO_2	790	1,070	1,350
ExternE (1997c)	UK/Germany	SO_2	9,390		12,350
Thayer *et al* (1994)	California	SO_2		1,040	
CSERGE (1993)	UK	NO_x		1,280	
ExternE (1997c)	UK/Germany	NO_x	4,860		7,250
Rowe *et al* (1995)	New York	NO_x	-1,260	-120	1,010
Thayer *et al* (1994)	California	NO_x		18,070	
CSERGE (1993)	UK	Particulates		15,530	
Rowe *et al* (1995)	New York	Particulates		26,060	
ExternE (1997c)	UK/Germany	Particulates	21,490		23,670
Thayer *et al* (1994)	California	Particulates		59,420	

Notes:

[1] All values were converted into US $ using exchange rates of; 1 ECU = US $1.269 and £1 = US $1.578. Adjustment to studies in earlier years was made using changes in the Consumer Price Index (CPI).

[2] Differences in the Rowe *et al* study emerge from different sites in New York.

[3] Differences in the ExternE values reflect the fact that one set of figures (minimum) were based on damages resulting from UK power sector emissions, whereas the other set (maximum) were based on damages resulting from German power sector emissions. The NO_x damages include damages from associated ozone for ExternE.

[4] Differences in NO_x arise partly because of different sources. Rowe *et al* argue that damages are negative because of ozone 'scavenging'. However, their study only looks at local impacts. Much of the damage from NO_x arises over a wider area, and this has been assessed in the ExternE study.

In addition to the unit damage costs contained in Table 9, some estimates have been made, and are being made for damages from the above pollutants in developing countries. These include the following:

1. Krupnick *et al* (1996) have made estimates for particulate damage for Bulgaria and Hungary, and come up with figures of US $4,300 to US $5,670 per tonne. These values were derived from US studies of the type described above, with damage estimates scaled using an ‘elasticity’ of damages with respect to real *per capita* GDP of one.

2. Florig (1993) provided estimates for the Tianjin province of China of health damages from particulate pollution based on US damage values. These were revised by Pearce (1996), using an elasticity of one for damages with respect real GDP. Unfortunately there is no data on emissions from the different sources for which damages could be reported in terms of US $/tonne.

3. There is ongoing work by the World Bank and others, to derive damage estimates for developing countries, by carrying out primary studies in these countries. To date these studies have not been published and the information is not available.

In view of the shortage of direct developing country studies it is proposed that estimates of damages be developed based on the EU/US studies, but adjusting the figures on the basis of differences in real *per capita* GDP, exactly as has been done in

Section 7. The elasticities used there were 1 and 0.35. Given the ranges of values for the damages per tonne, it is important to do the calculations for a range of values. From Table 9, the following values are proposed for each primary pollutant.

9.3.1 SO_2 Damages

The range of values is from US $790 / tonne to nearly US $12,350 / tonne. The ExternE studies, which give the higher values are, however, more comprehensive and include more impacts and cover much wider areas. The Rowe *et al* study, for example has too restricted a range to pick up all the impacts. Hence, it is proposed that damages in the EU be taken in the range of US $9,390 to US $12,350 per tonne emitted. Other countries should be scaled accordingly, using the average EU15 *per capita* GDP of US $17,907 as the deflator (as these unit damage costs are based on studies conducted in the EU).

9.3.2 NO_x Damages

The NO_x damages are clearly dependent on how the secondary species of nitrate aerosols and ozone, etc. are treated. The CSERGE study did not pick up the full range of such impacts, nor did the Rowe *et al* study. From the other two studies it is proposed that the range of value of damages be taken in the range of US $ 4,860 to US $18,070 per tonne. The lower estimate is based on a study conducted in the EU, hence, the appropriate deflator is the average EU15 *per capita* GDP of US $17,907. The higher damage cost estimate is based on a US study, the appropriate deflator is therefore US $25,880, i.e. the US *per capita* GDP.

9.3.3 Particulate Damage[19]

Particulate damage is particularly controversial, particularly the magnitude of the chronic health mortality effects and the valuation of the acute health effects. These are the values most likely to change in the near future. Hence, it is proposed that the full range shown in Table 9 (US $15,530 to US $59,420 per tonne) be taken for the study. Again, the lower estimate is based on a study conducted in the EU, whereas the higher value is derived from a US based study. The corresponding deflators are thus US $17,907 and US $25,880.

Tables 10 and 11 provide estimates of associated damages for the same group of countries for which employment benefits were provided in Section 7. Table 10 provides the range for an elasticity of one and Table 11 for an elasticity of 0.35. These values should be treated as highly uncertain, but indicative of the range of damages avoided when these pollutants are reduced. Moreover, they should be superseded by local damage estimates, should the latter be available.[20]

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[19] Particulate damage refers to damages from PM_{10}. Not all studies measure this particle size, and conversions have to be made if estimates are for other sizes or related pollutants (e.g. total suspended particulates of 'black smoke'). Approximate conversion figures are available for this purpose.

[20] The procedures of taking damage estimates from one source and applying them in another is called 'benefit transfer'. For a discussion of the issues involved see Navrud (1994).

TABLE 10 VALUE OF AIR POLLUTION DAMAGES FOR SO_2, NO_X AND PARTICULATES (US $[1996] per tonne)

Notes: Countries are arranged alphabetically.
Elasticity is assumed to be 1.00

Country	PPP GNP	SO_2		NO_X/ O_3		Particulates	
	US$ 1994	Lower	Higher	Lower	Higher	Lower	Higher
ARGENTINA	8,720	4,573	6,014	2,367	6,089	7,562	20,021
ARMENIA	2,160	1,133	1,490	586	1,508	1,873	4,959
AUSTRALIA	18,120	9,502	12,497	4,918	12,652	15,715	41,603
AZERBAIJAN	1,510	792	1,041	410	1,054	1,310	3,467
BANGLADESH	1,330	697	917	361	929	1,153	3,054
BELARUS	4,320	2,265	2,979	1,172	3,016	3,747	9,919
BENIN	1,630	855	1,124	442	1,138	1,414	3,742
BOLIVIA	2,400	1,259	1,655	651	1,676	2,081	5,510
BOTSWANA	5,210	2,732	3,593	1,414	3,638	4,518	11,962
BRAZIL	5,400	2,832	3,724	1,466	3,770	4,683	12,398
BULGARIA	4,380	2,297	3,021	1,189	3,058	3,799	10,056
BURKINA FASO	800	420	552	217	559	694	1,837
BURUNDI	700	367	483	190	489	607	1,607
CAMEROON	1,950	1,023	1,345	529	1,362	1,691	4,477
CANADA	19,960	10,467	13,766	5,417	13,937	17,310	45,828
CENTRAL AFR. REP.	1,160	608	800	315	810	1,006	2,663
CHAD	720	378	497	195	503	624	1,653
CHILE	8,890	4,662	6,131	2,413	6,207	7,710	20,411
CHINA	2,510	1,316	1,731	681	1,753	2,177	5,763
COLOMBIA	5,330	2,795	3,676	1,447	3,722	4,622	12,238
CZECH REPUBLIC	8,900	4,667	6,138	2,415	6,214	7,719	20,434
DOMINICAN REP.	3,760	1,972	2,593	1,020	2,625	3,261	8,633
ECUADOR	4,190	2,197	2,890	1,137	2,926	3,634	9,620
EGYPT	3,720	1,951	2,566	1,010	2,597	3,226	8,541
EL SALVADOR	2,410	1,264	1,662	654	1,683	2,090	5,533
ESTONIA	4,510	2,365	3,110	1,224	3,149	3,911	10,355
ETHIOPIA	430	225	297	117	300	373	987
GAMBIA	1,100	577	759	299	768	954	2,526
GHANA	2,050	1,075	1,414	556	1,431	1,778	4,707
GUATEMALA	3,440	1,804	2,372	934	2,402	2,983	7,898
GUINEA-BISSAU	820	430	566	223	573	711	1,883
HAITI	930	488	641	252	649	807	2,135
HONDURAS	1,940	1,017	1,338	527	1,355	1,682	4,454
HUNGARY	6,080	3,188	4,193	1,650	4,245	5,273	13,960
INDIA	1,280	671	883	347	894	1,110	2,939
INDONESIA	3,600	1,888	2,483	977	2,514	3,122	8,266
ISRAEL	15,300	8,023	10,552	4,152	10,683	13,269	35,129
JAMAICA	3,400	1,783	2,345	923	2,374	2,949	7,806
JAPAN	21,140	11,085	14,580	5,737	14,760	18,334	48,537
JORDAN	4,100	2,150	2,828	1,113	2,863	3,556	9,414
KAZAKSTAN	2,810	1,473	1,938	763	1,962	2,437	6,452
KENYA	1,310	687	903	356	915	1,136	3,008
KOREA	10,330	5,417	7,124	2,804	7,213	8,959	23,717
KUWAIT	24,730	12,968	17,056	6,712	17,267	21,447	56,780
KYRGYZ REPUBLIC	1,730	907	1,193	470	1,208	1,500	3,972
LATVIA	3,220	1,688	2,221	874	2,248	2,793	7,393
LESOTHO	1,730	907	1,193	470	1,208	1,500	3,972
LITHUANIA	3,290	1,725	2,269	893	2,297	2,853	7,554
MADAGASCAR	640	336	441	174	447	555	1,469

