Measuring the Indirect costs and benefits of Greenhouse Gas Mitigation options: Methodology and a case study from Hungary.

Alistair Hunt, Pamela Mason and Anil Markandya

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Section 3 of this paper draws on work carried out by Gyula Zilahy and Ágnes Nemcsicsné Zsóka of the Department of Environmental Economics and Technology at Budapest University of Economic Sciences

Address for correspondence:
Alistair Hunt
Department of Economics and International Development
University of Bath
Bath, BA2 7AY, UK
Email: hspasph@bath.ac.uk

SUMMARY

This paper considers the problem of how a government, having decided to reduce greenhouse gas emissions, identifies the policy or mix of policies that achieves this reduction at the lowest possible net economic cost. This involves accounting for the fact that each potential policy for reducing GHGs has a different financial cost, and implies a different set of direct and indirect costs and benefits, each of which must be weighted according to the government's particular priorities.

This paper reports on work that extends the existing analysis of the costs and benefits implied by different mitigation policies to include employment and income distribution effects, reduced air pollution and the achievement of environmental and economic sustainability. We outline an approach for compiling these elements into selection criteria that will help policymakers identify the lowest-cost mitigation policies. We present an application of the methodology to a prospective energy-saving project in Hungary. We argue that this methodology, although by no means precise at this stage, provides a useful decision-making tool.

Keywords: Climate change, mitigation, net costs, non-monetary, health, employment, pollution, sustainability
JEL: H40, Q28,Q48.

NON-TECHNICAL SUMMARY

Most of the world's governments have recognised the importance of reducing greenhouse gas (GHG) emissions as part of a wider commitment to sustainable development. Various policies can be used to reduce GHG emissions. These policies are costly in financial terms, but produce benefits e.g. reduced pollution, reduced energy use and increased employment. Each policy implies a different set of costs and benefits, and each cost and benefit is weighted differently by different governments. The problem tackled in this paper is how policymakers, having decided to reduce emissions by a certain amount, identify the policy or mix of policies that achieves this reduction at the lowest possible net economic cost. This involves accounting not only for the direct financial costs of the policies, but also for their impacts on various other factors of interest for government policy.

This paper reports on work undertaken to extend the existing analysis of the costs and benefits implied by different mitigation policies. Factors included in this extension are impacts on employment and income distribution, reduced air pollution and the achievement of environmental and economic sustainability.

We outline an approach for assessing systematically the elements that comprise the net costs of emissions reduction. This involves compiling the direct and indirect benefits, using monetary and non-monetary indicators, into selection criteria that will help policymakers identify the lowest-cost mitigation policies. We consider the effect that a particular policy has upon each of the relevant factors in turn. Where possible, the effect is given a monetary value. Otherwise, it may be compiled as a quantitative non-monetary indicator, or a qualitative indicator. This allows policymakers to compare the financial costs of each climate change policy with the indirect economic effects.

We present an application of the methodology to a prospective energy-saving project in Hungary, namely, the large scale installation of better-insulated windows. This study demonstrates the potential, as well as highlighting the current limitations, of the methodology. We argue that this methodology, although by no means precise, provides a useful decision-making tool for policymakers. Given a commitment to reducing GHGs, it allows them to make the best possible use of public funds by taking full account of the full spectrum of indirect impacts, and particularly indirect benefits associated with policies to reduce emissions.

1: Introduction

Most of the world's governments have recognised the importance of reducing greenhouse gas (GHG) emissions as part of a wider commitment to sustainable development. This will be costly in financial terms, but will involve a range of indirect effects including, for example: reduced pollution, reduced energy use and increased employment. Emissions reduction targets may be achieved by a variety of policies, each of which implies a different set of costs and benefits. It is not, therefore, straightforward to identify the policy that achieves the target reduction at the lowest net economic cost, particularly given that certain costs and benefits are weighted differently by different governments. For instance, in less affluent countries GHG limitation does not have a high priority relative to other goals such as poverty alleviation and reductions in unemployment.

Much of the work on appraising different GHG reduction projects and programmes (e.g. Haites and Rose, 1996; IPCC, 1996 and UNEP, 1997) has focussed on the correct methodologies for estimating the costs of GHG limitation, and those for measuring the amount of GHGs reduced. The most preferred policies will reduce GHGs at the least (net economic) cost per ton of carbon (or carbon equivalent) eliminated. This paper reports on work undertaken to extend the existing analysis of the costs and benefits implied by different mitigation policies, to include other critical factors involved in policy selection. These include impacts on employment and income distribution, and the benefits of GHG limitation in other spheres such as reduced air pollution and positive impacts on broader concerns such as the achievement of environmental and economic sustainability.

