Economics of Greenhouse Gas Limitations

HANDBOOK REPORTS

The indirect costs and benefits of greenhouse gas limitations: Hungary Case Study

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Published by: UNEP Collaborating Centre on Energy and Environment,
Risø National Laboratory, Denmark, 2000.

ISBN: 87-550-2690-7

Available on request from:

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Cover photo: Miklos Szabo / Billedhuset 2maj

Information Service Department, Risø, 2000

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List of Acronyms

CO2	carbon dioxide
CO	carbon monoxide
EGI	Energiiagazdalkodasi Intezet (Energy Management Institute, Hungary)
FICOSTEF	financial cost-effectiveness of a GHG limitation project
FUCOSTEF	(full) economic cost-effectiveness of a GHG limitation project
GDP	gross domestic product
GHG	greenhouse gases
GWP	Global Warming Potential
HUF	Hungarian Forint (216.50 per $US as of end 1998)
ISEW	index of sustainable economic welfare
kt	kilotonne
MAC	Marginal Abatement Cost
NO	nitrogen oxide
NOx	nitrogen oxides
NPV	net present value
SO2	sulphur dioxide
TJ	terajoule (1012 joules)
USD	US dollars
VSL	value of a statistical life
VOSL	value of a statistical life

Conversion Factors

The following prefixes are used from multiples of joules, watts and watt hours:

kilo (k)	10^3
mega (M)	10^6
giga (G)	10^9
tera (T)	10^{12}

The following table gives the factors used to convert between alternative units of energy:

to: / *from:*	**k TOE**	**TJ**	**GWh**	**M therms**
	multiply by:			
k TOE	1	41.87	11.63	0.3968
TJ	0.02388	1	0.2778	0.009478
GWh	0.08598	3.6	1	0.03412
M therms	2.52	105.5	29.31	1

The following factors were used to convert between alternative units of volume:

1 litre	= 0.22 imperial gallon (UK gal)
1 UK gal	= 1.201 US gallons (US gal)
1 barrel	= 159.0 litres

1 Introduction

1.1 Background to the Case Studies

There has been a considerable amount of work carried out on the appraisal of different projects and programmes that reduce greenhouse gases (GHGs)[1]. These studies have focused on the development of appropriate methodologies for estimating of the costs of GHG limitation, and measuring the amount of GHGs abated. These are two of the central issues that need to be considered prior to finalising a policy for GHG mitigation, and ideally one would pursue those policy measures that effectively reduce GHGs at least cost.

Although the cost (when correctly measured) should have a strong bearing on which policies to select, it is not the only consideration. Other factors will influence the decision, such as the impacts of the policies on different social groups in society, particularly on vulnerable groups, the benefits of the GHG limitation in other spheres (e.g. reduced air pollution), and the impacts of the policies on broader concerns such as sustainability. In developing countries these other factors are likely to be 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 therefore change the detailed design of a policy or programme, rather than being the main issue that determines the policy.

In recognition of the importance of these broader social and environmental issues in developing countries, a methodology has been developed which provides a framework for the assessment of the wider impacts arising from GHG limitation projects, and advice on how to incorporate them into the decision-making framework[2]. The purpose of this report is to apply the methodology to a set of selected GHG limitation projects currently being considered for implementation in Hungary.

1.1.1 GHG Mitigation Measures

In total, four GHG limitation projects were selected for application of the methodology. This second phase of the research in Hungary, co-ordinated by the Department of Environmental Economics and Law of the Technical University of Budapest, concentrated on four mitigation options in the household sector:

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[1] For example: UNEP (1998), "Mitigation and Adaptation Cost Assessment: Concepts, Methods and Appropriate Use", UNEP Collaborating Centre on Energy and the Environment, Risoe National Laboratory, Roskilde, DK.

Haites, E. and Rose, A. (1996), "Energy and Greenhouse Gas Mitigation: the IPCC Report and Beyond"(eds.), **Energy Policy** Special Issue, **24**, 10/11.

IPCC (1996), **Climate Change 1995. Economic and Social Dimensions of Climate Change: Scientific-Technical Analysis**, Contribution of Working Group III to the Second Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge: Cambridge University Press.

Halsnæs, k., Callaway, J.M. and Meyer, H. (1998**), Economics of Greenhouse Gas Limitation Guidelines. Methodological Guidelines**. UNEP Collaborating Centre on Energy and Environment, Risø National Laboratory, Denmark.

[2] Markandya, A. (1998), **The Indirect Costs and Benefits of Greenhouse Gas Limitation**, A report prepared for the UNEP Collaborating Centre on Energy and Environment, RISOE National Laboratory, Roskilde, DK. Henceforth called the *guidelines*.

Specifically, the selected GHG limitation projects involve[3]:

1. the installation of new, better insulated windows (Project 1);

2. the installation of water saving devices on water taps (Project 2);

3. the installation of active solar cells to prepare domestic hot water (Project 3); and

4. the replacement of traditional light bulbs by compact fluorescent bulbs (Project 4)[4].

1.1.2 Selection Criterion

The full methodology adopted in this country case study is presented in Markandya, (1998). Following application of the methodology, the information generated needs to be summarised so that different mitigation projects can be compared. This typically involves constructing a measure of the cost-effectiveness of each project. The cost-effectiveness of each project is obviously a function of its cost and environmental performance; it is also influenced by the choice of discount rate and the base case definition. The treatment of these latter two "influences" in this case study is outlined below. First however, the cost-effectiveness criteria are reviewed.

1.1.3 Cost-effectiveness Criteria

The decision as to whether to implement a mitigation measure will depend, for the most part, on its cost-effectiveness in abating GHGs. The cost-effectiveness criterion used in this study defined by the net present value cost per ton of GHG (CO_2 equivalent) 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 cost-effectiveness criteria for mitigation measure *P* is FUCOSTEF_p where:

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

The cost C_i is the net incremental cost of the mitigation measure, i.e. the incremental direct costs in time period *i* net of any associated incremental benefits. The term E_i is the carbon-weighted (CO_2 equivalent) 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 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. The term *r* is the rate of discount for costs and *d* is the rate of discount for emissions.

Both measures of cost-effectiveness (i.e. FU / FICOSTEF) have been estimated for each of the selected GHG mitigation measures.

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[3] The study originally intended to consider forestry sector reform as one project. Due to a change in the team composition, however, it has not been possible to assess this option.

[4] The analysis of the first three of these projects has been carried out by the Department of Environmental Economics and Technology at the Budapest University of Economic Sciences, Hungary. The fourth project, on replacement of traditional light bulbs by compact fluorescent bulbs has been carried out by the Department of Environmental Sciences and Policy, Central European University in collaboration with the Department of Information Management, Budapest University of Economic Sciences

1.1.4 Choice of Discount Rate

The guidelines recommend that a central discount rate of 3 per cent is used to determine the present value of the net incremental cost stream. In the first phase of the research a rate of 5 per cent was used. Hence, for comparative purposes, both 3 and 5 percent rates have been applied to the calculation of FICOSTEF and FUCOSTEF. The same rates of discount are used to determine the present value of the emission savings stream.

1.1.5 Definition of the Base Case

In this study, the marginal cost curves for the set of GHG limitation projects are constructed by projecting an “incremental mitigation” scenario where all cost and environmental performance data is already reported as the difference between those realised under the baseline and those realised when the limitation project is in place.

The base year for all cost data was 1995. The base year selected for computing the FU/FICOSTEF of each measure was 1997. The time horizon for the analysis is specific to each GHG limitation project, and depends on its estimated useful operating life. All cost data were assumed to remain constant in real terms over the selected time horizon. The same assumption was made regarding the environmental performance of each measure. Both these assumptions are somewhat unrealistic.

1.1.6 Special Features of the Hungarian Situation

A series of GHG mitigation options for Hungary have been identified and analysed from an economic perspective in an earlier UNEP/RISØ study[5]. That study was carried out as part of an inter-country program aimed at the comparison of different mitigation options across countries. The research focused primarily on the **direct** costs and benefits of GHG mitigation options including savings in CO_2 emissions, and in energy use and the direct costs of implementation.

The objective of the Hungarian direct cost study was to analyse possible greenhouse gas mitigation options in Hungary from an economic perspective. The study included the financial costs of implementing a range of mitigation options i.e. investment and administrative costs and energy savings. Table 1 lists the projects that were considered in this study.

The study incorporated a range of assumptions regarding, for example, future energy production mixes, time scale considered and discount rates adopted and these are discussed in detail in the full report. From this analysis it was possible to construct cost curves of the GHG mitigation options in Hungary. Figure 1 below shows the marginal and average cost curves, adopting a 3% discount rate. The study showed, through sensitivity analysis, that varying discount rates had little impact on the ranking of the projects.

Several of the examined options turned out to be no-regret options on this basis. It was therefore felt to be important to undertake a more detailed analysis of indirect costs in order to differentiate between these options and investigate instances where, for example, projects with a net direct cost may turn into no-regret options once indirect costs/benefits are included in the analysis. This second phase of the analysis, then, has as its’ focus the quantification of all impacts not covered in the initial exercise.

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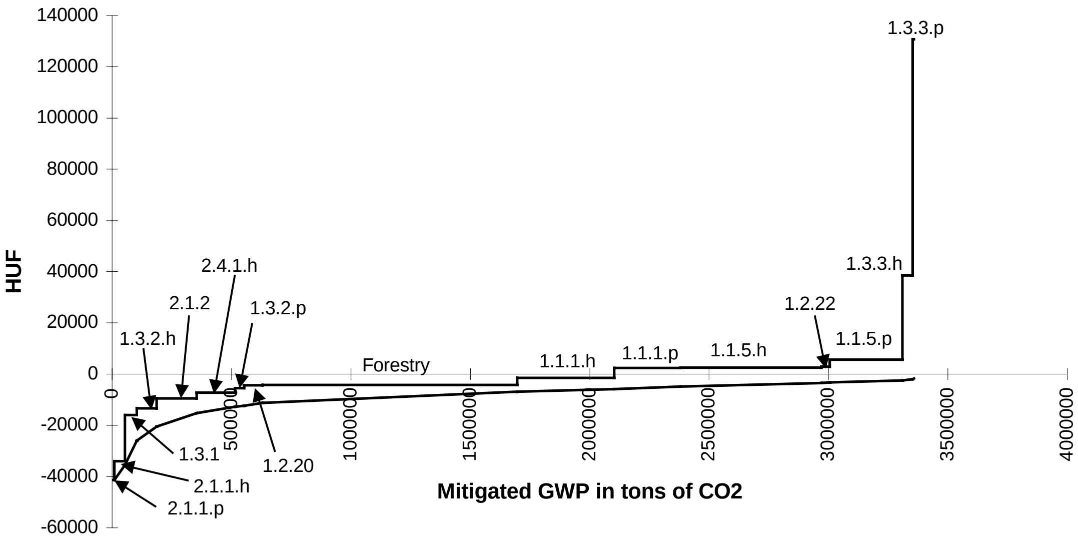
[5] G. Zilahy and M. Costura: Greenhouse Gas Abatement Scenarios for Hungary, UNEP 1997