TABLE 10 VALUE OF AIR POLLUTION DAMAGES FOR SO_2, NO_X AND PARTICULATES (US $[1996] per tonne)

Notes: Countries are arranged alphabetically.
Elasticity is assumed to be 1.00

Country	PPP GNP	SO_2		NO_X/ O_3		Particulate	
	US$ 1994	Lower	Higher	Lower	Higher	Lower	Higher
MALAWI	650	341	448	176	454	564	1,492
MALAYSIA	8,440	4,426	5,821	2,291	5,893	7,320	19,378
MALI	520	273	359	141	363	451	1,194
MAURITANIA	1,570	823	1,083	426	1,096	1,362	3,605
MAURITIUS	12,720	6,670	8,773	3,452	8,881	11,032	29,205
MEXICO	7,040	3,692	4,855	1,911	4,915	6,106	16,164
MOROCCO	3,470	1,820	2,393	942	2,423	3,009	7,967
MOZAMBIQUE	860	451	593	233	600	746	1,975
NAMIBIA	4,320	2,265	2,979	1,172	3,016	3,747	9,919
NEPAL	1,230	645	848	334	859	1,067	2,824
NEW ZEALAND	15,870	8,322	10,945	4,307	11,081	13,763	36,437
NICARAGUA	1,800	944	1,241	489	1,257	1,561	4,133
NIGER	770	404	531	209	538	668	1,768
NIGERIA	1,190	624	821	323	831	1,032	2,732
NORWAY	20,210	10,598	13,938	5,485	14,111	17,527	46,402
OMAN	8,590	4,504	5,924	2,331	5,998	7,450	19,722
PAKISTAN	2,130	1,117	1,469	578	1,487	1,847	4,890
PANAMA	5,730	3,005	3,952	1,555	4,001	4,969	13,156
PAPUA NEW GUINEA	2,680	1,405	1,848	727	1,871	2,324	6,153
PARAGUAY	3,550	1,862	2,448	963	2,479	3,079	8,151
PERU	3,610	1,893	2,490	980	2,521	3,131	8,288
PHILIPPINES	2,740	1,437	1,890	744	1,913	2,376	6,291
POLAND	5,480	2,874	3,779	1,487	3,826	4,753	12,582
ROMANIA	4,090	2,145	2,821	1,110	2,856	3,547	9,391
RUSSIAN FED	4,610	2,417	3,179	1,251	3,219	3,998	10,584
RWANDA	330	173	228	90	230	286	758
SAUDI ARABIA	9,480	4,971	6,538	2,573	6,619	8,222	21,766
SENEGAL	1,580	829	1,090	429	1,103	1,370	3,628
SIERRA LEONE	700	367	483	190	489	607	1,607
SINGAPORE	21,900	11,484	15,104	5,944	15,291	18,993	50,282
SLOVENIA	6,230	3,267	4,297	1,691	4,350	5,403	14,304
SOUTH AFRICA	5,130	2,690	3,538	1,392	3,582	4,449	11,778
SRI LANKA	3,160	1,657	2,179	858	2,206	2,741	7,255
SWITZERLAND	25,150	13,188	17,345	6,826	17,560	21,812	57,744
TAJIKISTAN	970	509	669	263	677	841	2,227
TANZANIA	620	325	428	168	433	538	1,424
THAILAND	6,970	3,655	4,807	1,892	4,867	6,045	16,003
TOGO	1,130	593	779	307	789	980	2,594
TRINIDAD & TOBAGO	8,670	4,546	5,979	2,353	6,054	7,519	19,906
TUNISIA	5,020	2,632	3,462	1,362	3,505	4,354	11,526
TURKEY	4,710	2,470	3,248	1,278	3,289	4,085	10,814
UGANDA	1,410	739	972	383	984	1,223	3,237
UKRAINE	2,620	1,374	1,807	711	1,829	2,272	6,015
URUGUAY	7,710	4,043	5,317	2,093	5,383	6,687	17,702
USA	25,880	13,571	17,849	7,024	18,070	22,445	59,420
UZBEKISTAN	2,370	1,243	1,635	643	1,655	2,055	5,441
VENEZUELA	7,770	4,074	5,359	2,109	5,425	6,739	17,840
ZAMBIA	860	451	593	233	600	746	1,975
ZIMBABWE	2,040	1,070	1,407	554	1,424	1,769	4,684

TABLE 11 VALUE OF AIR POLLUTION DAMAGES FOR SO_2, NO_X AND PARTICULATES (US $[1996] per tonne)

Notes: Countries are arranged alphabetically.
Elasticity is assumed to be 0.35

Country	PPP GNP	SO_2		NO_X/ O_3		Particulates	
	US$ 1994	Lower	Higher	Lower	Higher	Lower	Higher
ARGENTINA	8,720	7,299	9,600	3,778	12,348	12,072	40,605
ARMENIA	2,160	4,479	5,891	2,318	7,577	7,408	24,915
AUSTRALIA	18,120	9,429	12,401	4,880	15,951	15,594	52,451
AZERBAIJAN	1,510	3,951	5,197	2,045	6,684	6,535	21,980
BANGLADESH	1,330	3,780	4,971	1,956	6,394	6,251	21,025
BELARUS	4,320	5,709	7,508	2,955	9,657	9,441	31,755
BENIN	1,630	4,059	5,338	2,101	6,866	6,712	22,577
BOLIVIA	2,400	4,647	6,112	2,405	7,861	7,686	25,851
BOTSWANA	5,210	6,095	8,017	3,155	10,311	10,081	33,907
BRAZIL	5,400	6,172	8,118	3,195	10,441	10,208	34,335
BULGARIA	4,380	5,736	7,544	2,969	9,704	9,487	31,909
BURKINA FASO	800	3,164	4,161	1,637	5,352	5,232	17,599
BURUNDI	700	3,019	3,971	1,563	5,107	4,993	16,795
CAMEROON	1,950	4,321	5,684	2,237	7,310	7,147	24,038
CANADA	19,960	9,754	12,828	5,048	16,500	16,131	54,256
CENTRAL AFR. REP.	1,160	3,603	4,739	1,865	6,095	5,959	20,043
CHAD	720	3,049	4,010	1,578	5,158	5,043	16,961
CHILE	8,890	7,349	9,666	3,804	12,432	12,154	40,880
CHINA	2,510	4,721	6,209	2,443	7,986	7,807	26,259
COLOMBIA	5,330	6,144	8,081	3,180	10,394	10,162	34,178
CZECH REPUBLIC	8,900	7,352	9,669	3,805	12,437	12,159	40,896
DOMINICAN REP.	3,760	5,438	7,152	2,814	9,199	8,994	30,249
ECUADOR	4,190	5,648	7,428	2,923	9,554	9,341	31,417
EGYPT	3,720	5,417	7,125	2,804	9,165	8,960	30,136
EL SALVADOR	2,410	4,654	6,121	2,409	7,873	7,697	25,888
ESTONIA	4,510	5,795	7,622	2,999	9,804	9,585	32,237
ETHIOPIA	430	2,546	3,348	1,318	4,307	4,210	14,161
GAMBIA	1,100	3,537	4,652	1,830	5,983	5,849	19,674
GHANA	2,050	4,398	5,784	2,276	7,439	7,273	24,463
GUATEMALA	3,440	5,271	6,933	2,728	8,917	8,718	29,322
GUINEA-BISSAU	820	3,191	4,197	1,652	5,398	5,278	17,751
HAITI	930	3,335	4,386	1,726	5,641	5,515	18,551
HONDURAS	1,940	4,314	5,673	2,233	7,297	7,134	23,995
HUNGARY	6,080	6,434	8,462	3,330	10,884	10,641	35,790
INDIA	1,280	3,729	4,905	1,930	6,309	6,168	20,745
INDONESIA	3,600	5,356	7,044	2,772	9,060	8,858	29,792
ISRAEL	15,300	8,887	11,688	4,600	15,034	14,698	49,435
JAMAICA	3,400	5,250	6,904	2,717	8,881	8,682	29,202
JAPAN	21,140	9,952	13,089	5,151	16,835	16,459	55,358
JORDAN	4,100	5,605	7,372	2,901	9,482	9,270	31,180
KAZAKSTAN	2,810	4,911	6,459	2,542	8,307	8,122	27,318
KENYA	1,310	3,760	4,945	1,946	6,360	6,218	20,914
KOREA	10,330	7,745	10,187	4,009	13,103	12,810	43,085
KUWAIT	24,730	10,513	13,827	5,441	17,785	17,388	58,482
KYRGYZ REPUBLIC	1,730	4,144	5,450	2,145	7,010	6,854	23,052
LATVIA	3,220	5,151	6,774	2,666	8,713	8,518	28,651
LESOTHO	1,730	4,144	5,450	2,145	7,010	6,854	23,052
LITHUANIA	3,290	5,190	6,825	2,686	8,779	8,583	28,868
MADAGASCAR	640	2,926	3,848	1,514	4,950	4,839	16,276