Section 2 of the paper outlines a conceptual approach to assessing the elements identified above that make up net emissions reduction costs. We discuss also possible macroeconomic impacts, in terms of the effect of large-scale projects on GDP and its sectoral and regional composition. Climate change policies have obvious direct implications for environmental sustainability. However, they also have significant indirect impacts on the attainment of various other aspects of environmental and economic sustainability. We discuss the possibility of obtaining monetary estimates of these impacts. We describe a method for compiling these various indirect benefits, using monetary and non-monetary indicators, into selection criteria that will help to guide policymakers towards to programmes and policies that mitigate GHG at the lowest net economic cost. Section 3 presents evidence from a series of initial applications of this methodology in Hungary, and section 4 sets out the conclusions and areas of future work.

2: Methodology

There is a variety of policies that reduce GHG emissions, examples of which are; investment in energy efficiency, investment in renewable energy capacity and transport policies to reduce energy consumption. Whatever a government's emissions reduction target, it will wish to implement policies in order of increasing net economic cost. This study proposes a methodological development for identifying the most cost-effective policy, or policies, with which to achieve an emissions reduction target. This involves considering in turn each of the factors on which a policy impacts, directly and indirectly, and expressing them as far as possible in common units, both monetary and non-monetary. This allows us to derive an implicit increasing marginal cost curve for emissions reduction. We discuss each of the relevant factors in turn.

2.1 Employment

In neo-classical economic analysis, no social cost is normally associated with unemployment. The assumption is that the economy is effectively fully employed, and that any measured unemployment is the result of matching the changing demand for labour to a changing supply. We reject this assumption since these conditions are far from the reality in many of the countries in which GHG projects will be undertaken. Unemployment is a significant concern not only for the unemployed but for the population in general, and political pressure not to take measures that will further increase unemployment is very high. Under these circumstances it seems appropriate to treat the welfare gain of increased employment as a social gain.

These measured benefits of employment creation 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, and these have also to be considered as part of the social cost.

A physical measure of the number of jobs created would be 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 below. It is also possible to place a monetary value on the welfare gain from employment. 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 gain (a) minus (b) plus (c) by the period of employment created by the project. The following factors must be taken into consideration when calculating this figure:

<u>Net income gain</u>: The gain of income is the new wage, net of personal tax, less any 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 and varies between countries. There are some arguments in favour of using gross wages as the measure of income gain. However, here we assume that the social gain of increased employment can be measured by the aggregated net gain to the newly employed individuals.

Value of lost leisure: In gaining employment, an individual faces a loss of leisure, which has some value. The value of such non-working time depends on the elasticity of labour supply, with a higher elasticity indicating, other things being equal, a higher value of leisure. For economies in transition such elasticities are not available. However, from other industrialised 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). In transport-related literature, savings in travel time are valued at approximately 30-50 percent of the gross wage. However, for large scale enforced non-working this is almost certainly too high. This issue is being investigated, 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.

Health Related Impacts: It has long been known that people in employment tend to be healthier and have greater life expectancy than those who are unemployed, despite many jobs involving work-related hazards. There are two explanations for this phenomonon. The first is a selection bias effect since selection for employment, and its retention, depends on health. This generally better health of people in employment is known in occupational epidemiology as the "healthy worker effect" (HWE). However, recent studies have shown that such selection bias explains only part of the observed health differences , and that unemployment per se has health costs. Three such studies are from the United Kingdom: 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. They find that age-adjusted mortality is higher for unemployed men by an amount ranging from 21 percent to 95 per cent, and that the excess is not principally attributable to the selection bias of the “healthy worker effect”. There was a particularly high excess mortality from suicides and from "external" causes such as accidents, as opposed to "internal" causes such as disease or illness. 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 these studies 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[1]. These data are available only 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.

Valuing Health Effects Mortality impacts are often 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, (1995:ExternE report). 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 in 1990 prices ($3.1mn), which is broadly consistent with figures used for the US. Converting to 1995 prices gives a VOSL of ECU 3.14mn ($3.9mn). PACE (1992) used a VOSL for the US of

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[1] F.Hurley of the Institute of Occupational Medicine, Edinburgh (*pers. comm.*).