Table 1 Mitigation options included in direct cost study

1	2.1.1.p	Installation of Compact Fluorescent Lamp (CFLs) in public buildings
2	2.1.1.h	Installation of CFLs in households
3	1.3.1	Individual metering of hot water consumption
4	1.3.2.h	Efficient faucets and shower-heads in the residential sector
5	2.1.2	Technology change in lighting (replacement of luminaries and controls)
6	2.4.1.h	Replacement of common ventilation (in multi-storey buildings) by individual ventilation
7	1.3.2.p	Efficient faucets and shower-heads in the public sector
8	1.2.20	Programmable thermostats
9	Forestry:	Short rotation coppice wood-for-energy plantations
10	1.1.1.h	Post-insulation of roofs, walls, and basement of existing buildings, residential sector
11	1.1.1.p	Post-insulation of roofs, walls, and basement of existing buildings, public sector
12	1.1.5.h	Replacement of windows of existing buildings by efficient ones (low emissivity glazing, tight frames), residential sector
13	1.2.22	Upgrading existing combustion equipment by adjustment and better maintenance
14	1.1.5.p	Replacement of windows of existing buildings by efficient ones (low emissivity glazing, tight frames), public sector
15	1.3.3.h	Active solar Domestic Hot Water (DHW) system, residential sector
16	1.3.3.p	Active solar DHW system, public sector

Figure 1 Marginal and Average Cost Curve of Mitigation Options, Year 2010, Modified Energy Structure, r=3%



1.2 Structure of Report

The remainder of the report is structured as follows: Sections 2 – 5 explore four mitigation options further by adding in indirect costs / benefit into the existing direct cost / benefit analysis. Thus, Section 2 outlines the results from the analysis of the window insulation program. Section 3 reports on the installation of the low-flow faucets and shower-heads. Section 4 gives the results for the installation of the active solar water heating systems. Section 5 presents the results for the replacement of traditional light bulbs by compact fluorescent bulbs. Finally, Section 6 provides some conclusions on the analysis, its limitations and policy recommendations.

2 Mitigation Option 1: The Installation of New, Better-Insulated Windows

2.1 General Description of The Mitigation Option

2.1.1 Background

The installation of better-insulated windows is important in terms of climate change mitigation 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 coupled possibly with a grant/subsidy regime.

2.1.2 Project Implementation

The number of installations and the reduction in heating as a result of the project is shown in Appendix 1. 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 therefore result in the installation of 80,670 windows/year. Interviews in the construction sector showed that the number of windows and doors manufactured yearly in Hungary is approximately one million. This suggests that an 8% increase is a reasonable assumption. It has also been assumed that the life-span of the new installations is 30 years. The results in terms of energy saving for the next 40 years are therefore shown in Appendix 1.

The first phase of the research simply took implementation and operational costs into account and calculated the benefits of energy savings. It therefore identified the marginal abatement costs of the project in these terms. 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 are presented in Table 2. The direct costs were positive with both production mixes.

Table 2 Marginal cost of project (US$/t CO_2 equivalent (GWP))

	Discount rate	
	3%	5%
Baseline production mix	10.06	27.72
Simulation production mix	11.47	31.63

2.2 Indirect Effects

2.2.1 Assessment of Employment Effects

Net benefits of employment consist of two parts. 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.

Creation of new jobs

According to interviews with key industry personnel, an average 750 new jobs in the construction industry will be created for the ten years of the project. This is thought likely to be met by providing employment for 600 unemployed; the remaining 150 jobs will be undertaken by already employed persons. Such a high rate of 80% take-up from those unemployed is thought to be a reasonable assumption because unemployment in Hungary is relatively high compared to European countries.

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). Unemployment benefit is available to a claimant for 12 months. It should be noted that the complex income tax regime that operates in Hungary made it difficult to make a precise adjustment from gross wage rates to net wage rates in this context. Nevertheless, it is estimated that a 22.5% rate is a good approximation to the effective tax rate facing individuals and this could be used in the calculations below if net wage rates were to be adopted.

There are also likely to be health costs avoided as a result of individuals becoming employed. Calculations of health benefits, here the reduction in premature mortality, are based on the Value of Statistical Life, (VSL) provided by Halsnæs et. al (1997)[6] for Hungary taking income elasticity values of 0.35 and 1.00 into account. Results of the calculations are shown in Table 3 and the supporting calculations are given in Appendix 2. It can be seen that these health effects dominate employment effects.

The supporting calculations take an identical form in each of the mitigation options considered and so are presented once here. The results, however, are presented in each option case study.

Loss of jobs

A maximum annual saving in energy production of 7632 TJ is made as a result of this project. This equates to about 1.3% of Hungarian energy production. This size of fall in energy production is considered to be marginal to the employment structure of the industry and therefore no quantitative analysis of this effect has been undertaken for this effect.

Table 3 Net total employment benefits per year

Year	Net benefits, VSL e = 1 (US$ million)	Net benefits, VSL e = 0.35 (US$ million)
1998	0.0	0.0
1999	5.645	13.192
2000	6.160	13.707
2001	6.160	13.707
2002	6.160	13.707
2003	6.160	13.707
2004	6.160	13.707
2005	6.160	13.707
2006	6.160	13.707
2007	6.160	13.707
2008	6.160	13.707

[6] Halsnæs, K., Callaway, J.M. and Meyer, H. (1998), **Economics of Greenhouse Gas Limitation Guidelines. Methodological Guidelines.** UNEP Collaborating Centre on Energy and Environment, Risø National Laboratory, Denmark.

2.2.2 Income Distribution and Poverty

It is recognised that the effects of the mitigation project on income distribution and poverty might affect the overall judgement of the decision makers in their decision about whether to implement a mitigation strategy or not. However, in the case of new, better insulated windows, and generally in the case of demand side management programs these effects are thought to be of minor importance.

Income distribution

The installation of new windows is a relatively expensive investment for a household. People usually replace windows and doors only when a general renovation of the building or apartment is under way. It is estimated that installing new windows could increase renovation costs by as much as 20% -30%. Although this investment is significant no one household or other interest group is in the position of blocking the project, because participation would be voluntary.

Because of the relatively high investment cost it is sensible to assume that only households with an average or high income will be able to afford the replacement of old windows in spite of any possible government intervention. The poorest 50% of families can not afford such an expenditure. Clearly, these are the families that would benefit most, in relative terms, from the savings in energy consumption and therefore savings in costs. At the same time the state budget is not able to finance total project costs and only a 20-30% subsidy can realistically be envisaged.

For families with lower incomes other options such as the insulation of existing doors and windows may be feasible. Such an option requires about 5-10% of the window replacement project expenditure and could also be carried out with the help of a government subsidy. In this case some marketing devices concentrating on the energy savings of such an investment could also be effective.

Geographical distribution

Differences between households living in towns and in the countryside can not easily be made apart from in terms of income distribution by geographical location. The general observation is that households living in large towns and cities are usually better off than households in the countryside. This implies that net benefits are likely to be concentrated in urban areas – other things being equal.

There is also likely to be a positive distributional effect as a result of the increase in income levels of those formerly unemployed. However these have not been examined further in this section.

Conclusions

It has proved very difficult to carry out a quantitative analysis of these income distribution consequences. We concluded that any analysis would produce only uncertain and, in all likelihood, negligible results. This is because I) there was insufficient information available and ii) the employment and environmental effects of demand side management projects are of much greater perceived importance. It was also thought that government intervention was likely to be far the most significant influence on income and distributional impacts, outweighing effects of individual projects.

2.2.3 Assessment of Environmental Impacts

The replacement of old windows by new, better insulated ones results in certain indirect environmental effects. These mainly include the emission savings of different air pollutants as a result of lower energy demand and production. There may also be some saving of renewable and non-renewable resources.

Energy saved

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 analysis quantifies the effects of SO_2, NO_x and particulate matter. Other environmental benefits have been analysed qualitatively. Table 4 shows the share of different energy sources saved in the household sector by the mitigation project.

Table 4 Share of Energy Savings by Source

Energy source	**Share** (%)
Solid	19
Heating oil	9
Natural gas	44
Electricity	1
District heating	26
Total	**100**

This table has been calculated on the basis of data on heating energy usage in Hungary taking the structure of housing and the practical implementation rate in the case of each type of housing into account. From Appendix 1 and the table above, it is possible to calculate the savings of each type of heating method for each year up to 2038. These savings are shown in Appendix 3.

Emissions saved

Estimates of emissions saved as a result of the mitigation option considered are calculated on the basis of average emissions of energy production as shown in Table 5.

Table 5 Typical pollutant quantities from energy production

Energy source	**Particulate matter**	**SO_2**	**NO_x**	**CO**	**Metals**
	Kg/TJ				
Coal	50	200-1000	200-1000	15	1
Brown coal	65	500	250	15	1
Crude oil	10	200-1500	50-500	15	0.1
Natural gas	10	100	30-300	15	0.1

In the case of estimates where only a data range was available, (as in the cases of SO_2 and NO_x), an average value has been used in the calculations below.

For the purpose of calculating the emission values of electricity generation the average emission values of the Hungarian power generation sector have been used. 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. This seems to be a reasonable assumption because older power plants with high emission rates are likely to suffer a reduction in their production first in this instance. The energy generated by this type of power station was 400,454 TJ in 1995. The emissions resulting from the production process and the emission/TJ values are shown in Table 6.

Table 6 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

More than one quarter of the heating of households is carried out through district heating. A typical natural gas burning district heating facility has been interviewed to identify the most important emissions from this type of energy generation. Figures obtained are shown in Table 7.

Table 7 Emissions of a 333 TJ/year production district heating plant

Emission	Kg
SO_2	0
NO_x	18,441
CO	1,705
Particulates	0

Benefits in Economic Terms

The figures presented above show indirect environmental benefits in physical terms. In order to make a rational choice on economic grounds between projects it is important to quantify benefits in monetary terms as well. This has been carried out with the help of valuation data provided in the *Guidelines*. The data given in the *Guidelines* were derived from a number of European and U.S. studies. Differences in income levels between Hungary and the U.S., which may be assumed to affect the valuations, were taken into account through the use of income elasticities. Values of 1 and 0.35 are adopted as income elasticities. A sensitivity analysis is also implicit since low and high estimates of environmental damage are used, as given in the *Guidelines*. Total environmental benefits are presented in Appendix 4.

2.3 Adjustment to Financial Costs

In analysing this project, adjustment to financial costs have been considered in the following fields:

1. External costs
2. Shadow prices for resources
3. Cost of time
4. Hidden or implementation costs.

1. External costs of the project are discussed in sections 2.2 and 2.5 concerning environmental effects and the impacts on sustainability respectively.