TABLE 11 VALUE OF AIR POLLUTION DAMAGES FOR SO_2, NO_X AND PARTICULATES (US $[1996] per tonne)

Notes: Countries are arranged alphabetically.
Elasticity is assumed to be 0.35.

Country	PPP GNP	S O_2		NO_X/ O_3		Particulates	
	US$ 1994	Lower	Higher	Lower	Higher	Lower	Higher
MALAWI	650	2,942	3,869	1,523	4,977	4,866	16,365
MALAYSIA	8,440	7,217	9,491	3,735	12,208	11,935	40,143
MALI	520	2,721	3,579	1,408	4,603	4,500	15,135
MAURITANIA	1,570	4,006	5,268	2,073	6,776	6,625	22,282
MAURITIUS	12,720	8,331	10,957	4,312	14,093	13,778	46,341
MEXICO	7,040	6,773	8,908	3,505	11,457	11,201	37,674
MOROCCO	3,470	5,287	6,954	2,736	8,944	8,744	29,411
MOZAMBIQUE	860	3,245	4,268	1,679	5,489	5,366	18,050
NAMIBIA	4,320	5,709	7,508	2,955	9,657	9,441	31,755
NEPAL	1,230	3,678	4,837	1,903	6,221	6,082	20,458
NEW ZEALAND	15,870	9,001	11,839	4,659	15,227	14,887	50,072
NICARAGUA	1,800	4,202	5,527	2,175	7,108	6,950	23,374
NIGER	770	3,122	4,106	1,616	5,281	5,163	17,365
NIGERIA	1,190	3,635	4,781	1,882	6,150	6,012	20,223
NORWAY	20,210	9,796	12,884	5,070	16,572	16,202	54,493
OMAN	8,590	7,261	9,550	3,758	12,283	12,009	40,392
PAKISTAN	2,130	4,457	5,862	2,307	7,540	7,371	24,793
PANAMA	5,730	6,302	8,288	3,262	10,660	10,422	35,055
PAPUA NEW GUINEA	2,680	4,830	6,353	2,500	8,171	7,988	26,868
PARAGUAY	3,550	5,330	7,010	2,758	9,016	8,814	29,647
PERU	3,610	5,361	7,051	2,775	9,069	8,866	29,821
PHILIPPINES	2,740	4,868	6,402	2,519	8,234	8,051	27,077
POLAND	5,480	6,204	8,160	3,211	10,495	10,261	34,512
ROMANIA	4,090	5,600	7,366	2,899	9,474	9,262	31,153
RUSSIAN FED	4,610	5,840	7,681	3,023	9,879	9,658	32,486
RWANDA	330	2,321	3,052	1,201	3,926	3,838	12,908
SAUDI ARABIA	9,480	7,516	9,885	3,890	12,715	12,431	41,810
SENEGAL	1,580	4,015	5,280	2,078	6,791	6,640	22,332
SIERRA LEONE	700	3,019	3,971	1,563	5,107	4,993	16,795
SINGAPORE	21,900	10,075	13,251	5,215	17,044	16,664	56,047
SLOVENIA	6,230	6,489	8,535	3,359	10,977	10,732	36,097
SOUTH AFRICA	5,130	6,062	7,974	3,138	10,256	10,027	33,724
SRI LANKA	3,160	5,117	6,730	2,648	8,656	8,463	28,463
SWITZERLAND	25,150	10,575	13,909	5,474	17,890	17,490	58,828
TAJIKISTAN	970	3,384	4,451	1,752	5,725	5,597	18,826
TANZANIA	620	2,894	3,806	1,498	4,895	4,786	16,097
THAILAND	6,970	6,749	8,876	3,493	11,417	11,162	37,543
TOGO	1,130	3,570	4,696	1,848	6,039	5,905	19,860
TRINIDAD & TOBAGO	8,670	7,285	9,581	3,770	12,323	12,048	40,523
TUNISIA	5,020	6,017	7,913	3,114	10,178	9,951	33,469
TURKEY	4,710	5,884	7,739	3,045	9,954	9,731	32,730
UGANDA	1,410	3,858	5,074	1,997	6,526	6,380	21,460
UKRAINE	2,620	4,792	6,303	2,480	8,106	7,925	26,656
URUGUAY	7,710	6,992	9,196	3,619	11,827	11,563	38,892
USA	25,880	10,682	14,049	5,529	18,070	17,667	59,420
UZBEKISTAN	2,370	4,627	6,085	2,395	7,827	7,652	25,737
VENEZUELA	7,770	7,011	9,221	3,628	11,860	11,595	38,998
ZAMBIA	860	3,245	4,268	1,679	5,489	5,366	18,050
ZIMBABWE	2,040	4,390	5,774	2,272	7,427	7,261	24,421

In some cases, only partial local data will be available. For example a local study may be available for health benefits of reducing particulate pollution (as in the case of China). While no general prescription is available for incorporating such information, it may be useful to note the 'shares' of damages associated with each of the impacts (e.g. health, agriculture, etc.). The range of damages in the ExternE study for the three pollutants listed above is given in Table 12. Hence if a study is available for health benefits and gives damages from particulate pollution as US $*X* per tonne, total damages may be computed noting that of the *valued* damages, health damages are the dominant ones, accounting for over 98 percent of the total.[21]

Table 12 Shares of Damages by Impact

Pollutant	Impact	Share (%)
SO_2	Health	98.0
	Materials	1.9
	Crops	0.1
NO_x	Health	98.6
incl. Ozone	Materials	0.3
	Crops	1.1
Particulates	Health	100.0
	Materials	0.0
	Crops	0.0

Source: Adapted from ExternE (1997a).

9.4 Other Environmental Damages

Other environmental impacts that need to be considered are: natural and semi-natural eco-systems, forestry and water. It is difficult to give general guidance on such impacts. Each case is special and has to be treated as such. What one can say, however, is that a preliminary screening of the projects will reveal what impacts are likely to be important. These should be investigated as part of an Environmental Impact Assessment (EIA). The major findings of that EIA should then be reported. That in turn will influence the selection of the project and, perhaps more importantly, it will influence the *design* of the project. For example, if the GHG limitation project consists of a micro-hydro development, the beneficial or detrimental environmental impacts will be identified in the EIA. That in turn should result in a modified design, which takes account of such impacts. Details of how such impacts may be assessed are available in World Bank (1991) and World Bank (1995).