$4.0mn.

For non-OECD countries, this value may seem to be too high; 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). Calculating real GDP involves accounting for differences in purchasing power (PP) in converting GDP to dollar or ECU terms. This implicitly assumes a unitary "elasticity" of willingness to pay to reduce mortality risks. A different value for this elasticity is cited in Krupnick *et al* (1996). They refer to the work of Mitchell and Carson (1986), who argue that a case can be made for a value of 0.35 (meaning that a one percent increase/decrease in real income should result in a 0.35 percent increase/decrease in damages).

The practice of mortality risk valuation has been criticised on ethical grounds, being perceived as an attempt to attach a value to human life. In the context of global warming, a failure to implement climate change policies is likely to cause lives to be lost in the future. The (discounted) values of these lives would be included in a cost-benefit analysis as to whether or not to implement climate change policies (see Pearce (1995). However this is not an issue in the present analysis. Here we assume that a commitment to tackle global warming has been made, as part of a wider commitment to environmental sustainability. The health risk effects that we consider are on-going, and can be compared to other risks to which people are regularly exposed, some of which, e.g. transport risks, are mitigated by public spending. If a climate change policy implies a reduction in health risks, this is a social benefit, and if the most socially efficient policy is to be implemented, it must be included in the assessment of overall net cost. The fact that the public spending on the reduction of this type of risk is related to a country's GDP explains the decision, in this context, to adjust the VOSL for GDP.

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.

2.2 Income distribution

The distributional impacts of a policy are important for two reasons. The first is that reducing inequality is often a development goal in itself. The second is that 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 may fail. A matrix of the distribution of gains and losses is therefore required, classified in the categories that are believed to be important, both for a correct estimate of the true costs of the project and for a successful implementation of the project. We believe that the main research effort should be devoted to collecting information on the income groups and sections of the population that will be affected by the measures proposed.

Estimates of Income Distribution Weights

We have seen that including data on gainers and losers from the project provides a separate criterion by which project may be judged. Since the costs and benefits of different GHG programmes accrue to individuals from different income classes, it is also possible to incorporate distributional considerations into monetary measures of social costs by using weights. A weighting system can be applied to costs and benefits in order to convert changes in income into changes in welfare, assuming that an addition to the welfare of a lower income persons is worth more that of a richer person. For an example of a social welfare function that uses this type of weight, see Atkinson (1970).

2.3 Environment

Most, if not all, GHG limitation projects will have environmental impacts other than those related to climate change. It is suggested that all impacts be reported in physical terms and those that can be expressed in monetary terms be so valued. The method we have used to apply the values is given below. The impacts are divided into changes in air quality, changes in natural and semi-natural ecosystems, and changes in amenity.

Changes in Air Quality: Health

The main airborne pollutants known to damage health 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. In analysing the effects of pollutants on health it is very important to distinguish between *acute* effects, that is death on the same day as exposure or shortly afterwards, and *chronic* effects, where long term exposure to air pollution contributes to premature death. The acute effects of various pollutants include respiratory infections and asthma attacks. It is more difficult to establish relationships for chronic effects such as bronchitis or other longer term respiratory infections.

Changes in Air Quality:Crops

Atmospheric pollution affects agricultural outputs, both in terms of yield and quality. There are two basic pathways through which pollutants act on plants. 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, research has concluded that the impacts are quite small. Research in this area is still in its infancy and more comprehensive analyses are required.

Changes in Air Quality: Forests

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 relevant area. 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 reason to believe that pollution damage to forests could be quite significant.

Estimates of Damages from Industrialised Countries

Recent research on the values of emissions damages in industrialised countries includes the ExternE project (1997), CSERGE (1993), Thayer *et al* (1994) and Rowe *et al* (1992)[2]. All of the calculated damages in these studies have very wide ranges. Estimates of damage from NO_x emissions 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

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[2] IPCC (1996) 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 used.

next 1 - 2 years.

Additional estimates have been made, and are being made, for pollution damages in developing countries (see Krupnick *et al* (1996) and Florig (1993)). However 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 relation to the valuation of the health benefits of employment, using a range of values for the elasticity of the marginal utility of reduced pollution.

We propose, using the results from these studies, that SO_2 damages in the EU be valued in the range of US $9,390 to US $12,350 per tonne emitted, that NO_x damages be valued in the range of US $ 4,860 to US $18,070 per tonne, and that particulate damage be valued in the range US $15,530 to US $59,420 per tonne. Values calculated in this way 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[3].