2. The calculation of the economic opportunity, or shadow, costs of resources is an important question in all mitigation options. Resources used (saved) in the case of new, better-insulated windows consist mainly of fossil fuel savings. Prices in the energy sector are determined by government authorities through a negotiation process with the, now, mostly privately owned major utilities. During the negotiation process the interests of both Hungarian households and utilities are taken into account. The result is a set of prices which are close to international market prices whilst providing a margin of profit for the

owners of the utilities. As a consequence, it is thought reasonable to assume that energy prices in the Hungarian household sector can be equated with market prices.

3. Inclusion of the value of time savings has a minor effect on the overall valuation of this project. A little time could be saved through the installation of new windows because of a reduction in the heating requirements of households still using coal or fuel-wood. Since the heating system of these households is not affected, the storing of fuel, the lighting of fire and the cleaning process related to this type of heating are only very marginally affected.

4. The implementation costs related to the project were considered in the first phase of the project and are included in the calculated FICOSTEF values. These values are therefore assumed to include all costs concerning the allocation of subsidies and marketing of the project.

2.4 Macro-economic Impacts

Macro-economic impacts include the effects on GDP, employment and trade and the sectoral/regional breakdown of output. The installation of 80 thousand new windows to replace old ones is not thought to have a significant influence on these indicators. The investment cost of 6.1 million US$/annum is 2.7% of the total output of the construction industry which itself comprises approximately 5% of Hungary's GDP.

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. In fact, negative employment effects in the energy sector may cancel this small positive impact.

2.5 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.

In 1996 45.2% of Hungarian energy production was consumed domestically whilst 54.8% was exported. Out of total energy production, only 0.2% of total energy was produced by hydroelectric power plants and only 1.2% of total production was through the burning of fuel wood in households. It is estimated that 814,000 tons of fuel wood are used for the heating of households. This equates to 70% of the total fuel wood consumption. Assuming that households with low levels of income would not be able to afford the implementation of new windows with any form of government intervention less than a full subsidy for the costs of the installation the share of this type of renewable resource, as a proportion of total energy production, will grow as a result of the project. This change, however, is expected to be negligible and is not quantified here.

2.6 Full Economic Cost 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 included an analysis of the costs of installation and administration and energy savings only. This research identified a positive marginal cost for this mitigation option - as shown in Table 2 above.

The second phase of the research undertakes a much broader analysis of other costs and benefits that could be included in an economic analysis of the project and that could therefore influence the overall decision on its' implementation. 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.

2.6.1 Calculation of FICOSTEF Values

In the first phase of the research, marginal cost values were calculated for a range of discount rates. Net costs of the mitigation option include investment costs, administration costs and cost savings resulting from energy savings. Table 8 shows the appropriate FICOSTEF values for the project with 3% and 5% discount rates for both the net costs and resulting GWP savings of the project.

Table 8 FICOSTEF values obtained

	FICOSTEF ($/t of GWP)	
GWP	**Costs**	
	3%	5%
3%	-5.87	-14.68
5%	-8.15	-20.41

2.6.2 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 9 summarises the results of calculations. Figures have been calculated for both low and high estimates of environmental damages given in the *Guidelines* and using income elasticities of 0.35 and 1 as recommended in the *Guidelines*. Discount rates of 3% and 5% have been used.

Table 9 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 a mitigation option can turn from a net cost option into a no-regret option. The choice of discount rate, income elasticity and the estimate of the environmental effects all have significant effects on resulting values. By choosing a higher discount rate the 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.

2.7 Conclusions

The reasons for a possible difference between financial costs and economic costs of an environmental investment have been identified in economic theory. Externalities, macroeconomic effects, environmental considerations and a less than optimal operation of market forces all result in costs and benefits not identified in a financial project appraisal of, for example, greenhouse mitigation options. This study focused on the empirical measurement of indirect costs of one such mitigation option.

In some cases these costs and benefits can be calculated in monetary terms. In others only a qualitative analysis is possible. This obviously means that the quantitative results calculated and given here still do not contain all economic impacts. The effects that have been reported on a qualitative basis are thought unlikely to significantly change the results as they stand. The effect on sustainability is positive whilst the macro-economic and distributional effects are indeterminate. It is uncertain what effect the implementation of this project will have in creating unemployment in the energy sector. Clearly, any unemployment effect will reduce the attractiveness of the project on a FUCOSTEF basis.

2.8 Bibliography

Környezetstatisztikai adatok (Environmental statistics data), 1996, Központi Statisztikai Hivatal

Magyar Statisztikai Évköny (Statistical Yearbook of Hungary), 1996, Központi Statisztikai Hivatal

Energia felhasználói kézikönyv (Handbook of Energy Usage), ed. dr. István Barótfi, Környezet-technika Szolgáltató Kft., 1993

Energetika I., György Vajda, Akadémiai Kiadó, Budapest, 1981

2.9 Appendices

Appendix 1: Number of windows to be installed and resulting energy savings

Year	Number of installations	Reduction in heating (TJ)	
	Thousands	Local heating source	District heating source
1999	80.67	565.53	197.68
2000	80.67	1131.05	395.35
2001	80.67	1696.58	593.03
2002	80.67	2262.10	790.70
2003	80.67	2827.63	988.38
2004	80.67	3393.15	1186.05
2005	80.67	3958.68	1383.73
2006	80.67	4524.20	1581.40
2007	80.67	5089.73	1779.08
2008	80.67	5655.25	1976.75
2009	0.00	5655.25	1976.75
2010	0.00	5655.25	1976.75
2011	0.00	5655.25	1976.75
2012	0.00	5655.25	1976.75
2013	0.00	5655.25	1976.75
2014	0.00	5655.25	1976.75
2015	0.00	5655.25	1976.75
2016	0.00	5655.25	1976.75
2017	0.00	5655.25	1976.75
2018	0.00	5655.25	1976.75
2019	0.00	5655.25	1976.75
2020	0.00	5655.25	1976.75
2021	0.00	5655.25	1976.75
2022	0.00	5655.25	1976.75
2023	0.00	5655.25	1976.75
2024	0.00	5655.25	1976.75
2025	0.00	5655.25	1976.75
2026	0.00	5655.25	1976.75
2027	0.00	5655.25	1976.75
2028	0.00	5655.25	1976.75
2029	0.00	5655.25	1976.75
2030	0.00	5089.73	1779.08
2031	0.00	4524.20	1581.40
2032	0.00	3958.68	1383.73
2033	0.00	3393.15	1186.05
2034	0.00	2827.63	988.38
2035	0.00	2262.10	790.70
2036	0.00	1696.58	593.03
2037	0.00	1131.05	395.35
2038	0.00	565.53	197.68

Appendix 2: Calculation of employment effects

Employment generated: Base data					
	Totals	No. employed at present	No. unemployed at present	Duration of empt. (yrs)	Monthly wage** (US$)
Number of installations (each year)	80000				
Number of persons to be employed*	750	150	600	10	261.00

* Based on management interview

** Average gross monthly wage in the construction industry: HUF 56,506 (HUF216.50/US$)

Unemployment benefits and value of leisure time					
No. unemployed	Monthly benefit (US$/person)	Duration of benefit (months)	Value of leisure /month/person	Total monthly benefits (unempt. Benefit plus value of leisure time).	
				Months 1 - 12	Months 13 - 120
600	85.96	12	39.15	125.11	39.15

***Average benefit: HUF 18611/month (HUF216.50/US$)

Health benefits of employment					
No. formerly unemployed	Excess mortality (75%)	Benefit/person/annum. VSL e = 1	Benefit/person/annum. VSL e = 0.35	Benefit per person per month, VSL e = 1 (US$)	
				Months 1-12	Months 13-120
600	10.275	9658.5	24752.48	804.88	804.88
VSL, e=1	940000			Benefit per person per month, VSL e = 0.35 (US$)	
VSL, e=0.35	2409000			Months 1-12	Months 13-120
Deaths per thousand inhabitants	13.7			2062.71	2062.71

Appendix 3: Energy saved by type of energy source in the household sector

Year	Solid	Heating oil	Natural gas	Electricity	District heat.
	TJ				
1999	148.48	70.25	337.68	9.13	197.68
2000	296.95	140.50	675.35	18.25	395.35
2001	445.43	210.75	1013.03	27.38	593.03
2002	593.90	281.00	1350.70	36.50	790.70
2003	742.38	351.25	1688.38	45.63	988.38
2004	890.85	421.50	2026.05	54.75	1186.05
2005	1039.33	491.75	2363.73	63.88	1383.73
2006	1187.80	562.00	2701.40	73.00	1581.40
2007	1336.28	632.25	3039.08	82.13	1779.08
2008	1484.75	702.50	3376.75	91.25	1976.75
2009	1484.75	702.50	3376.75	91.25	1976.75
2010	1484.75	702.50	3376.75	91.25	1976.75
2011	1484.75	702.50	3376.75	91.25	1976.75
2012	1484.75	702.50	3376.75	91.25	1976.75
2013	1484.75	702.50	3376.75	91.25	1976.75
2014	1484.75	702.50	3376.75	91.25	1976.75
2015	1484.75	702.50	3376.75	91.25	1976.75
2016	1484.75	702.50	3376.75	91.25	1976.75
2017	1484.75	702.50	3376.75	91.25	1976.75
2018	1484.75	702.50	3376.75	91.25	1976.75
2019	1484.75	702.50	3376.75	91.25	1976.75
2020	1484.75	702.50	3376.75	91.25	1976.75
2021	1484.75	702.50	3376.75	91.25	1976.75
2022	1484.75	702.50	3376.75	91.25	1976.75
2023	1484.75	702.50	3376.75	91.25	1976.75
2024	1484.75	702.50	3376.75	91.25	1976.75
2025	1484.75	702.50	3376.75	91.25	1976.75
2026	1484.75	702.50	3376.75	91.25	1976.75
2027	1484.75	702.50	3376.75	91.25	1976.75
2028	1484.75	702.50	3376.75	91.25	1976.75
2029	1484.75	702.50	3376.75	91.25	1976.75
2030	1336.28	632.25	3039.08	82.13	1779.08
2031	1187.80	562.00	2701.40	73.00	1581.40
2032	1039.33	491.75	2363.73	63.88	1383.73
2033	890.85	421.50	2026.05	54.75	1186.05
2034	742.38	351.25	1688.38	45.63	988.38
2035	593.90	281.00	1350.70	36.50	790.70
2036	445.43	210.75	1013.03	27.38	593.03
2037	296.95	140.50	675.35	18.25	395.35
2038	148.48	70.25	337.68	9.13	197.68
2039	0.00	0.00	0.00	0.00	0.00