10 CASE STUDIES

10.1 Introduction

This section provides three case studies of projects that have been analysed using the techniques discussed in this report. These case studies are based on real data, but have been embellished and added to, so that they illustrate some of the key issues covered in this report. The first case looks at a biogas plant in Tanzania and is based on some data from a GEF Project Document (UNDP, 1994). The second is based on a forestry project proposed for the Russian Federation prepared by the Environmental Defence Fund (EDF, 1995). The third is an energy efficiency project in Thailand, based on another GEF project document (World Bank, 1993). In each case the basic objectives of the projects are discussed and the conventional analysis presented alongside the broader analysis. Some comments on the implications of the broader analysis for project selection and project design are offered.

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21 For example, particulate pollution has some identified impacts on materials. It is just that these have not been quantified and valued.

10.2 Biogas in Tanzania

10.2.1 Introduction to the Project

This project aimed to reduce GHGs in Tanzania by replacing fossil fuels with bioenergy produced from anaerobic 'digestion' of industrial and municipal waste. A plant was to be built in the Dar-es-Salaam area, which would capture methane for use as a fuel and for the generation of electricity, and to provide organic fertiliser.

The conventional analysis of the project looked at the capital and labour costs, which amounted to $2.23 million. The operating costs of the project are around $9,500 per annum. The project is estimated to reduce the emissions of methane annually by 0.3 million cubic meters. In addition the use of the methane for electricity and for transportation fuel will save 1,700 tons of diesel oil, with a net reduction of carbon dioxide emissions of 6,200 tons per year. Hence, the net annual reduction of GHG gases from the plant in carbon equivalent terms is, in tonnes,

$$21 \times 300{,}000 \text{ m}^3 \times 0.68 \text{ kg } CH_4/\text{m}^3 \times 0.001 \text{ t/kg} + 6{,}200 \text{ t}CO_2 = 10{,}484 \text{ t}CO_2.$$

Twenty one is the GWP for methane, and the weight at 15^0C is 0.68 kg/m^3. The plant is assumed to last for 25-30 years.

10.2.2 Financial Analysis

The summary financial analysis is provided in Table 13. It implies a value of FICOSTEF of around $26/tonne of carbon dioxide, which is at the lower end of the range of value obtained for GHG limitation projects. Since this project only deals with 4 percent of the total biogas potential, it would suggest that this demonstration project, if successful, should be replicated. The financial analysis also looked at the return on the operations of the plant to the operators. These are expected to be around $245,000 to $305,000, assuming sales of energy at prices currently prevailing. This is useful in that it points to the financial sustainability of the project. Finally, the above analysis shows that the estimate of FICOSTEF is not very sensitive to the underlying rates of discount for money and carbon flows.

Table 13 Financial Analysis of Biogas Plant in Tanzania					
	Notes:	Figures are in ' 000 dollars			
Year	Local Cost	Foreign Cost	Operating Cost	Total Cost	Tonnes of CO_2 Reduced
1	65,2	3.511,0	-	3.576,2	-
2	10,6	330,0	-	340,6	-
3	-	150,0	9,5	159,5	10.484
4	-	-	9,5	9,5	10.484
5	-	-	9,5	9,5	10.484
6	-	-	9,5	9,5	10.484
7	-	-	9,5	9,5	10.484
8	-	-	9,5	9,5	10.484
9	-	-	9,5	9,5	10.484
10	-	-	9,5	9,5	10.484
11	-	-	9,5	9,5	10.484
12	-	-	9,5	9,5	10.484
13	-	-	9,5	9,5	10.484
14	-	-	9,5	9,5	10.484
15	-	-	9,5	9,5	10.484
16	-	-	9,5	9,5	10.484
17	-	-	9,5	9,5	10.484
18	-	-	9,5	9,5	10.484
19	-	-	9,5	9,5	10.484
20	-	-	9,5	9,5	10.484
21	-	-	9,5	9,5	10.484
22	-	-	9,5	9,5	10.484
23	-	-	9,5	9,5	10.484
24	-	-	9,5	9,5	10.484
25	-	-	9,5	9,5	10.484
Total PV Cost at 3% (US $ '000)					4.078,1
Total Discounted Reduction at 3% ('000 tonnes)					162,5
FICOSTEF (US $ per tonne)					**25,1**
Total PV Cost at 10% (US $ '000)					3.715,3
Total Discounted Reduction at 1% ('000 tonnes)					210,2
FICOSTEF (US $ per tonne)					**17,7**
Total PV Cost at 5% (US $ '000)					3.961,1
Total Discounted Reduction at 3% ('000 tonnes)					162,5
FICOSTEF (US $ per tonne)					**24,4**
Total PV Cost at 3% (US $ '000)					4.078,1
Total Discounted Reduction at 2% ('000 tonnes)					184,3
FICOSTEF (US $ per tonne)					**22,1**

10.2.3 Broader Socio-economic Analysis

The above analysis ignores the following aspects of the project:

a) The social benefits of any employment created.

b) The scarcity of domestic employment on the project capital.

c) The benefits of reduced time spent collecting fuelwood by some of those to whom the energy will be provided.

d) The health benefits of reduced use of fuelwood for cooking in the home.

e) The benefits of transfers of benefits to low income households.

f) Estimate of the shift to a sustainable use of energy.

Employment benefits

The social benefits of employment can be assumed to arise with respect to unskilled employees in the construction and operations of the plant. Information is needed on the number of persons who will be employed in this capacity and amount paid. In Table 14 it is assumed that 500 unskilled labourers will be employed for the first two years and 20 persons will be employed thereafter for the duration of the project. Their annual wage is taken as $1,200. Next it is necessary to estimate the benefit of employment to this group. Typical values for the shadow price of labour are taken as 0.5, so that the actual cost imputed to the project is only 50 percent of the financial cost. This, however, makes no allowance for the health benefits of employment. From Table 5, these are estimated at

$\$96,000 \; x \; 0.75 \; x \; 8/1,000 = \$576$

where

$96,000 is the VOSL for Tanzania as given in Table 5 for an income elasticity of one;

0.75 is the excess mortality rate for unemployed persons; and

8/1,000 is the age specific death rate in Tanzania for males.

This has to be added as a benefit of employment; i.e. deducted from the actual labour cost of the project.

Scarcity of capital employed

The scarcity of capital employed is represented through a shadow price coefficient for capital. For Tanzania this is taken as 1.5 for domestic and foreign capital.

The benefits of reduced time spent collecting fuelwood by some of those to whom the energy will be provided

The benefits of time saved in fuelwood collection can be estimated as follows:

Number of households who shift from firewood to biogas for energy	500
Time spent in collecting firewood (hours per annum)	700
Value of time ($ per hour)	0.50
Total value of fuelwood time savings ($000)	175

This value increases over time at the expected rate of growth of households (i.e. 2 per cent) plus the rate of growth of *per capita* income (i.e. 2 percent).

These benefits assume that the benefits of biogas to the households is at least equal to the cost fuelwood it replaces. They may be higher than that, if allowance is made for the cleanliness of the fuel, etc. Ideally what one would like is the willingness to pay for the biogas, but unfortunately that is not available.

The health benefits of switching out of fuelwood for domestic use

No direct estimate of the health damages from fuelwood has been provided in this report. There are, however, some estimates available in the literature and the same method can be applied to them as to the values derived in Sections 7 and 9. Smith (1991) reports health damages of around $10 per annum per household in Nepal in 1988, based on losses of income and work productivity. This method underestimates the welfare costs associated with health because they will be willing to pay more than the loss of working capacity to avoid the illness. Smith takes a value of $15 per year per household as the welfare cost. This seems reasonable, if anything it is on the low side.[22] Adjusting for dollar inflation between 1988 and 1995 increases this to $19.3. Adjusting for the difference in *per capita* income between Nepal and Tanzania would imply an adjustment of (620 / 1,230 = 0.5) see Table 5, income elasticity of one). Applying the adjusted value of $9.65 per household per year for the 500 households yields a benefit of $4,825.