Other Environmental Damages
Other environmental impacts that need to be considered are natural and semi-natural eco-systems and water. 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.

2.4. Macro-economic impacts

Certain categories of GHG limitation projects will have macroeconomic impacts, particularly those involving 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 factor most commonly considered is the change in the level of GDP. This is useful, but is perhaps not the most important macroeconomic impact. Other important effects of GHG policies are on employment, the trade balance and 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. GDP is not, in fact, the correct measure of welfare, primarily because of the presence of non-market benefits and costs. Likewise, changes in income distribution, poverty, etc. affect welfare but are not picked up in the crude macroeconomic measures of GDP change. All these factors imply that macroeconomic analysis can provide only a partial picture of the impacts of climate change measures.

There are many approaches to modelling the macroeconomic impacts of GHG mitigation, with key differences being assumptions about how the economy operates and how efficiently markets, and particularly the labour market, clear.[4] In particular, since GHG models have long horizons (often more than 20 years), assumed rates of technological change are crucial. Results can vary widely across models, as demonstrated by the IPCC (1996).

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[3] 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).

[4] 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.

2.5 Sustainability

Climate change relates to the broader concern of sustainable development since it is an important, although partial, aspect of aggregate global sustainability. It is clear that a condition of sustainable development is avoiding the potentially catastrophic effects of climate change. However, even assuming that sufficient action is taken to mitigate the effects of climate change, there is still an issue for sustainable development in that the choice of policy will impact on other areas of sustainability. We can think of an aggregate sustainability policy as maintaining various economic, environmental and social indicators such as Climate change, Employment, Income, Energy availability, Pollution, Biodiversity, and Land availability. Maintaining each of these indicators implies a certain monetary cost and while some objectives are complementary, others conflict.

GHG mitigation policies have can affect several other factors relating to the overall problem of sustainability. The most important are likely to be the impacts on energy use and on emissions of pollutants other than GHG. For instance, if a policy of increased energy efficiency reduces the amount of energy consumed, this relaxes the energy sustainability constraint by increasing the number of years that non-renewable energy resources will last. It could also increase the proportion of energy use that comes from renewable sources, as would a programme of investment in increased renewable energy capacity.

Many transport-related policies will have impacts on urbanisation and on land available for agriculture and for conservation of natural habitats. Trends in land use are a sustainability issue, a concern being that as more land is absorbed into urban and suburban use there is a loss of natural habitat and thus amenity and biodiversity, and also a loss of agricultural land. Therefore a policy's contribution towards attaining sustainability of land-use could be measured by its expected effect on the percentage of urban/suburban land.

How might the sustainability implications of various policies be measured? First, they may be considered as useful complements to the monetary measures of the net costs of GHG limitation projects. However, it is also possible, in theory, to obtain monetary measures of a policy's contribution to sustainability. We noted above that attaining each of the broad sustainability indicators implies a certain monetary cost. For instance, given expected technical progress and resource discoveries, energy sustainability may require a certain reduction in energy consumption, and investment of a certain sum in renewable substitutes. From this one can calculate the cost of a country's energy sustainability. Therefore the contribution of a climate change policy to sustainability in general may be estimated as the net reduction in cost of attaining all other aspects of aggregate sustainability. The figures required to estimate the financial costs of achieving aggregate economic, environmental and social sustainability are not currently available, because research into the implications of macroeconomic sustainability is in its early stages[5].

2.6 Selection Criteria

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[5] An example of such research is the SAUNER project, which studies sustainable development and the use of non-renewable energy resources on a regional and global scale. SAUNER is funded by DGXII involving partners from the University of Bath, the IER at the University of Stuttgart, and the University of Leoben.

Sections 2.1 to 2.5 have described the procedures with which information on the various impacts of a GHG limitation project or programme may be collected. The rationale behind this is that the information may be presented in such a way as to give policymakers a tool with which to decide between different GHG mitigation projects. 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. In preparing summary indicators it is therefore important not to count the same information twice.

Quantitative Monetary Data on the Project

The Cost Effectiveness Criterion

For programmes that estimate the cost of achieving a certain reduction in GHGs from a baseline level, 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 criterion for project *P* is FUCOSTEF_p where:

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

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). This distinguishes it from FICOSTEF, which represents the direct **financial costs** (hence FI) of the project and which will be discussed below. The term *r* is the rate of discount for costs and *d* is the rate of discount for emissions.