Appendix 4: Total Environmental Benefits

Year	Elasticity = 1		Elasticity = 0.35	
	Low estimate	High estimate	Low estimate	High estimate
	1000 USD			
1998	0.00	0.00	0.00	0.00
1999	823.30	1425.64	1661.57	3256.71
2000	1,646.60	2,851.28	3323.13	6513.42
2001	2,469.90	4,276.93	4984.70	9770.13
2002	3,293.20	5,702.57	6646.26	13026.84
2003	4,116.51	7,128.21	8307.83	16283.55
2004	4,939.81	8,553.85	9969.39	19540.26
2005	5,763.11	9,979.49	11630.96	22796.97
2006	6,586.41	11,405.13	13292.52	26053.68
2007	7,409.71	12,830.78	14954.09	29310.39
2008	8,233.01	14,256.42	16615.65	32567.11
2009	8,233.01	14,256.42	16615.65	32567.11
2010	8,233.01	14,256.42	16615.65	32567.11
2011	8,233.01	14,256.42	16615.65	32567.11
2012	8,233.01	14,256.42	16615.65	32567.11
2013	8,233.01	14,256.42	16615.65	32567.11
2014	8,233.01	14,256.42	16615.65	32567.11
2015	8,233.01	14,256.42	16615.65	32567.11
2016	8,233.01	14,256.42	16615.65	32567.11
2017	8,233.01	14,256.42	16615.65	32567.11
2018	8,233.01	14,256.42	16615.65	32567.11
2019	8,233.01	14,256.42	16615.65	32567.11
2020	8,233.01	14,256.42	16615.65	32567.11
2021	8,233.01	14,256.42	16615.65	32567.11
2022	8,233.01	14,256.42	16615.65	32567.11
2023	8,233.01	14,256.42	16615.65	32567.11
2024	8,233.01	14,256.42	16615.65	32567.11
2025	8,233.01	14,256.42	16615.65	32567.11
2026	8,233.01	14,256.42	16615.65	32567.11
2027	8,233.01	14,256.42	16615.65	32567.11
2028	8,233.01	14,256.42	16615.65	32567.11
2029	8,233.01	14,256.42	16615.65	32567.11
2030	7,409.71	12,830.78	14954.09	29310.39
2031	6,586.41	11,405.13	13292.52	26053.68
2032	5,763.11	9,979.49	11630.96	22796.97
2033	4,939.81	8,553.85	9969.39	19540.26
2034	4,116.51	7,128.21	8307.83	16283.55
2035	3,293.20	5,702.57	6646.26	13026.84
2036	2,469.90	4,276.93	4984.70	9770.13
2037	1,646.60	2,851.28	3323.13	6513.42
2038	823.30	1,425.64	1661.57	3256.71
2039	0.00	0.00	0.00	0.00

3 Mitigation Option 2: Installation of Low-Flow Faucets and Shower Heads

3.1 General Description of the Mitigation Option

This project is an example of an energy conservation measure in the residential housing sector. It is characterised by negative direct marginal abatement costs and a relatively short payback period (2 years in the residential sector). However, it is thought that citizens' environmental awareness is not high enough in Hungary for the device to become widespread without an education campaign and financial incentive. In the short to medium term, therefore, only a 25% implementation rate is to be expected. In the longer run widespread use is more likely since both energy and water prices are expected to rise steeply. As well as energy savings the installation of the devices also has a significant water saving effect. In this report these two effects are examined in terms of their indirect costs.

With a life span of 5 years for new devices, the implementation level of 25% can be achieved with the installation of 196,930 devices / year over a 12-year period. Appendix 1 shows the resulting energy savings for the next 15 years.

In the first phase of the research marginal abatement costs were calculated based on implementation and administration costs on the one side, and benefits of direct energy savings on the other side. Calculations using both 3% and 5% discount rates resulted in negative marginal abatement costs. Results for baseline (present) and possible future (mitigated) energy structures are shown in Table 10.

Table 10 Marginal abatement cost and mitigated GWP of project 2

		Discount rate	
		3%	**5%**
	NPV of project in 1997 (US$ million)	73.626	60.97
	Levelised cost (US$ million)	-7.39	-6.88
	MAC US$/TJ	-3410	3170
Mitigated GWP, t CO2	Baseline energy structure	8485.24	7887.58
	Baseline energy structure in 2030	8371.94	7782.26
	Mitigation energy structure in 2030	9551.30	8878.55

3.2 Indirect Costs

3.2.1 Assessment of Employment Effects

In considering the introduction of low flow faucets and shower-heads, two separate employment effects need to be taken into account. First, there are those jobs that are likely to be created through the increased demand for the production of the devices. Second, there are those jobs that might be lost in the energy sector and at the water and canalisation company as a result of lower energy and water demand. Although these effects are almost negligible, we attempted to quantify them according to the method described in the *Guidelines*.

Based on interviews with producers of such devices, we found that eight net new jobs were expected to be created for the 10 year time period of the project and two additional jobs being undertaken by those already in employment. The quantified benefit of employment can be divided into two parts: the net direct benefit of employment and the health benefits. To estimate the benefit of employment and value of leisure time we used the base data of: US$ 307.15 - the average monthly gross wage rate of the manufacturing industry; US$ 85.96/month - average unemployment benefit; US$ 46.07 - the value of leisure time equal to 15% of the average wage. To estimate health benefits, (premature mortality avoided), we adopted the Values of Statistical Life for Hungary provided in the *Guidelines* of US$904,000 and US$2.409m, using income elasticities of 1 and 0.35 respectively. The results are presented in Table 11.

Table 11 Total Employment Benefits

Year	**Net benefit, low** US$ (000's)	**Net benefit, high** US$ (000's)
1998	0.0	0.0
1999	94.079	214.831
2000	102.331	223.083
2001	102.331	223.083
2002	102.331	223.083
2003	102.331	223.083
2004	102.331	223.083
2005	102.331	223.083
2006	102.331	223.083
2007	102.331	223.083
2008	102.331	223.083
2009	102.331	223.083
2010	102.331	223.083

We also considered the employment effect of the reduction in energy and water production resulting from implementation of the project. With regard to the energy sector we can say that the resulting energy savings of the project, which are a maximum of 2170.75 TJ annually, are equivalent to 0.37% of Hungarian energy production. This amount is assumed to be marginal with respect to the employment structure of the industry.

The case of water savings is more complicated. In an average public water service company with a production capacity of 22,080 m^3/year about 290 people are employed. Calculating with total water savings of 234851.75 m^3/ for the years 1998-2015, this would equate to an average water saving of 13814.8 $m^{3/}$year. This is estimated to result in 181 people being made unemployed and suggests that a public water service company with a smaller capacity than the average may be closed down. However, there are two problems with this calculation. One is that production capacity is not equal to their real production and sales. Water service companies in Hungary produce only at 30%-50% of their capacity, but still need to employ almost the same number of people as at full capacity - reflecting a relatively inflexible demand for labour. The other problem with this calculation is that water savings are spread across the country, which means that the employment effect cannot be seen as concentrated on one single water service company. Calculating with at least 150 service companies throughout the country, an average water saving of 92 m^3/year/company would occur, which is marginal at such a low elasticity and is unlikely to result in unemployment. Even if the calculations are made with higher/lower population concentrations and therefore higher/lower water savings than the average in different settlements, it is likely that positive and negative employment effects will neutralise each other.

3.2.2 Income Distribution and Poverty

Since the installation of these water saving devices is relatively inexpensive there are likely to be only minor effects on income distribution. Indeed a combination of advertising which emphasises the rapid payback period of the devices and a general awareness-rising education campaign may result in even low-income households considering the acquisition of such devices. However, to achieve a higher than 25% implementation rate in the long run, government intervention in the form of financial incentives would be needed to ensure the participation of the poorest households. There is no reliable information about the size of inducement that might be necessary to achieve a higher implementation rate and so we are unable to quantify this here.

3.2.3 Assessment of Environmental Impacts

The installation of low-flow faucets and shower-heads has considerable indirect environmental impacts other than the mitigation of greenhouse gases. These include the mitigation of different air pollutants as a result of the energy saving. Furthermore, this project also has another important positive environmental effect: the saving of water as renewable resource. The latter will be quantified under the subheading, "Other environmental impacts", below, with some cross reference in the "Sustainability" section

Energy saved

In the analysis we have quantified the emission reductions of different air pollutants – such as SO_2, NO_x, particulate matter, CO and metals – corresponding with the share of different energy sources and energy savings (see Table 13 and Table 14). Table 14 additionally includes the electricity savings as a consequence of water savings (electricity savings at waterworks). Although these latter are small amounts in this case, we mention them in order to demonstrate that this effect may be significant in other projects and need to be considered.

Table 12 Share of energy savings by source

Energy source	Share (%)
Solid	0
Heating oil	0
Natural gas	58.14
Electricity	22.09
District heating	19.77
Total	100

Table 12 has been calculated based on data about heating energy usage in Hungary, regarding the structure of housing and the practical implementation rate for each type of housing. Applying the data available, the annual energy savings can be calculated for each type of heating method from 1998 to 2015. These results are shown in Appendix 2.

Emissions saved

Estimates of emissions saved as a result of the mitigation option are calculated on the base of average emissions of energy production. These average emission rates are shown in Table 13.

Table 13 Typical pollutants of energy production[7]

Energy source	Particulate matter	SO_2	NO_x	CO	Metals
	kg/TJ				
Coal	50	200-1000	200-1000	15	1
Brown coal	65	500	250	15	1
Crude oil	10	200-1500	50-500	15	0.1
Natural gas	10	100	30-300	15	0.1

In the calculations undertaken, where a range is given the average values of those data have been used. For the purpose of calculating the emission values of electricity generation the average emission values of the Hungarian power generation sector have been used. 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 in the calculation of mean values. This seems to be a reasonable assumption because older power plants with higher emission rates are likely suffer a reduction in their production first in this instance. The energy generated by this type of power station was 400454 TJ in 1995. The emissions resulting from the production process and the emission / TJ values are shown in Table 14.

Table 14 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

Almost 20% of the heating of households is carried out through district heating. A typical natural gas burning district heating facility has been interviewed to identify the most important emissions of this type of energy generation. Figures obtained are as follows:

Table 15 Emissions of a 333 TJ/year production district heating plant

Emission	kg
SO_2	0
NO_x	18441
CO	1705

The calculation of energy savings has been carried out using the information in Table 14 and Table 15.

Benefits in economic terms

Results given in the two previous sub-sections represent the indirect environmental effects of energy saving in physical terms. However, for different projects to be made comparable in economic terms, it is helpful to quantify environmental benefits monetarily as well. In our calculations we used the values provided by the *Guidelines* which, in turn, are based on values from a large number of European and U.S. studies.

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7 Papp, S. - Kümmel, R., 1988

The original data have been modified with the use of income elasticities in order to take differences in incomes of Hungary and the U.S. / Western Europe into account. Appendix 3 shows the summarised annual environmental benefits in money terms from energy saving.

Other environmental effects: water savings

As mentioned above, by installing low-flow faucets and shower-heads a considerable flow of excess water can be avoided. Through the implementation of this project it is estimated that water savings of approximately 16.6% would be achieved in the residential sector. Appendix 4 shows the annual drinking water and waste water savings at 25% implementation level.