The benefits of transfers to low income households

Low-income households will be beneficiaries of the time savings and of the reduction in health damages. According to the valuations given in Section 8, the value of these transfers should be increased according to the ratio of the average household income of the beneficiaries relative to the average. If it assumed that the beneficiaries have an income of 30 percent of the average, the adjustment coefficient is 3.1 (Table 8 for an inequality aversion parameter of 1). Adjusting the time savings and health benefits by this gives the following benefits:

Time savings ($000)	542.5
Health benefits ($000)	15.1

It is assumed that employment creation is for individuals at the average level of income. If that is not the case, a similar adjustment needs to be made for employment benefits.

Change to sustainable energy

This project is too small to have a significant impact on the move to sustainable energy. The net costs associated with the above impacts are presented in Table 14 below. The table shows that the benefits are significant and that the costs per tonne of carbon reduced become negative when these benefits are considered. Hence the project is justified *in its own right* and does not need GHG support to justify it. Of course, there may be some hidden costs and these should be evaluated. Typically these will relate to support for the administration of the project and training, capacity building, etc.

22 Markandya (1996) cites some of the evidence on the relationship between the costs of illness as measured by productivity and income losses and the full social costs. For the US the latter can be between 2-3 times the former. Hence the value of 1.5 taken by Smith is not unreasonable.

Table 14 Full Socio-economic Analysis of Biogas Plant in Tanzania[1]

Year	Local Capital Cost[2]	Foreign Capital Cost[2]	Economic Labour Cost[7]	Employ. Health Benefit[3]	Time Saved[4]	Fuel-switch Health Benefit[5]	Op. Cost	Total Net Cost	Tonnes of CO_2 Reduced
1	78.3	4,213.2	357.6	288.0	-	-	-	4,361.1	-
2	12.8	396.0	34.1	288.0	-	-	-	154.8	-
3	-	180.0	15.0	11.5	542.5	15.1	9.5	- 364.6	10,484
4	-	-	-	11.8	564.2	15.7	9.5	- 582.1	10,484
5	-	-		12.0	586.8	16.3	9.5	- 605.5	10,484
6	-	-		12.2	610.2	17.0	9.5	- 629.9	10,484
7	-	-		12.5	634.6	17.6	9.5	- 655.2	10,484
8	-	-		12.7	660.0	18.3	9.5	- 681.6	10,484
9	-	-		13.0	686.4	19.1	9.5	- 709.0	10,484
10	-	-		13.2	713.9	19.8	9.5	- 737.4	10,484
11	-	-		13.5	742.4	20.6	9.5	- 767.1	10,484
12	-	-		13.8	772.1	21.5	9.5	- 797.8	10,484
13	-	-		14.0	803.0	22.3	9.5	- 829.9	10,484
14	-	-		14.3	835.2	23.2	9.5	- 863.2	10,484
15	-	-		14.6	868.6	24.1	9.5	- 897.8	10,484
16	-	-		14.9	903.3	25.1	9.5	- 933.8	10,484
17	-	-		15.2	939.4	26.1	9.5	- 971.2	10,484
18	-	-		15.5	977.0	27.2	9.5	- 1,010.1	10,484
19	-	-		15.8	1,016.1	28.2	9.5	- 1,050.6	10,484
20	-	-		16.1	1,056.7	29.4	9.5	- 1,092.7	10,484
21	-	-		16.5	1,099.0	30.5	9.5	- 1,136.5	10,484
22	-	-		16.8	1,143.0	31.8	9.5	- 1,182.0	10,484
23	-	-		17.1	1,188.7	33.0	9.5	- 1,229.3	10,484
24	-	-		17.5	1,236.2	34.4	9.5	- 1,278.5	10,484
25	-	-		17.8	1,285.7	35.7	9.5	- 1,329.7	10,484
Total PV Cost at 3% (US $ '000)									- 8,591.0
Total Discounted Reduction at 3% ('000 tonnes)									162.5
FUCOSTEF (US $ per tonne)									**- 52.9**
Total PV Cost at 10% (US $ '000)									- 1,355.2
Total Discounted Reduction at 1% ('000 tonnes)									210.2
FUCOSTEF (US $ per tonne)									**- 6.4**
Total PV Cost at 5% (US $ '000)									- 5,582.0
Total Discounted Reduction at 3% ('000 tonnes)									162.5
FUCOSTEF (US $ per tonne)									**- 34.4**
Total PV Cost at 3% (US $ '000)									- 8,591.0
Total Discounted Reduction at 2% ('000 tonnes)									184.3
FUCOSTEF (US $ per tonne)									**- 46.6**

Notes:

1 Figures are in $'000.

2 This is equal to 80% of the financial capital cost, multiplied by a shadow price of 1.5.

3 The employment health benefit is $576 per person p.a.; rising at 2% p.a. to reflect real income growth.

4 The total value of fuelwood time savings is $175,000 p.a.; rising at 4% p.a. to reflect household and income growth.

5 The health benefits of switching out of fuelwood are $15,100 p.a.; rising at 2% p.a. to reflect real income growth.

6 Four and five have been adjusted to take account of impacts on income distribution.

7 This is equal to 20% of the financial capital cost, multiplied by a shadow price of 0.5.

It is interesting to note that the results of the economic analysis are more sensitive to the discount rates than those of the financial analysis. At a 10 percent discount rate for economic costs and benefits the net cost is only just negative, whereas at a 3 percent rate it is significantly negative.

Given the overall benefits of the project, the government should place a much higher priority on these changes in energy use than on others which may have a lower financial cost per tonne but will not have such a low economic cost per tonne.

This example has demonstrated that both financial and socio-economic analysis are relevant to the analysis but that the latter adds an important dimension.

10.3 Afforestation In Russia

10.3.1 Introduction

In 1995 the Environmental Defense Fund based in New York prepared a project for afforestation of 2,000 hectares of agricultural land in the Vologda region, approximately 500 kilometres from Moscow. The region or 'oblast' has 1.4 million inhabitants, with about 70% of the land area as forest and more than 10% in agricultural use. The forests are dominated by spruce, pine, aspen and birch. The selected site is near the Russky Sever National Park, which was selected by the Russian authorities for replanting anyway, following a cutting that took place 12 years ago. The adjacent land where the project will be implemented is used as hayfields.

10.3.2 Financial and Economic Analysis

The main costs associated with the project are the costs of the land, of replanting and managing the site, and that of monitoring the project. The costs of the land were valued at the current value of the hay produced. Because the hay is not sold, it was valued in terms of its nutritional content (in terms of grain). On this basis the value of the hay was in the range $9.4 / ha to $11.7 / ha in 1995. Since the project will yield benefits over 60 years, some key assumptions have to be made about the value of the land in the future. EDF made no such valuation but in the analysis below, it is assumed that land values would rise with economic growth, at 3 percent per annum.

The other costs of the project are the planting, monitoring, equipment, administration and verification costs. Of these, only the planting and monitoring costs have a divergence between financial and economic costs. It is assumed that the project provides employment for 20 local previously unemployed persons over 4 years. The financial "plantation" cost is estimated at $122 per person-month, or $29,280 in the first year, and thereafter increasing at the rate of economic growth. If, however, the benefits of the employment are taken, based on Russian data for VOSL (Table 5), unemployment payments and risks of death during unemployment (0.0075 for Russia), the net costs of employment become negative (Markandya, 1997). In other words the benefits of employment exceed the payments to the workers. As there are a range of values possible for the employment benefits, and as there is uncertainty about them, it has been assumed below that it is reasonable to place an upper bound of zero on the economic cost of the labour employed in the project for planting and monitoring.

The carbon assumed to be sequestered by the project is taken as 1.4 Mg / ha / year for the first ten years and 2.0 Mg / ha / year for years 11 to 60. This includes above ground biomass net sequestration as well as root biomass accumulation.

Tables 15 and 16 provide estimates of the financial and economic costs of the project, respectively. The financial costs are low, even assuming that the hay has an implicit value to the users. The implied values of FICOSTEF are in the range $3 to $11 per tonne of carbon, which is relatively low. The higher the discount rate applied to the carbon the higher the value of FICOSTEF.[23]

The economic costs are even lower, as they do set the planting costs at zero. It should be noted here that the economic analysis did not include any impacts of the project on the biodiversity of the region or the shelterbelt or other benefits of afforestation. These could not be quantified, but should be presented and discussed in the final report.