The values of FUCOSTEF_p will depend on the precise value attached to the different components of costs, which as noted are uncertain, with ranges of possible values. It is therefore important to present a range of such values and to indicate the impacts from which the uncertainty arises.

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[6]) 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

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[6] 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%.

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. There is sensitivity; at high rates energy projects with long gestation periods become unattractive compared to those with a shorter period. We therefore adopt 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 question of the choice of the appropriate rate, however, remains unresolved and, again, taking a range of plausible values is the only solution. It is therefore suggested 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.

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, namely (a) to (c), is converted into monetary units. 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 (e) 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 Keeney and Raiffa (1993) and Meier and Munasinghe (1994). A guide to the weighting of different indicators is critical to decisions about the rankings of different projects, and would also be useful in assisting 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.

Qualitative Information

Qualitative information on impacts is important. 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.

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. These rules will not provide unique guidance on which policies or projects to choose. However, 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.

3: Application of Methodology – A Case study in Hungary

We apply the methodology described above to one mitigation option – widow replacement for improved insulation – that has been considered in the Hungarian context. The installation of better insulated windows is a good example of a climate change mitigation option to study since it is a simple measure that can have significant effects on domestic heating in the residential sector. It is an example of an energy conservation programme that may be implemented through an environmental awareness raising policy, possibly coupled with a grant/subsidy regime.

In our case study, an implementation rate of 25% of the total technically feasible replacements, (equivalent to 806,700 installations), is assumed over a ten year span of implementation. This would result in the installation of 80,670 windows/year. Interviews in the construction sector showed that the number of windows and doors manufactured annually in Hungary is approximately one million. An 8% increase in installation appears to be a reasonable assumption, although it is likely that it could be achieved only with the help of government intervention. We assume that the life-span of the new installations is 30 years.

The first phase of the research simply took implementation and operational costs into account and calculated the benefits of energy savings. It identified the marginal abatement costs (MAC) as the costs of installing the new equipment. Calculations were carried out at 3% and 5% discount rates, taking both the present energy structure (Baseline production mix) and a possible future energy structure (Simulation production mix) into account. Results for the window replacement project can be seen in Table 1.

Table 1 Marginal cost of project (\$/t CO_2 equivalent (GWP))

	Discount rate	
	3%	5%
Baseline production mix	10.1	27.7
Simulation production mix	11.5	31.6

We now outline and summaries the application of the additional components of the analysis.

3.1 Assessment of employment effects

Two elements within the net benefits of employment can be isolated. First, new jobs are created in the construction industry - a considerable number of which are likely, in this instance, to be filled by formerly unemployed individuals. Second, a fall in the employment levels of the energy sector may be expected to occur as a result of energy savings and a consequent lower level of production required. However, the fall in energy production, about 1.3% of Hungary's total production, is considered to be marginal to the employment structure of the industry. Therefore, no quantitative analysis of this effect was undertaken.

Creation of new jobs
Interviews undertaken by the researchers with key industry personnel showed that approximately 750 new jobs in the construction industry would be created for the ten years of the project. This demand for labour is likely to be met by providing employment for 600 unemployed; the remaining 150 jobs will be undertaken by those already employed. An 80% take-up from the unemployed is thought to be a reasonable assumption given the relatively high level of unemployment in Hungary.

The social benefits of the 600 newly employed are calculated using an average monthly gross wage in the construction industry of US$ 261/month, an average unemployment benefit of US$ 85.96/month and a 15% value of leisure time, (compared to the wage rate). Results of the calculations are shown in Table 2.The calculation of health costs avoided, as a result of individuals becoming employed, are also included in Table 2.

Table 2. Employment effects: Total net benefits/annum

Year	Net benefits, VSL e=1 US$ million	Net benefits, VSL e=1 US$ million
1998	0.0	0.0
1999	5.65	13.19
2000	6.16	13.71
2001	6.16	13.71
2002	6.16	13.71
2003	6.16	13.71
2004	6.16	13.71
2005	6.16	13.71
2006	6.16	13.71
2007	6.16	13.71
2008	6.16	13.71

3.2 Income distribution and poverty

Because the installation of new windows is relatively expensive for a Hungarian household, it is sensible to assume that only households with an average or high income will be able to afford the replacement of old windows, even given government intervention. Unfortunately lower income families would benefit most, in relative terms, from the savings in energy consumption and therefore costs. Households living in large towns and cities tend to be better off than rural households implying, other things being equal, that net benefits are likely to be concentrated in urban areas. There is also likely to be a positive distributional effect from the increase in income of those formerly unemployed, although these are not likely to be significant.