It is also important to quantify water savings in money terms. Since water is a renewable resource, its economic value cannot be calculated simply on the basis of its price and several other factors also have to be taken into account. The next section includes the calculations of the financial and economic value of water, based on the available information.

3.3 Adjustment to Financial Costs

In former planned economies such as Hungary there has long been a significant difference between real costs of resources and prices used in transactions. This was a result of the lack of markets for most of the basic energy and other natural resource commodities. During the last ten years, Hungary has been in the forefront of the movement in transition countries in establishing such markets. However, there are still some commodities whose prices do not reflect the economic value of the natural resource. Water supply and waste water treatment are two of those commodities where it is more appropriate to use shadow prices for calculations.

Water prices are, in many countries, subsidised or based on current extraction and cleaning costs. However, the economic value of water should reflect extraction and cleaning costs which are valid over the long term[8]. These are higher than current cost. The reasons for this are firstly that those water bases are first used which are easier to extract, and secondly that with generally rising incomes over time water demand also increases. If we do not consider the long term costs of water supply, then incorrect decisions will be made on the rate of water extraction. The additive cost element which should therefore be incorporated into the price of water is called scarcity rent[9] in the literature. At the moment there are only a few countries in the world where the scarcity rent is used in water price determination.

In Hungary, the water pricing system does not include the scarcity rent[10]. There is a charge for water stock use that increases the water price, but its level is too low to reflect the scarcity of water. The basic value of this charge was 1.15 HUF / m^3 in 1997, (1 USD = 216.5 HUF), though this is then modified according to the type of water stock and to the economic characteristics of the region.

Both drinking water and waste-water prices are subsidised, though to different extents[11]. The average price of drinking water would be 15% higher without subsidy and the price of water, including drinking water and waste-water, would be on

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8 OECD, 1994

9 Tietenberg, 1992, p.234

10 Csutora, M. - Bisztriczky, J, 1998

11 ÖKO Rt., 1998

average 40% higher without subsidy. (The water prices vary from municipality to municipality, from region to region). The extent and amount of subsidy depend mainly on extraction and cleaning costs which, nevertheless, do not include amortisation and development costs in many cases. These costs should be included in the economic costs and have been calculated as:

Amortisation costs/annum	0.03 US$/ m^3
Development costs/annum	0.07 US$/ m^3

There is a Water Fund in Hungary which provides 3.4 billion HUF, (15.7 million USD), for water service companies as subsidy in order that they are able to cover their operating costs. There is a threshold value of approximately 1.3 USD/m^3, over which water suppliers and canalisation companies are subsidised in order to compensate for higher costs and to set lower prices for households. The FUCOSTEF calculations are based on average drinking water and waste water shadow prices. These are:

Average price of drinking water	0.48 US$/ m^3
Average price of waste water	0.57 US$/ m^3

The total economic benefits of water savings are shown in Appendix 5.

In addition to consideration of the shadow price of water the implementation costs that would be incurred in the realisation of the project need to be noted. In the case of water saving devices the implementation does not require large additional institutional or human capacity or monitoring costs, though there exist information costs in the provision of an awareness rising campaign. These costs may be difficult to quantify and they are not included here

With regard to energy prices, the tax rates in the energy prices are usually the same or very similar to those in OECD countries. The only indirect subsidy is reflected in the lower VAT rate (12%), compared to normal consumption commodities (25%). The market rate is therefore assumed to be adequate in this context.

3.4 Macroeconomic Effects

The macroeconomic effects of the project – which can be measured as effects on GDP, employment, trade and the sectoral/regional breakdown of output – are not judged to be very significant. The annual installation of 196,930 water saving devices has a marginal positive impact on both employment, (8 new jobs), and GDP, (the small price of the device). The negative employment effects as a result of water and energy savings cancel the positive ones from job creation. Water and energy savings would be reflected in a reduction of the country's GDP. This reduction has not been quantified. In any case, we would argue that the GDP indicator does not reflect the true social costs and benefits in relation to environmental resources. By using other welfare measuring indicators (such as GPI or ISEW), these resource saving effects would appear instead as a positive effect. It is intended that these indicators will be used in future.

3.5 Effects on Sustainability

There are several ways in which this mitigation project influences sustainability. Mainly through energy savings, a reduction in the use of non-renewable fossil energy resources is expected. This means a change in the energy structure: the share of renewable energy is growing within the total energy usage. This, however does not mean that more renewable resources will be used instead of non-renewable resources. It simply shows that energy savings lead to a decrease of non-renewable resource use.

The 0.37% energy savings of Hungarian energy production (as a result of the project) can be regarded as marginal in the shift of resource usage, especially if we consider that only half of Hungarian energy demand is met from domestic resources, whilst the other half has to be imported.

The reduction of air-pollutants is likely to have a positive impact on biodiversity. However it has not been possible to determine the range of these impacts in money terms.

Another aspect is the saving in water use. This is a significant consequence of the project. We tried to quantify this impact in both physical and monetary terms in Sections 3.4. and 3.5 above. In Section 3.5. the economic price of water was quantified based on long term extraction costs. Due to the lack of information, however, we have not been able to estimate the real scarcity rent and the value of alternative uses of water.

3.6 Full Economic Cost of Mitigation Option

The first phase of the research, regarding direct costs and benefits of mitigation options, resulted in a negative marginal cost for this project. In the second phase of the project we extended the analysis by including significant indirect effects. This analysis considerably modified the cost effectiveness values by making the size of the negative costs much greater. Regarding the installation of low-flow faucets and shower-heads the far most important benefits resulted from environmental impacts such as water savings and energy savings. Other impacts were rather marginal, therefore we quantified only employment effects. In the following sub-sections we interpret the results of financial cost and full economic cost calculations.

3.6.1 Calculation of FICOSTEF Values

Net direct costs of the mitigation option consist of investment costs, administration costs, and cost savings resulting from energy savings. During the first phase of the research marginal cost values have been calculated for a range of discount rates, where a zero discount rate for GWP has been assumed. In this section we calculated both the net costs and the according GWP savings with 3% and 5% discount rates. Results are summarised in Table 16.

Table 16 FICOSTEF values obtained

GWP	**FICOSTEF** (US$/t of GWP)	
	Costs	
	3%	5%
3%	-42.79	-35.42
5%	-50.83	-42.07

3.6.2 Calculation of FUCOSTEF Values

The calculation of full economic costs for the mitigation option was based on FICOSTEF values, plus the cost saving values of environmental and employment effects. Since the first phase of the research used a 5% discount rate for the 25% implementation level, we calculated with 5% and 3% discount rates, as suggested by the *Guidelines*. Table 17 summarises the results of FICOSTEF and FUCOSTEF calculations.

Table 17 Comparison of FICOSTEF and FUCOSTEF values, US$/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%	-42.79	-157.35	-166.75	-171.87	-194.83
Cost: 3%, GWP: 5%	-50.83	-186.93	-198.10	-204.17	-231.45
Cost: 5%, GWP: 3%	-35.42	-131.49	-139.43	-143.71	-163.06
Cost: 5%, GWP: 5%	-42.07	-156.21	-165.64	-170.73	-193.71

The comparison of values shows that the incorporation of indirect effects significantly influences the results. Calculating with the same discount rate for both costs and GWP savings, the results are almost the same. Using a higher discount rate for costs, the benefits are significantly lower, since costs should generally be born in the first years, while benefits occur somewhat later. At the same level of cost discounting the higher discount rate for GWP savings increases the FUCOSTEF value.

3.7 Conclusions

The mitigation option of low-flow faucets and shower heads is a good example for demonstrating that the pure analysis of direct financial costs and benefits cannot provide a full picture about the entire social and economic effects of a project.

For this project, water savings and energy savings were two environmental impacts that could be quantified. However, these two effects clearly do not reflect all benefits: other impacts could only be qualitatively described. It has been suggested that the positive employment effects could be entirely negated by the loss of jobs in the energy and water sectors as the result of the project. The impact on sustainability appears to be favourable. The macro-economic and distributional effects were indeterminate.

3.8 References

Csutora, M. - Bisztriczky, J.(1998): “The change of water stock in the Szigetköz and the determination of water price”, in: The change in the real economic value of natural resources in the Szigetköz, research paper, Budapest University of Economic Sciences, Department of Environmental Economics and Technology, Budapest, 1998

Environment-Statistical Data 1996, KSH, Budapest, 1998

OECD (1994), Integrating Economics and Environment, Project and Policy Appraisal, OECD, Paris.

ÖKO Rt. (1998). National Review of Hungary, Final Report, Part A: Social and Economic Analysis in Relation to Impact of Water Pollution, Budapest.

Papp, S. – Kümmel, R. (1988) Environmental Chemistry, Deutscher Verlag für Grundstoffindustrie, Leipzig.

Statistical Data of the Members of the Association of Waterworks and Canalisation --- Companies, 1997

Titenberg, T (1992), Environmental and Natural Resource Economics, Harper Collins.

Vajda, Gy.: Energetika I., Akadémiai Kiadó, Budapest, 1981

Vajda, Gy.: Energetika II., Akadémiai Kiadó, Budapest, 1984

3.9 Appendixes

Appendix 1: Number of devices to be installed and resulting energy savings

Year	Number of installations (thousands)	Reduction in heating (TJ)	
		Not district heating	District heating
1998	0	0	0
1999	196.93	347	86.95
2000	196.93	694	173.90
2001	196.93	1041	260.85
2002	196.93	1388	347.80
2003	196.93	1735	434.75
2004	196.93	1735	434.75
2005	196.93	1735	434.75
2006	196.93	1735	434.75
2007	196.93	1735	434.75
2008	196.93	1735	434.75
2009	196.93	1735	434.75
2010	196.93	1735	434.75
2011	0	1388	347.80
2012	0	1041	260.85
2013	0	694	173.90
2014	0	347	86.95
2015	0	0	0

Appendix 2: Energy saved by type of energy source in the household sector

Year	Solid	Heating oil	Natural gas	Electricity	District heating	Electricity due to water savings
TJ						
1998	0	0	0	0	0	0
1999	0	0	252.30	95.87	85.78	0.16
2000	0	0	504.59	191.75	171.56	0.34
2001	0	0	756.89	287.62	257.34	0.51
2002	0	0	1009.19	383.49	343.12	0.70
2003	0	0	1261.48	479.36	428.90	0.89
2004	0	0	1261.48	479.36	428.90	0.90
2005	0	0	1261.48	479.36	428.90	0.92
2006	0	0	1261.48	479.36	428.90	0.93
2007	0	0	1261.48	479.36	428.90	0.95
2008	0	0	1261.48	479.36	428.90	0.96
2009	0	0	1261.48	479.36	428.90	0.98
2010	0	0	1261.48	479.36	428.90	1.00
2011	0	0	1009.19	383.49	343.12	0.81
2012	0	0	756.89	287.62	257.34	0.62
2013	0	0	504.59	191.75	171.56	0.42
2014	0	0	252.30	95.87	85.78	0.21
2015	0	0	0	0	0	0