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[23] The analysis assumes that the afforestation will be a one-off exercise. The benefits of cutting and replanting at the end of 60 years would make a small difference to the calculations.

The uncertainties associated with this project relate to (a) uncertainties about the level of carbon sequestration and (b) the possibilities of loss of plantation due to fire. The carbon figures taken here are on the conservative side and should, given no mishaps in the implementation of the project, be realised. The risk of fire loss and other losses is small. Less than 0.016 percent of the forested area in Vologda was damaged by fire between 1984 and 1993 and less than half that by blight or disease.

Finally in terms of sustainability, the project can contribute a little if the afforestation is implemented as a sustainable project – i.e. the area will be scheduled for replanting at the end of the rotation period of 60 years. Of course this is only a statement of intent at this stage but is nevertheless useful as a guide to local government intentions.

Table 15 Financial Analysis of Reforestation Project in the Russian Federation

Year	Land Cost[1] (US $'000)	Planting Cost[2] (US $'000)	Monitoring Cost[2] (US $'000)	Equipment Cost (US $'000)	Admin & Verification Cost (US $'000)	Total Cost (US $'000)	Carbon Reduction (tonnes)
1	10.55	29.28	1.10	21.00	60.50	122.43	2,800
2	10.87	30.16	20.10	-	36.57	97.70	2,800
3	11.19	31.06	0.10	-	34.06	76.42	2,800
4	11.53	32.00	0.10	-	35.08	78.71	2,800
5	11.87	-	1.10	-	38.13	51.11	2,800
6	12.23	-	0.10	-	37.21	49.54	2,800
7	12.60	-	0.10	-	38.33	51.03	2,800
8	12.98	-	0.10	-	39.48	52.56	2,800
9	13.36	-	0.10	-	40.67	54.14	2,800
10	13.77	-	4.50	8.20	43.89	70.36	2,800
11	14.18	-	0.10	-	-	14.28	4,000
12	14.60	-	0.10	-	-	14.71	4,000
13	15.04	-	0.10	-	-	15.14	4,000
14	15.49	-	0.10	-	-	15.60	4,000
15	15.96	-	0.10	-	-	16.06	4,000
16	16.44	-	0.10	-	-	16.54	4,000
17	16.93	-	0.10	-	-	17.03	4,000
18	17.44	-	0.10	-	-	17.54	4,000
19	17.96	-	0.10	-	-	18.06	4,000
20	18.50	-	4.50	8.20	-	31.20	4,000
21	19.05	-	0.10	-	-	19.16	4,000
52	47.64	-	0.10	-	-	47.74	4,000
53	49.07	-	0.10	-	-	49.17	4,000
54	50.54	-	0.10	-	-	50.64	4,000
55	52.06	-	0.10	-	-	52.16	4,000
56	53.62	-	0.10	-	-	53.72	4,000
57	55.23	-	0.10	-	-	55.33	4,000
58	56.88	-	0.10	-	-	56.98	4,000
59	58.59	-	0.10	-	-	58.69	4,000
60	60.35	-	4.50	8.20	-	73.05	4,000
Total PV Cost at 3% (US $ '000)							1,148.4
Total Discounted Reduction at 3% ('000 tonnes)							100.5
FICOSTEFF (US $ per tonne)							**11.4**
Total PV Cost at 10% (US $ '000)							542.3
Total Discounted Reduction at 1% ('000 tonnes)							168.5
FICOSTEFF (US $ per tonne)							**3.2**
Total PV Cost at 5% (US $ '000)							844.1
Total Discounted Reduction at 3% ('000 tonnes)							100.5
FICOSTEFF (US $ per tonne)							**8.4**
Total PV Cost at 3% (US $ '000)							1,148.4
Total Discounted Reduction at 2% ('000 tonnes)							128.3
FICOSTEFF (US $ per tonne)							**9.0**

Notes:

[1] Land costs are based on the value of hay (i.e. 9.4 + 11.7 divided by 2), and are assumed to rise at 3% p.a.

[2] Undertaken by previously unemployed local labour.

Table 16 Full Socio-economic Analysis of Reforestation in the Russian Federation

Year	Land Cost[1] (US $'000)	Planting Cost[2] (US $'000)	Monitoring Cost[2] (US $'000)	Equipment Cost (US $'000)	Admin & Verification Cost (US $'000)	Total Cost (US $'000)	Carbon Reduction (tonnes)
1	10.55	-	-	21.00	60.50	92.05	2,800
2	10.87	-	-	-	36.57	47.44	2,800
3	11.19	-	-	-	34.06	45.25	2,800
4	11.53	-	-	-	35.08	46.61	2,800
5	11.87	-	-	-	38.13	50.00	2,800
6	12.23	-	-	-	37.21	49.44	2,800
7	12.60	-	-	-	38.33	50.93	2,800
8	12.98	-	-	-	39.48	52.46	2,800
9	13.36	-	-	-	40.67	54.03	2,800
10	13.77	-	-	8.20	43.89	65.86	2,800
11	14.18	-	-	-	-	14.18	4,000
12	14.60	-	-	-	-	14.60	4,000
13	15.04	-	-	-	-	15.04	4,000
14	15.49	-	-	-	-	15.49	4,000
15	15.96	-	-	-	-	15.96	4,000
16	16.44	-	-	-	-	16.44	4,000
17	16.93	-	-	-	-	16.93	4,000
18	17.44	-	-	-	-	17.44	4,000
19	17.96	-	-	-	-	17.96	4,000
20	18.50	-	-	8.20	-	26.70	4,000
21	19.05	-	-	-	-	19.05	4,000
52	47.64	-	-	-	-	47.64	4,000
53	49.07	-	-	-	-	49.07	4,000
54	50.54	-	-	-	-	50.54	4,000
55	52.06	-	-	-	-	52.06	4,000
56	53.62	-	-	-	-	53.62	4,000
57	55.23	-	-	-	-	55.23	4,000
58	56.88	-	-	-	-	56.88	4,000
59	58.59	-	-	-	-	58.59	4,000
60	60.35	-	-	8.20	-	68.55	4,000
Total PV Cost at 3% (US $ '000)							1,000.5
Total Discounted Reduction at 3% ('000 tonnes)							100.5
FUCOSTEFF (US $ per tonne)							**10.0**
Total PV Cost at 10% (US $ '000)							423.7
Total Discounted Reduction at 1% ('000 tonnes)							168.5
FUCOSTEFF (US $ per tonne)							**2.5**
Total PV Cost at 5% (US $ '000)							707.3
Total Discounted Reduction at 3% ('000 tonnes)							100.5
FUCOSTEFF (US $ per tonne)							**7.0**
Total PV Cost at 3% (US $ '000)							1,000.5
Total Discounted Reduction at 2% ('000 tonnes)							128.3
FUCOSTEFF (US $ per tonne)							**7.8**

Notes:

[1] Land costs are based on the value of hay (i.e. 9.4 + 11.7 divided by 2), and are assumed to rise at 3% p.a.

[2] An upper bound of zero has been placed on the economic cost of locally employed labour.

10.4 Demand Side Management in Thailand

10.4.1 Introduction

This project was prepared by the Global Environment Facility of the World Bank. A five year Demand Side Management (DSM) programme was proposed, with two major objectives: (1) to build sufficient institutional capability in the Thai electric power sector, and the energy related private sector, to deliver cost-effective energy services throughout the economy; and (2) to pursue policies and actions that would lead to the development, manufacture and adoption of energy efficient equipment and processes within the economy. The DSM project has four main elements:

1. To provide user and manufacturer incentives and consumer education to influence practices and attitudes towards energy-efficient technologies.
2. To develop energy efficiency standards, testing capabilities and monitoring procedures.
3. To develop and promulgate appliance codes so as to enforce minimum standards.
4. To continue to pursue technological improvements appropriate to Thai conditions.

The DSM programme would be managed by the Electricity Generating Authority of Thailand (EGAT). Actions would be taken in the commercial, residential and industrial sectors with a projected annual electricity saving of 1,427GWh after five years. This is equivalent to a generation saving of 436 million litres of oil, where oil is assumed to be the marginal fuel.