It has proved very difficult, due to insufficient information, to perform a quantitative analysis of these income distribution consequences. We therefore concluded that any analysis would produce only uncertain and, in all likelihood, negligible results.

3.3 Assessment of environmental impacts

The replacement of old windows by new, better insulated ones has indirect environmental effects. These include the emission savings of different air pollutants as a result of lower energy demand and production, and any saving of renewable and non-renewable energy resources. A maximum annual saving in energy production of 7632 TJ is made from this project. In the case of the implementation of better insulated windows environmental effects include the mitigation of SO_2, NO_x, particulate matter, CO, metals etc. The study quantifies the effects of SO_2, NO_x and particulate matter. Other environmental benefits have been analysed qualitatively.

Total emission savings can be quantified from information on the total energy saved, the share of different energy sources saved in the household sector, the fuel mix used by each source and the pollutant emission factors associated with each fuel. In the case of estimates where only a data range was available, (as in the cases of SO_2 and NO_X), average values were used in the calculations. The average emission values of the Hungarian power generation sector have been used to calculate the emission values of electricity generation. We assumed that the reduction in power generation, (energy saved), would occur at older power stations which burn fossil fuels. Thus nuclear and hydroelectric power plants have been omitted from the calculation of mean values.

The emissions resulting from the production process and the emission/TJ values are shown in Table 3.

Table 3. Emissions of the Hungarian energy sector in 1995

Pollutant	Total, kt	T/TJ
CO	18.3	45.69
SO_2	435.7	1088.01
NO_x	40.9	102.13
Particulates	19.7	49.19

3.4 Macroeconomic impacts

The installation of 80,000 new windows to replace old ones is not thought to have a significant influence on the principal macro-economic indicators. The investment cost of 16 billion HUF/per year is 2.7% of the total output of the construction industry. The additional 600 new employees needed to carry out the project equates to a 0.23% increase in the number of employees in the construction sector, or 0.01% of total employment in the country. Such a small rate indicates that no significant macroeconomic impacts exist and moreover negative employment effects in the energy sector may cancel this small positive impact.

3.5 Effects on sustainability

The change in the structure of energy use as a result of the project has implications for sustainability. The implementation of the project directly affects the use of renewable and exhaustible resources since energy resources that would have been used for domestic heating are saved. Only 0.2% of total energy was produced by hydroelectric power plants and only 1.2% of total production by the burning of fuel wood in households. It is estimated that 814 thousand tons of fuel wood are used for household heating . This accounts for 70% of total fuel wood consumption. The share of renewable resources as a proportion of total energy production will grow as a result of the project. This change, however, is expected to be negligible.

3.6 Full economic costs of the mitigation option.

The first phase of the research on the costs and benefits resulting from the installation of new, better insulated windows in the household sector includes an analysis of the costs of installation and administration and energy savings only. The second phase of the research undertakes a much broader analysis of costs and benefits. Employment and environmental benefits were judged to be the most important and a quantitative analysis was undertaken on these. Other indirect costs have been analysed qualitatively. The quantitative results have therefore been used to calculate the financial costs and full economic costs of the project.

A) Calculation of FICOSTEF values

Net costs of the mitigation option include investment costs, administration costs and cost savings resulting from energy savings. The following table shows the appropriate FICOSTEF values for the project expressed in terms of dollars per ton of Global Warming Potential (GWP) reduced. These are calculated using 3% and 5% discount rates for both the net costs and resulting GWP savings of the project.

Table 4 FICOSTEF values obtained

	FICOSTEF $/t of GWP	
GWP	Costs	
	3%	5%
3%	5.87	14.68
5%	8.15	20.41

B) Calculation of FUCOSTEF values

On the basis of the FICOSTEF values and the values gained from the analysis of employment and environmental effects, it was possible to calculate the net economic cost of the mitigation option.

Table 5 summarises the results of calculations, where e refers to the income elasticity assumed and low and high refer to low and high estimates of environmental damage, as per section 2.3.