Appendix 3: Total environmental benefits due to air pollutant emission savings

	Total environmental benefits (1000 USD)			
Year	Elasticity =1		Elasticity = 0.35	
	Low estimate	High estimate	Low estimate	High estimate
1998	0.00	0.00	0.00	0.00
1999	538.23	867.54	1086.24	1927.43
2000	1076.48	1735.12	2172.53	3854.94
2001	1614.76	2602.73	3258.86	5782.52
2002	2153.06	3470.38	4345.25	7710.18
2003	2691.38	4338.06	5431.69	9637.92
2004	2691.44	4338.15	5431.81	9638.11
2005	2691.50	4338.24	5431.94	9638.30
2006	2691.57	4338.33	5432.06	9638.49
2007	2691.63	4338.42	5432.19	9638.68
2008	2691.69	4338.51	5432.31	9638.87
2009	2691.75	4338.60	5432.44	9639.06
2010	2691.81	4338.69	5432.56	9639.26
2011	2153.50	3471.02	4346.15	7711.56
2012	1615.16	2603.32	3259.68	5783.78
2013	1076.80	1735.58	2173.17	3855.93
2014	538.41	867.81	1086.61	1928.00
2015	0.00	0.00	0.00	0.00

Appendix 4: Annual water savings due to the project

Year	Drinking water savings (thousand m^3)	Waste water savings (thousand m^3)
1998	0.00	0.00
1999	3420.81	1995.87
2000	6973.19	4068.49
2001	10657.14	6217.89
2002	14472.66	8444.04
2003	18419.75	10746.97
2004	18748.67	10938.88
2005	19077.59	11130.79
2006	19406.52	11322.70
2007	19735.44	11514.61
2008	20064.37	11706.52
2009	20393.29	11898.43
2010	20722.21	12090.34
2011	16840.91	9825.80
2012	12828.04	7484.49
2013	8683.59	5066.43
2014	4407.58	2571.60
2015	0.00	0

Appendix 5. Total economic benefits of water savings

Year	Economic benefits of water savings (US$ million)
1998	0
1999	3.314
2000	6.755
2001	10.323
2002	14.019
2003	17.843
2004	18.162
2005	18.480
2006	18.799
2007	19.117
2008	19.436
2009	19.755
2010	20.073
2011	16.313
2012	12.426
2013	8.412
2014	4.270
2015	0

4 Mitigation Option 3: The Installation of Active Solar Water Heating Systems in the Household Sector

4.1 General Description of the Mitigation Option

4.1.1 Background

This project considers the installation of active solar water heating systems in the domestic household sector as a greenhouse gas mitigation option. It is an example of an energy conservation measure, aimed at the reduction of household energy use in Hungary.

Such installations are not yet widespread in Hungary for a number of reasons. First, the initial investment in the necessary equipment is relatively high. Whilst it has been shown that such projects will result in a full pay back, the investment cost appears to pose a barrier to installations on a large scale. Second, energy prices have been subsidised until recently which means that savings from the installation of such equipment would have been of minor interest to households. Third, up to date technological innovations have only recently –in the last 6-8 years– reached consumer markets. There is therefore a relatively low awareness of the product and its' merits.

At the same time, government programs that provide subsidies for environmental investments of households have not been widespread. Unlike the European Union, value added tax is paid on this equipment, (although with a relatively low tax rate compared to other consumer goods), and there are no other incentives to invest in such devices.

4.1.2 Project Implementation

Active solar systems are solar thermal systems. In active systems collectors are used to transfer the sun's energy into useful heat for hot water or for other heating purposes. The project concentrates on substitution possibilities in households using electric water heaters at the moment and does not include households where gas boilers are used.

There are approximately 1.4 million households operating electric boilers in Hungary. The total annual energy consumption from these boilers is estimated to be 11643 TJ/yr. Once the categories of different housing and the orientation of the buildings have been taken into account the maximum feasible number of installations is 443,000. Energy savings resulting from the new equipment reach 60%. Therefore, maximum savings of 2193 TJ/year can be expected.

The number of installations and the resulting reduction in energy use is shown in Appendix 1. An implementation rate of 25%, (of the total technically feasible installations), is assumed which, combined with a ten year span of implementation, would result in the installation of approximately 11,000 devices per year. A 25% rate of implementation would then be achieved by the year 2008, (110,900 water heating devices). It has been assumed that the life-span of the new installations is 15 years. Energy savings are therefore made over a 25 year period and these are shown in Appendix 1. The full analysis of these energy savings is shown in Appendix 2.

The first phase of the research identified the marginal abatement costs of the installation of the new equipment. These included implementation and operational costs and the benefits of energy savings. Calculations were undertaken with 3% and 5% discount rates, using the present energy structure (Baseline production mix) and a possible future energy structure (Simulation production mix). The results showed that the installation of active solar water heating devices has one of the highest marginal costs of all the projects examined, as a consequence of very high initial investment costs. These results are shown in Table 18.

Table 18 Marginal cost of project ($/t CO_2 equivalent (GWP))

	Discount rate	
	3%	5%
Baseline production mix	156	170
Simulation production mix	178	194

4.2 Assessment of Employment Effects

Net benefits of employment that result from this project consist of two parts. First, new jobs are created in the construction industry, a considerable number of which can be filled by former unemployed. Second, there is likely to be a fall in energy sector employment as a result of energy savings and the consequently lower level of production required.

4.2.1 Effects: Construction industry

According to interviews conducted by the researchers in the sector approximately 500 new jobs would be created over the ten years of the project. This in turn is forecast to provide employment for 400 unemployed with the remaining 100 jobs being undertaken by already employed persons. Such a high rate of 80% is assumed because of the relatively high level of unemployment in Hungary.

In order to calculate the net employment benefits for the 500 newly employed we used the following base data: 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, (relative to the gross wage rate). Results of the calculations are shown in Table 19.

Table 19 Employment effects

Year	Net benefits, lower estimate (US$ million)	Net benefits, higher estimate (US$ million)
1998	0.0	0.0
1999	4.516	10.553
2000	4.928	10.966
2001	4.928	10.966
2002	4.928	10.966
2003	4.928	10.966
2004	4.928	10.966
2005	4.928	10.966
2006	4.928	10.966
2007	4.928	10.966
2008	4.928	10.966

Calculations of health benefits are based on the Value of Statistical Life provided by the *Guidelines* for Hungary using income elasticity values of 0.35 and 1.00 to adjust the VOSL relative to GDP / capita.

4.2.2 Effects: Energy Sector

A maximum yearly savings in energy production of 548 TJ equates to about 0.1% of Hungarian energy production. We have been unable to quantify this effect. However, this amount of decrease in energy production is assumed to be marginal to the employment structure of the industry.

4.3 Income Distribution and Poverty

4.3.1 Income Distribution

The installation of active solar water heaters is a relatively expensive investment for a household. These types of installations are usually only made when a general renovation of the building or apartment is being undertaken. Installation includes the installation of heat collectors, additional piping, and other devices located inside and outside the building - usually on the roof and connected to original piping. According to the estimate of EGI, the investment cost is in the range of US$ 1100-1600 - depending on the type and size of the building and the chosen system. This investment cost is approximately 20% of the renovation cost of an average apartment. Relative to an average US$ 180-230 cost of traditional heating devices the extra cost is therefore significant.

A project such as this, with a high initial investment cost, is only likely to be implemented with the help of special financing designed for investments in energy conservation. Since we would expect participation to be voluntary, no one household or other interest group is likely to be in the position of blocking the project.

Without any type of subsidy the high investment costs mean that only households with an average to high income can afford the replacement of old equipment without government intervention. Lower income families who would benefit most in relative terms from the savings in energy consumption and resulting costs cannot afford such an expenditure. For lower income households other options, such as a switch from electric water heaters to gas burning water heaters are possible. Although this switch has a positive effect on household costs it does not affect GHG emissions significantly.

4.3.2 Geographical Distribution

Whether a household is located in a town or in the countryside has some effects on the implementation of the project. Families in the countryside usually own a house compared to apartments in big cities. Because active solar water heating systems require the implementation of equipment outside the apartments it is more feasible in the case where there is only one owner. On the other hand households in the countryside are usually poorer. As a result of these two factors it is very hard to identify the distribution of the number of installations between big towns and the countryside.

4.3.3 Conclusions

It has proved very difficult to undertake a quantitative analyses of these consequences which, it is thought, would produce only uncertain and negligible results. This is due to i), the lack of quantitative information and ii), much greater perceived importance of employment and environmental effects of demand side management projects.

4.4 Assessment of Environmental Impacts

Demand side energy management projects, such as the one considered here, are often found to entail substantial indirect environmental effects. These mainly include the emission savings of different air pollutants as a consequence of lower energy demand and production. These type of projects also result in non-renewable resource savings.

4.4.1 Energy and Emissions saved

The implementation of active solar water heating devices, and the resulting substitution of fossil fuels, would result in the reduction of SO_2, NO_x, particulate matter, CO, metals etc. We analyse the effects of SO_2, NO_x and particulate matter quantitatively. The effects of the other environmental benefits have been analysed qualitatively. As explained above, we assume that only electric boilers are replaced so that energy savings take the form of savings in electricity consumption.

In order to calculate the emission values of electricity generation the average emission values of the Hungarian power generation sector have been used. We assumed that the reduction in power generation (energy saved) would occur at traditional power stations burning fossil fuels. Thus nuclear and hydroelectric power plants have been omitted from the calculation of mean values. This seems to be a reasonable assumption because traditional power plants are generally the oldest ones with relatively high emission levels. Therefore initial reductions in the production of these plants would be sensible. The energy generated by these type of traditional power utilities in 1995 was 400454 TJ. The emissions resulting from the production process and the emission / TJ values are shown in Table 20.

Table 20 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

From this data set it is possible to calculate the emissions saved as a result of energy savings.

4.4.2 Benefits in Economic Terms

In order to make a rational choice between projects it is useful to quantify benefits in money terms as well. Monetising the benefits has been undertaken with the help of values provided by the *Guidelines* which bases its estimates on several European and U.S. studies. Differences in income levels between Hungary and the U.S. were taken into account through the use of income elasticities. Appendix 2 provides a summary table of the resulting flows of total environmental benefits.

4.5 Adjustment to Financial Costs

Adjustments that may need to be made to financial costs in order to derive economic costs for this project have been considered in the following ways:

1. External costs
2. Shadow prices for resources
3. Cost of time
4. Hidden implementation costs.

External costs of the project are considered in the sections concerning environmental effects and sustainability in this report.

The analysis of the economic opportunity, or shadow, costs of resources is identical in its conclusions to that for Mitigation Option 1 in this Case Study. Resources used (saved) in the case of solar powered water heating systems consist of fossil fuel savings. Prices in the energy sector are determined by government authorities through a negotiation process with the, now, mostly privately owned major utilities. During the negotiation process, the interests of both Hungarian households and utilities are taken into account. The result is a set of prices which are close to international market prices whilst providing a margin of profit for the owners of the utilities. As a consequence, it is thought reasonable to assume that energy prices in the Hungarian household sector can be equated with market prices.