The total financing required would be US $189 million over the five year period. Of this, around 84% would constitute local capital, the balance would be foreign. The project offers significant GHG reduction opportunities through the need to defer the building of new generation capacity.

10.4.2 The Financial Cost Analysis

The financial analysis of the project is presented in Table 17 below. It assumes that the benefits of the project will last for 15 years; in other words, the energy savings from this programme will continue for 15 years after the project has been completed. This is an assumption that needs to be tested. The report gives little guidance as to how long the benefits will last, and yet the cost-effectiveness of the project is crucially dependent on this. Assuming a life of 15 years the present value of the costs is between $143 and $173 million, and the discounted value of total carbon emissions abated is between 11.9 and 15.3 thousand tonnes. The cost per tonne saved thus ranges between $9.4 and $14.5, depending on what discount rates are applied. By comparison with other methods of reducing carbon this is in the middle of the range.[24]

10.4.3 Broader Socio-economic Analysis

The economic cost analysis makes the following additional assumptions:

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[24] The financial analysis should also look at the financial viability of the project for the implementing agencies. This is not reported here as the information is not available. With GEF funding for most of the project, however, this viability should not be difficult to establish.

a) Capital (both domestic and foreign) has a scarcity premium of 1.5.

b) There are benefits from the reduction in fossil fuel emissions. The amounts of gases emitted per MWh of generation from diesel (which is the fuel assumed to be saved) are: 798 grams of SO_2, 938 grams of NO_x and 25 grams of Total Suspended Particulates (TSP). Corresponding annual generation saved is given as 1,472 GWh a year after 5 years. The annual value of the savings are taken from Table 10 for Thailand as: $3,655 to $4,807 per tonne for SO_2, $1,892 to $4,867 per tonne for NO_x and $6,045 to $16,003 per tonne for particulates.[25] In Table 18 the averages of these ranges have been used to calculate the net costs per tonne saved of each of these pollutants.

The implications of making these adjustments are considerable. The net costs of the project decrease between 8 and 35 per cent, depending on the discount rate used. The resulting values of FUCOSTEF are therefore lower; however, they are more sensitive to the discount rates than are the corresponding values of FICOSTEF. Clearly, in this case, a broader analysis would give a higher priority to a DSM project.

25 TSP values should be different from those for PM_{10}. This report does not provide the adjustment figure, although one can be made for the final report.

Table 17: Financial Analysis of DSM in Thailand

Year	Foreign Capital Cost (US $$10^6$)	Domestic Capital Cost (US $$10^6$)	Total Capital Cost (US $$10^6$)	Total Labour Cost (US $$10^6$)	Total Project Cost (US $$10^6$)	Tonnes of CO_2 Reduced
1	3.05	16.03	19.08	18.72	37.80	-
2	3.05	16.03	19.08	18.72	37.80	-
3	3.05	16.03	19.08	18.72	37.80	-
4	3.05	16.03	19.08	18.72	37.80	-
5	3.05	16.03	19.08	18.72	37.80	-
6	-	-	-	-	-	1,160
7	-	-	-	-	-	1,160
8	-	-	-	-	-	1,160
9	-	-	-	-	-	1,160
10	-	-	-	-	-	1,160
11	-	-	-	-	-	1,160
12	-	-	-	-	-	1,160
13	-	-	-	-	-	1,160
14	-	-	-	-	-	1,160
15	-	-	-	-	-	1,160
16	-	-	-	-	-	1,160
17	-	-	-	-	-	1,160
18	-	-	-	-	-	1,160
19	-	-	-	-	-	1,160
20	-	-	-	-	-	1,160
Total PV Cost at 3% (US $ '000)						173.1
Total Discounted Reduction at 3% ('000 tonnes)						11.9
FICOSTEF (US $ per tonne)						**14.5**
Total PV Cost at 10% (US $ '000)						143.3
Total Discounted Reduction at 1% ('000 tonnes)						15.3
FICOSTEF (US $ per tonne)						**9.4**
Total PV Cost at 5% (US $ '000)						163.7
Total Discounted Reduction at 3% ('000 tonnes)						11.9
FICOSTEF (US $ per tonne)						**13.7**
Total PV Cost at 3% (US $ '000)						173.1
Total Discounted Reduction at 2% ('000 tonnes)						13.5
FICOSTEF (US $ per tonne)						**12.8**

Table 18 Full Socio-economic Analysis of DSM in Thailand

Year	Foreign Capital Cost (US $106)	Domestic Capital Cost (US $106)	Total Capital Cost (US $106)	Total Labour Cost (US $106)	Total Project Cost (US $106)	SO2 Emission Savings (tonnes)	SO2 Savings Benefits (US $106)	NOX Emission Savings (tonnes)	NOX Savings Benefits (US $106)	TSP Emission Savings (tonnes)	TSP Savings Benefits (US $106)	Benefits Emission Savings (US $106)	Net Project Cost (US $106)	Tonnes of CO2 Reduced
1	4.58	24.04	28.62	18.72	47.34	-	-	-	-	-	-	-	47.34	-
2	4.58	24.04	28.62	18.72	47.34	-	-	-	-	-	-	-	47.34	-
3	4.58	24.04	28.62	18.72	47.34	-	-	-	-	-	-	-	47.34	-
4	4.58	24.04	28.62	18.72	47.34	-	-	-	-	-	-	-	47.34	-
5	4.58	24.04	28.62	18.72	47.34	-	-	-	-	-	-	-	47.34	-
6	-	-	-	-	-	1,174.66	4.97	1,380.74	4.67	36.80	0.41	10.04	- 10.04	1,160
7	-	-	-	-	-	1,174.66	4.97	1,380.74	4.67	36.80	0.41	10.04	- 10.04	1,160
8	-	-	-	-	-	1,174.66	4.97	1,380.74	4.67	36.80	0.41	10.04	- 10.04	1,160
9	-	-	-	-	-	1,174.66	4.97	1,380.74	4.67	36.80	0.41	10.04	- 10.04	1,160
10	-	-	-	-	-	1,174.66	4.97	1,380.74	4.67	36.80	0.41	10.04	- 10.04	1,160
11	-	-	-	-	-	1,174.66	4.97	1,380.74	4.67	36.80	0.41	10.04	- 10.04	1,160
12	-	-	-	-	-	1,174.66	4.97	1,380.74	4.67	36.80	0.41	10.04	- 10.04	1,160
13	-	-	-	-	-	1,174.66	4.97	1,380.74	4.67	36.80	0.41	10.04	- 10.04	1,160
14	-	-	-	-	-	1,174.66	4.97	1,380.74	4.67	36.80	0.41	10.04	- 10.04	1,160
15	-	-	-	-	-	1,174.66	4.97	1,380.74	4.67	36.80	0.41	10.04	- 10.04	1,160
16	-	-	-	-	-	1,174.66	4.97	1,380.74	4.67	36.80	0.41	10.04	- 10.04	1,160
17	-	-	-	-	-	1,174.66	4.97	1,380.74	4.67	36.80	0.41	10.04	- 10.04	1,160
18	-	-	-	-	-	1,174.66	4.97	1,380.74	4.67	36.80	0.41	10.04	- 10.04	1,160
19	-	-	-	-	-	1,174.66	4.97	1,380.74	4.67	36.80	0.41	10.04	- 10.04	1,160
20	-	-	-	-	-	1,174.66	4.97	1,380.74	4.67	36.80	0.41	10.04	- 10.04	1,160
Total PV Cost at 3% (US $' 000)														113.4
Total Discounted Reduction at 3% ('000 tonnes)														11.9
FUCOSTEF (US $ per tonne)														**9.5**
Total PV Cost at 10% (US $' 000)														132.0
Total Discounted Reduction at 1% ('000 tonnes)														15.3
FUCOSTEF (US $ per tonne)														**8.6**
Total PV Cost at 5% (US $' 000)														123.3
Total Discounted Reduction at 3% ('000 tonnes)														11.9
FUCOSTEF (US $ per tonne)														**10.3**
Total PV Cost at 3% (US $' 000)														113.4
Total Discounted Reduction at 2% ('000 tonnes)														13.5
FUCOSTEF (US $ per tonne)														**8.4**

The issues that have not been included in the above are: (a) the question of hidden costs; (b) the sustainability contribution of this project; and (c) uncertainties arising from these estimates. With regard to the hidden costs, more work would need to be done to establish what such costs were. This would reduce the cost-effectiveness of the project but is unlikely to change the conclusion that on economic grounds the project is more viable than financial grounds. The sustainability of the project is increased as the dependence on non-sustainable energy is reduced by 1,472 GWh, or about 2.4 percent of total energy consumption now, and about 1 percent of total electricity consumption at the end of the project period. Finally, on the question of uncertainty, the values taken in the above analysis for fossil fuel benefits have been relatively conservative. Even more conservative values could be taken (the lower end of the ranges in Table 10). But this would not change the conclusion that the project has relatively low economic costs per tonne of CO_2 abated, at plausible discount rates. Hence it can be assumed that the uncertainty will not affect the judgement that the DSM project is a more desirable one than the financial analysis would suggest.