Table 5 Comparison of FICOSTEF and FUCOSTEF values, USD/t of GWP

Discount rate	FICOSTEF	FUCOSTEF			
		e=1, low	e=1, high	e=0,35, low	e=0,35, high
Cost: 3%, GWP: 3%	5.87	-10.77	-19.72	-28.67	-52.37
Cost: 3%, GWP: 5%	8.15	-14.97	-27.41	-39.85	-72.79
Cost: 5%, GWP: 3%	14.68	1.90	-4.54	-11.99	-29.04
Cost: 5%, GWP: 5%	20.41	2.64	-6.31	-16.66	-40.36

It can be seen from the results that taking quantifiable indirect costs into account this mitigation option can turn into a "no-regret" option, in that implementing a project may prove to have a net economic benefit.

The choice of discount rate, income elasticity and the estimate of the environmental effects all have a significant effect on resulting values. By choosing a higher discount rate the net costs increase markedly since benefits usually occur later in time while costs are borne in the first ten years. At the same time a higher discount rate for GWP savings increases the FUCOSTEF value.

4: Conclusions and areas for future work.

The problem of mitigating climate change and reducing greenhouse gas emissions is complex. The science of global warming is inexact, and it is unclear to what extent reducing GHG emissions will be reflected in reduced climate change in the future. However, the problem tackled in this paper is a distinct one. This is the problem of how policymakers, having decided to reduce emissions by a certain amount, identify the policy, or mix of policies, that achieves this reduction at the lowest net economic costs. This involves accounting not only for the direct financial costs of the policies, but also for their impacts on various other factors of interest for government policy. These include the employment that projects create, their impact on income distribution, their effect on the environment over and above climate change and their macroeconomic impacts in terms of changes in the level of GDP and its sectoral and regional composition.

We have presented a methodology with which the indirect impacts of climate change policies may be considered in a systematic fashion. This involves considering the effect that a particular policy has upon each of the relevant factors in turn. Where possible the effect may be given a monetary value. Otherwise, it may be compiled as a quantitative non-monetary indicator, or a qualitative indicator. This allows policymakers to compare the financial costs of each climate change policy with the other economic effects. Other indirect costs and benefits must be measured in quantitative non-financial and qualitative terms, leaving a significant political factor in the final decision.

We argue that this methodology, although by no means precise, provides a useful decision-making tool for policymakers. Given a commitment to reducing GHGs, it allows them to make the best possible use of public funds by taking account of the full spectrum of indirect impacts, and particularly indirect benefits associated with policies to reduce emissions. The monetary measurement of as many as possible of these indirect benefits maximises the objectivity of the information. The provision of additional quantitative and qualitative information allows decision-makers to discriminate further according to their own priorities. One of the most controversial aspects of the methodology is the valuation of the risk to human life associated with unemployment. However we have argued that the types of risk considered here are comparable to the types of risk that governments spend money to reduce. A reduction in such a risk therefore implies a social benefit which, if policy decisions are to be socially efficient, must be included in the measurement of the net economic cost of each potential project.

Another important consideration is the contribution that climate change policies make towards the attainment of sustainable development in general. Mitigation of climate change is an essential aspect of global environmental sustainability, but has many positive implications for other areas of sustainability, in particular energy use and pollution. It is not currently possible to measure financially the effects of various climate change policies on the costs of attaining environmental and economic sustainability in general. Therefore these considerations are limited for the moment to the quantitative non-monetary selection criteria. However, we have argued that this methodological gap offers an opportunity to expand the nascent discipline of environmental macroeconomics, in exploring the possibility of analysing sustainable development in a general equilibrium framework.

We have presented an application of the methodology to a prospective energy-saving project in Hungary, namely, the large scale installation of better-insulated windows. This study has shown the potential, as well as the current limitations of the methodology. We estimated the value of the estimated employment created, in terms of gains in income as well as health effects. The environmental effects that have been quantified suggest that the reduction of pollution, and associated health benefits, would be significant. However, the proposed project is on too small a scale to generate distributional impacts, macroeconomic effects or sustainability effects.

Research to estimate the values of reducing the types of long term and latent mortality risk associated with air pollution would allow more reliable estimates of the indirect environmental benefits of climate change policy. Likewise, studies are needed to measure the value attached to risk reduction in developing countries, and economies in transition. General equilibrium studies of environmental sustainability would allow measures of the value of the indirect contribution to sustainability of climate change policies. Scientific research is required to measure the effects of air pollution on crops and on forest growth. Therefore, while this methodology is, we feel, both useful and promising, it requires further scientific and economic research.

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