There appear to be no significant time costs associated with the implementation of this project since the extra time needed to operate the device is negligible.

The implementation costs related to the project were included in the first phase of this work which focused on the direct costs. They are therefore included in the FICOSTEF values. Figures calculated are assumed to include all costs concerning the allocation of subsidies and marketing of the project.

4.6 Macroeconomic Impacts

The installation of 10,000 solar energy powered water-heating devices does not have a significant influence on the leading macroeconomic indicators in this instance: GDP, employment and trade and the sectoral / regional breakdown of output. The investment cost of US$ 15.8 million / year equates to 0.58%. of the total output of the construction industry – a minor impact. The additional 400 new employees needed to carry out the project is equivalent to a 0.18% increase in the number of employees in the construction sector (less than 0.01% of total employment). It should also be noted that negative employment effects in the energy sector may cancel this small positive impact in any case. Such small percentage figures indicate that no macroeconomic impacts are likely to be identified

4.7 Effects on Sustainability

The shift from traditional water heating systems to new, active, solar water heating systems is likely to result in greater use of renewable energy since the energy of the sun is utilised directly to meet human needs. In 1996 45.2% of energy was produced in Hungary while 54.8% had to be exported. Only 0.2% of the total energy produced in Hungary used renewable sources, (hydroelectric power plants). All other energy resources used in Hungary were exhaustible. As a result of the project the share of renewable resources should increase from 0.2% to 0.3% in total energy production. Therefore the switch from fossil fuel generated energy to solar energy appears to be a significant step towards sustainability.

4.8 Full Economic Cost of the Mitigation Option

The first phase of the research identified a high positive marginal cost for this mitigation option - as shown in Table 18. This analysis only included costs of installation and administration and energy savings. The second phase of research, reported here, identifies a range of other costs and benefits which could influence a decision regarding the implementation of the project. Employment and environmental benefits have been found to be the most important. These effects are quantified whilst other indirect costs and benefits have been analysed qualitatively. The results of the research have been combined to calculate the financial costs and full economic costs of the project.

4.8.1 Calculation of FICOSTEF Values

In the first phase of the research, the financial cash-flow of the project was used to derive marginal cost values using a range of discount rates - the cost elements included being investment costs, administration costs and cost savings resulting from energy savings. A zero discount rate for GWP was assumed in the calculation of the marginal cost values. Table 21 shows the appropriate FICOSTEF values for the project with 3 and 5% discount rates for both the net costs and resulting GWP savings of the project.

Table 21 FICOSTEF values obtained

GWP	FICOSTEF $/t of GWP	
	Costs	
	3%	5%
3%	144.6	142.9
5%	181.6	179.5

4.8.2 Calculation of FUCOSTEF Values

On the basis of FICOSTEF values and the values derived from the analysis of employment and environmental effects it has been possible to calculate a net economic cost of the mitigation option.

Results have been calculated for both low and high estimates of environmental damages and using income elasticity rates of 0.35 and 1 applied to the VSL. Discount rates of 3% and 5% have been used because calculations in the first phase of the research concentrated on a 5% discount rate in the case of a 25% implementation rate. Lower discount rate (3%) estimates are also provided, as recommended by the *Guidelines*. Table 22 summarises the results of this exercise.

Table 22 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%	144.6	22.4	2.1	-119.5	-166.9
Cost: 3%, GWP: 5%	181.6	28.1	2.6	-149.6	-209.7
Cost: 5%, GWP: 3%	142.9	37.1	21.0	-86.1	-124.1
Cost: 5%, GWP: 5%	179.5	46.6	26.4	-108.1	-155.9

Table 22 shows that the choice of discount rate and the assumptions concerning income elasticity and the value of statistical life influence the results to a great extent. Nevertheless FUCOSTEF values tend to estimate a significantly lower cost of the mitigation option. Indeed, in the case of a 0.35 elasticity the costs become negative (a net benefit). The broad conclusion is therefore that if indirect costs are taken into account the project becomes much more feasible – though the negative impact of lost employment in the energy generation sector are not included in this analysis. Of the non-quantified effects, the effects on sustainability appear to be positive whilst the macro-economic and distributional effects are indeterminate or negligible.

4.9 Conclusions

The inclusion of indirect costs and benefits in the analysis of this GHG mitigation option showed that such a project can be carried out with a positive economic benefit to society. Although results vary according to the assumptions chosen, it can be concluded that it would be reasonable to promote this type of investment in the household sector.

If this was the case, promotion would most effectively be focused on creating a more attractive financial background to investments in solar energy. A subsidy or tax incentive can be envisaged similar to those adopted in more developed countries and in the European Union. At the same time it would be important to advertise such possibilities and to raise the environmental awareness of the population. It would also be helpful for banks to be backed by government measures in order to develop construction finance that could accelerate the implementation process.

4.10 References

Energia felhasználói kézikönyv (Handbook of Energy Usage) (1993) ed. dr. István Barótfi, Környezet-technika Szolgáltató Kft.

Energetika I. (1981), György Vajda, Akadémiai Kiadó, Budapest.

Golob, R. and E. Brus, (1993). The Almanac of Renewable Energy, Henry Holt and Company, 1993

Környezetstatisztikai adatok (Environmental statistics data) (1996), Központi Statisztikai Hivatal

Magyar Statisztikai Évköny (Statistical Yearbook of Hungary) (1996), Központi Statisztikai Hivatal

Ulrich Förstner, Környezetvédelmi technika (Environmental protection technique) (1993), Springer Hungarica Kiadó.

4.11 Appendices

Appendix 1: Number of water heaters to be installed and resulting energy savings

Year	Number of installations thousands	Energy savings TJ
1999	11.09	54.83
2000	11.09	109.65
2001	11.09	164.48
2002	11.09	219.3
2003	11.09	274.13
2004	11.09	328.95
2005	11.09	383.78
2006	11.09	438.6
2007	11.09	493.43
2008	11.09	548.25
2009	0.00	548.25
2010	0.00	548.25
2011	0.00	548.25
2012	0.00	548.25
2013	0.00	548.25
2014	0.00	548.25
2015	0.00	493.43
2016	0.00	438.6
2017	0.00	383.95
2018	0.00	328.95
2019	0.00	274.13
2020	0.00	219.3
2021	0.00	164.48
2022	0.00	109.65
2023	0.00	54.83
2024	0.00	0.00

Appendix 2: Total environmental benefits (1000 US$)

Year	Elasticity = 1		Elasticity = 0.35	
	Low estimate	High estimate	Low estimate	High estimate
1998	0.00	0.00	0.00	0.00
1999	213.65	311.56	431.18	662.30
2000	427.25	623.07	862.27	1324.47
2001	640.90	934.63	1293.45	1986.76
2002	854.51	1246.14	1724.55	2648.94
2003	1068.15	1557.70	2155.72	3311.23
2004	1281.76	1869.21	2586.82	3973.41
2005	1495.40	2180.77	3018.00	4635.70
2006	1709.01	2492.28	3449.09	5297.88
2007	1922.66	2803.84	3880.27	5960.17
2008	2136.26	3115.35	4311.37	6622.35
2009	2136.26	3115.35	4311.37	6622.35
2010	2136.26	3115.35	4311.37	6622.35
2011	2136.26	3115.35	4311.37	6622.35
2012	2136.26	3115.35	4311.37	6622.35
2013	2136.26	3115.35	4311.37	6622.35
2014	2136.26	3115.35	4311.37	6622.35
2015	1922.66	2803.84	3880.27	5960.17
2016	1709.01	2492.28	3449.09	5297.88
2017	1495.40	2180.77	3018.00	4635.70
2018	1281.76	1869.21	2586.82	3973.41
2019	1068.15	1557.70	2155.72	3311.23
2020	854.51	1246.14	1724.55	2648.94
2021	640.90	934.63	1293.45	1986.76
2022	427.25	623.07	862.27	1324.47
2023	213.65	311.56	431.18	662.30
2024	0.00	0.00	0.00	0.00

5 Mitigation Option 4: The Installation of Compact Fluorescent Lights

5.1 Introduction

5.1.1 General description of the mitigation option

This report analyses the indirect costs associated with a specific greenhouse gas mitigation option for Hungary: the replacement of traditional incandescent lamps with Compact Fluorescent Lamps, (CFLs), in the residential and communal sectors. The direct costs, energy saving potential, and greenhouse gas mitigation costs of this mitigation option are discussed in the Hungarian Country Study of the project report on "Economics of Greenhouse Gas Mitigation Assessment". The basic assumptions and direct impacts of the mitigation option are described in more detail in that report.

The analysis in this report is based on the guidelines for "The Indirect Costs and Benefits of Greenhouse Gas Limitation" by A. Markandya (1998). For a consistent treatment with other mitigation options this report is also structured according to these guidelines.

5.1.2 Project Implementation

Most homes in the residential sector in Hungary are lit by incandescent lamps. The estimated average number of incandescent lamps in a household is 10. Because the CFLs are expensive and frequent switching sharply decreases their lifetime, only those incandescent lamps which are often used for long periods are worth replacing. This is true for half (5) of the incandescent lamps in a typical household, and, aggregating across the whole country, equates to the replacement of 19.7 x 10^6 lamps. The estimated electricity consumption for residential lighting is approximately 4,000 TJ per year. The living rooms and kitchens are the principal rooms in which the lamps are used for long periods and these lamps comprise 70% of the total household lighting energy consumption. Therefore, the total energy consumption of the replaceable incandescent lamps in the residential sector is around 2800 TJ per year.

In the commercial and communal sectors the linear fluorescent lamps are the most wide-spread lights used, whilst incandescent lamps are placed in less used rooms of such as toilets, bathrooms, etc. The lighting energy consumption in the commercial sector is around 12,100 TJ per year, and it is estimated that the incandescent lamps account for approximately 570 TJ/year. The number of replaceable incandescent lamps in the communal sector is estimated at 1.763 million.

Key Assumptions

1. The luminous efficacy of the CFLs is approximately five times higher than that of the incandescent lamps. Therefore, we can assume that the electricity savings are circa 80%.
2. The average investment cost is US$11.5 and US$13.9 per unit in the in the residential sector and commercial/communal sector respectively. The latter case is higher since theft-proof sockets are judged necessary, and these add to the cost. The total investment cost in the residential sector is US$ 2.27 * 10^8 and US$ 2.4 x 10^7 in the commercial sector.
3. The number of installations and the subsequent reduction in energy consumption as a result of the mitigation option are shown in Appendix 1. An implementation

rate of 25% (of the total technically feasible replacements) is assumed. Combined with a five year span of implementation, this results in the installation of 1,072,650 CFLs / year (984,500 in households and 88,150 in the public sector). A 25% rate of implementation would then be achieved by 2003 (5,363,250 CFLs).