11 Conclusions

This report has analysed the broader implications of GHG limitation analysis and how they might be estimated and used in the appraisal of GHG projects. Clearly there are many social and economic issues that arise in projects that seek to reduce carbon emissions. The key ones relate to employment, income distribution / poverty, environmental impacts, social pricing issues, macroeconomic impacts and sustainability.

Employment benefits arise because the persons involved in GHG projects may not otherwise be employed. Section 7 provided a methodology for estimating the benefits of such employment and presents an illustration in the case of Egypt for the benefits of employment. They arise because the loss of output in moving an unemployed person to employment is less than the wage paid to that person, and because there are social costs to unemployment that are alleviated, principally health related. All these benefits can be quantified and included in a broader analysis of the effects of GHG limitation projects. Some guidance on the quantitative values to be attached to the benefits is offered.

Although this section has provided a method of estimating the health consequences of unemployment, it is by no means clear that such valuations will be accepted by policy-makers. The ‘transfer’ of method and values from the OECD countries may not be appropriate. Further research is needed to establish whether or not this is the case. Until such research has been carried out, analysts may prefer simply to report the health consequences qualitatively.

Income distribution impacts should be reported for all GHG related projects that have significant distributional effects. In addition, these impacts can be converted into money terms by weighting the transfers of costs and benefits to different groups by their income status. Section 8 provided a methodology for doing this and provides some estimates of weights for different inequality aversion parameters.

Environmental impacts of GHG related projects are discussed under the categories of changes in fossil fuel use on health, materials and agriculture; and changes in eco-systems and amenities. The former can be quantified in money terms whereas the latter generally cannot. Section 9 provided ranges of damage cost estimates per tonne of pollutant for SO_2, NO_x and particulates. This is done for different countries based on benefit transfers of damages estimates in the EU and the US. For other impacts a qualitative description is required. Some suggestions on how this might be framed are offered.

The adjustments to financial costs to obtain economic costs were discussed in Section 2. A clear understanding of the term economic cost and its role in the analysis is critical to the correct and consistent estimation of the costs of mitigation and adaptation to climate change. The main points to note are:

1. The key concept of cost in evaluating mitigation programmes is the *economic opportunity cost*. This may not be equal to the financial flows arising from the programmes.

2. To estimate the *economic opportunity cost* of a programme it is necessary to adjust the data received from market transactions. One set of adjustments is to add any *external costs or benefits* that arise.

3. A second set of adjustments is to correct for distortions in the market prices. Such distortions arise because of government taxes and subsidies, because markets do not always clear, or function with money transactions, and because of monopoly or other factors.

4. The full set of corrections described above can provide an estimate of the *social cost* of the programme.

5. Conventionally, the main corrections that arise are in relation to the value of capital, the exchange rate and taxes or subsidies. Methods for making such adjustments are discussed. In addition many projects fail to value changes in time, which often does not have a direct financial counterpart. This is particularly important in developing countries where the projects deal with rural energy. Again some guidance is offered on the valuation of time in this context.

6. Finally there is the issue of implementation, or hidden, costs. Many GHG related projects have such costs, arising from the inertia to change and the need for training and experience in order to implement the project. The estimation of such costs was discussed in Section 2.

Macroeconomic impacts were discussed in Section 3. These are impacts of GHG limitation policies on national output (GDP), employment, trade, and the sectoral/regional breakdown of output and employment, and are important considerations for some policies. In particular, they are important for market based policies that affect a large number of individuals or on wholesale changes in energy sources and land use. For these policies some such assessment is desirable. The problem is that the answers depend considerably on what assumptions one makes, and there is little guidance on what these assumptions should be. Consequently, it is important to provide a range of estimates of the macroeconomic impacts. The analysis should be carried out under the most realistic assumptions of what would be the situation without the policy (the baseline) and what would be the case with the policy. Exploiting the opportunities of GHG policies to affect other changes, such as changes in the tax structure, should not be built into the analysis unless there is clear evidence that these changes can in fact be implemented.

The sustainability issue was discussed in Section 4. A key indicator of sustainability is the impact the project or policy has for the share of total energy that will come from renewable sources at the beginning and at the end of the planning period. This applies to almost all interventions that are likely to be considered, and could, in fact, be reported for *all* interventions, even those that will not impact on the use of renewable resources.

For fossil fuel policies it is important to look at how long such policies will last. This is not mainly a physical consideration, but an economic one. At some time the fossil energy source may be so depleted that the costs of extraction will rise above those of the renewable source. That is the point at which the fossil fuel is effectively depleted. An idea of when this is likely to happen will provide useful information on the length of time for which the present project (and its successors) can last.

For projects that impact on the natural resource base directly, e.g. forestry and biomass production, an assessment of the impacts on key forms of natural capital, particularly biodiversity related, should be provided. This information will probably not be quantitative, but rather a qualitative description of what impacts are expected.

For biomass projects it is important to monitor how agricultural land use will affect yields in the medium to long term. Placing a reporting requirement on this will ensure that estimates are prepared. A range will typically need to be reported to allow for the uncertainty arising from the estimation procedures.

Finally, some projects involving transport will have impacts on urbanisation and on land available for agriculture. One sustainability concern is that the trends in land use are not sustainable; that as more and more land is taken into urban and suburban use, there is a loss of amenity and of biodiversity. A proxy for that is the change in the percentage of urban/suburban land. Polices in the transport sector that reduce energy use could reverse present trends and cause a fall in the areas of suburban land (or at least arrest the rate of growth of such land).

The above measures of sustainability are useful complements to the monetary measures of the costs of GHG limitation projects.

Section 5 looked at the criteria for selecting projects given all the above information. The financial cost information should be summarised in the form of a cost per tonne of GHG gas removed as a result of the project. There are quite precise rules to follow in developing such estimates and these were outlined in Section 5. At the same time, an economic cost measure should also be computed, including the monetary information on the broader impacts. Both these measures should be accompanied by information on the data that have only a physical quantification and data that have no quantification. Methods for analysing a mixture of quantified monetary and non-monetary data were discussed (multi-criteria methods).

Ultimately, the decisions on which projects to undertake is a political one. The screening rules discussed above are a guide to those decisions. These rules will not provide unique guidance on which policies or projects to choose. But they will provide a range of indicators on financial costs, full economic costs and on the other quantitative and qualitative impacts that are inputs to the decision-making process.

Finally, Section 10 offered some examples, based on actual projects, of how such techniques can be implemented and what the implications of their application are. The cases are, however, only loosely based on actual data, which have been added to, so that the value of the different techniques can be demonstrated. The first case looks at a biogas plant in Tanzania and is based on some data from a GEF Project Document (UNDP, 1994). The second is based on a forestry project proposed for the Russian Federation, and prepared by the Environmental Defense Fund (EDF, 1995). The third is a an energy efficiency project in Thailand, based on another GEF project document (World Bank, 1993). In each case the basic objectives of the projects were discussed and the conventional analysis presented alongside the broader analysis. Some comments on the implications of the broader analysis for project selection and project design were offered.

The cases show that the economic analysis is sometimes (but not always) substantially different from the financial analysis. Both are important sources of information for the decision-maker. In addition, however, there are other types of information, about key parameters, about sustainability and about socio-economic impacts that need to be included in the impacts ‘portfolio’. Projects rankings and design can be substantially affected by these wider considerations.

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