4. It should be noted that the lifetime of the new installations has been assumed to be 10 years. Therefore, after 10 years new installations in two consecutive years are needed to maintain the net quantity of CFL installations and to ensure that the programme runs for a 20 year period.

The first phase of the research identified the marginal abatement costs of the installation of the new equipment, taking account of implementation and operational costs and calculating the benefits of energy savings. Real discount rates of 3% and 5% were used and the present energy structure (Baseline production mix) and a possible future energy structure (Simulation production mix) were used as scenarios. Final direct costs calculated for the lamp replacement mitigation option are included in Table 23.

Table 23 Marginal cost of project (US$/t CO_2 equivalent (GWP))

	Discount rate	
	3%	**5%**
Baseline production mix	91.04	70.99
Simulation production mix	103.87	80.99

5.2 Indirect impacts of CFL installations

5.2.1 Outline

The indirect impacts of the mitigation option are summarised in Table 24. These impacts will be described in more detail in the sections below.

Table 24 Broader impacts of CFL implementation

Indirect effects	**Implementing CFLs**
Employment	+ new jobs in CFL industry less job in normal lamp industry less job in energy sector
Income distribution/poverty	+ affordable price of CFLs and relatively short time of return
Associated environmental benefits	+++ several other air pollutants from energy production mercury pollution; decreased stream of waste
Adjustment to financial costs	++ saves labour costs of lamp installations saves lamp costs opportunity cost of saved time
Macroeconomic impacts	+ small impact on competition
Sustainability	+++ saving of exhaustible resources

5.2.2 Assessment of employment effects

The number of new jobs created by the increased production needs of CFLs is estimated to be negligible. This is because, firstly, the assumed intensity of implementation does not need any significant change in employment in the lamp industry. The industry has well-developed, mechanised technology which implies a low demand for labour in any case. For example, based on interviews with Hungarian CFL manufacturer TUNGSRAM, machine lines produce 2500 incandescent lamps per hour. and 900 CFLs / hour. The loss of production resulting from the reduced need for incandescent lamps has been estimated to result in an approximately comparable number of job losses as is created by the increased CFL production. The net result is therefore likely to be no change in the number of jobs, but, rather, a redirection of people from one production line to the other.

Another important factor to consider is that approximately two-thirds of CFLs sold in Hungary are not manufactured in the country, but are imported (Ürge-Vorsatz and Medián 1997). Thus. the net employment effect, even if negligible, depends on the details of the implementation program: for example, whether local manufacturers are somehow promoted thereby boosting the domestic market share, or whether, in the absence of any explicit promotion, we simply assume that the increase in market penetration is proportional to the current market shares.

There is a maximum annual saving in energy production of 674.5 TJ which equates to 0.11 % of Hungarian energy production. This fall in energy production is assumed to be marginal to the employment structure of the industry. On balance, we can conclude that positive and negative employment effects are negligible and, in any event, are expected to neutralise each other.

5.2.3 Income distribution and poverty

Market research by Urge-Vorsatz (Ürge-Vorsatz and Medián 1997) showed weak correlation between household earnings and the use of CFLs. A combination of advertising campaign that emphasised the rapid payback period of CFLs and a general awareness rising education campaign may be sufficient to persuade households with lower earnings levels to consider the purchase of CFLs. However, targeting a higher than 25 % implementation rate in the long run would most certainly require government intervention in the form of financial incentives for the poorest households.

The impact of the energy savings on income distribution has been estimated to be proportional to income levels. This is because higher income households have a tendency to use more electricity. Energy savings will therefore be proportional to their incomes. Overall, however, it is clear that in the case of the CFL implementation project the effects on income distribution and poverty are minimal.

5.2.4 Assessment of environmental impacts

Demand side management projects such as the replacement of incandescent lamps by CFLs frequently have considerable environmental benefits – generally in the form of air pollution emission savings resulting from lower energy demand or production. There may also be environmental benefits (or costs) from a reduced waste stream in the case of a large-scale introduction of CFLs to replace incandescent lamps. Both of these environmental impacts need to be considered.

We therefore first assess the indirect costs associated with three major air pollutants: SO2, NOx and particulate matter, before examining the reduced emissions of mercury in the waste stream. Although it has been documented, (Vorsatz 1996), that the net change in mercury emissions to air as a result of the replacement of incandescent lighting by a CFL is in fact negative, (assuming a mixed electricity production mix relying partially on fossil fuels), we assume these are negligible. Since the additional mercury emissions to the environment substantially appear as a result of discarded CFLs we discuss the issue of additional mercury when assessing the effect of the mitigation option on waste disposal and costs.

Emissions saved as a result of conserved electricity

The emission factors, production mix, and other assumptions related to the estimation of emission savings related to electricity conservation are consistent with the analysis of the other mitigation options analysed for Hungary. Therefore, in calculating the emission values of electricity generation the average emission values of the Hungarian power generation sector have been used. We assumed that the reduction in power generation would occur at traditional power stations burning fossil fuels. Thus, nuclear and hydroelectric power plants have been omitted from the calculation of mean values. This seems to be a reasonable assumption because traditional power plants are associated with significant amounts of emissions so that, from an environmental policy perspective, a reduction in their production first would be sensible. The energy generated by these type of traditional power utilities in 1995 was 400454 TJ. The emissions resulting from the production process and the emission/TJ values are shown in Table 25.

Table 25 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
Particulate	19.7	49.19

Based on these emission values, the emission savings in physical terms as a result of the discussed mitigation options can be calculated.

Benefits in Economic Terms

Converting physical impacts into monetary terms has been carried out with the help of values provided by the guidelines [Markandya 1998], based on estimates given in several European and U.S. studies. Differences in average income levels between Hungary and the U.S. were taken into account through the use of appropriate income elasticities.

Appendix 2 contains the results using income elasticities of 1 and 0.35 and for low and high estimates of environmental damages. Low and high estimates of environmental damage values are used in order to reflect the uncertainty that exists in these measures.

Other environmental effects: decreased stream of municipal waste and increased hazardous waste

The replacement of incandescent lamps results in an avoided waste stream of 90% of existing levels since the otherwise high turnover of these lamps, and their subsequent disposal, is avoided. However, the disposal of CFLs can also be considered as hazardous waste due to their mercury content. The costs of the treatment of this waste are therefore included in the analysis below.

It should be noted, however, that this is likely to be an overestimation of indirect costs for two reasons. First, manufacturers have invested considerable efforts into reducing the mercury content of CFLs and, as a result, this has been reduced significantly in recent years. It is therefore possible that in the near future the mercury content will be at such low levels that CFLs will not be needed to be classified as hazardous waste. Second. several manufacturers are developing, or are already operating, schemes in which CFLs are returned to the producer from large users, whereupon the manufacturer dismantles the lamps and reuses some parts. This obviously also reduces mercury emissions and the hazardous waste stream.

Since the lifetime of incandescent lamps is assumed to be 1 year, the number of replaced incandescent lamps that would be discarded annually is the amount of municipal waste avoided. Appendix 3 shows the calculations of this impact. The totals are insignificant in the overall Option costs. However, it is included here as an example of an application of the methodology that can be used.

5.3 Adjustment to financial costs

Adjustment to financial costs have been considered in the following fields:

- Shadow prices for resources
- Hidden costs and other implementation costs and benefits
- Cost of time.

Resources used (saved) in the case of CFLs consist primarily of fossil fuel savings. Prices in the energy sector are determined by government authorities through a negotiation process with major utilities who, as a result of widespread privatisation in the energy sector are mostly in private ownership. This negotiation process results in prices which are close to international market prices. As a result energy prices in the Hungarian residential sector can be assumed as market prices.

The implementation costs related to the project were considered in the first phase of the project and are included in the calculated FICOSTEF values. However, these calculations did not include the additional savings in incremental costs which stem from the avoided expenditures on replacement of incandescent lamps. Obviously, the longer lifetime of CFLs means less frequent replacement and thus the saving of expenses for 9 years. These savings are quantified in Appendix 4.

Time preference has only a minor effect on the valuation of the mitigation option. but we give an approximate estimate of this effect. The duration of a lamp installation (including the time for lamp purchase) is assumed to be 15 minutes for households and it is a loss of leisure time. The value of leisure time is assumed to be one third of average hourly wage. In the communal/commercial sector a shorter time is assumed and it is a loss of work time of technical workers in this sector. The value of this time needed is the average wage of such workers. The time saved and the value of time saved are calculated on the basis of these data together with the number of installations saved in using the long-lifetime CFLs instead of short-lifetime incandescent lamps. Appendix 4 also shows the quantification of this project impact.

5.4 Macroeconomic impacts

Possible macroeconomic impacts of the project include the effects on GDP, employment and trade and the sectoral/regional breakdown of output. However, we conclude that the installation of CFLs to replace incandescent lamps does not have a significant influence on most of these indicators.

From a macroeconomic perspective, there is no significant extra investment cost since this measure mainly involves a shift of investment from incandescent lamps to CFLs. Although some advantage to the lamp industry may result, it is not possible to show this in financial terms. One of the issues to be considered here is the fact that whilst most incandescent lamps purchased in Hungary are manufactured in Hungary, only one-third of CFLs are manufactured in Hungary. Therefore this measure may result in increasing imports. However, since the CFL market is in dynamic change and no recent market research data are available on exact market shares of locally produced and imported lighting products, this impact is impossible to quantify in monetary terms at this time.

As outlined above, the net impact on employment is negligible. Negative employment effects in the energy sector may cancel the possible small positive impact in the lamp industry. The same line of argument applies clearly applies to changes in total output. There are therefore no significant effects on GDP.

5.5 Effects on sustainability

There are several ways in which this mitigation project influences sustainability, albeit in minor ways. First, the implementation of the project affects the use of exhaustible resources through energy savings. Everything else being equal, a reduction in the use of non-renewable fossil resources implies a change in the energy structure: the share of renewable energy would necessarily grow within total energy usage. However, the 0.11 % savings in Hungarian energy production as a result of the project can be regarded as marginal in the shift of resource usage.

Second, the reduction of air pollutants is likely to have a positive impact on biodiversity. It has not proved possible, however, to determine the range of these impacts in physical or monetary terms.

Third, in the replacement of incandescent lamps the use of the rare metal, Tungsten, is avoided. Incandescent lamps contain approximately 12-13 mg of Tungsten whilst CFLs have no Tungsten content. The amount of Tungsten saved as a result of the project was calculated to be a fraction under one tonne. This is negligible from the perspective of global sustainability.

5.6 Full economic cost of the mitigation option

The previous sections discussed the likely indirect costs and benefits resulting from the installation of compact fluorescent lamps in both the residential and communal sectors. The costs / benefits identified can now be aggregated in order to make a comparison between financial costs (FICOSTEF) and full economic costs (FUCOSTEF).

5.6.1 Calculation of FICOSTEF values

These costs comprised of investment costs, administration costs and cost savings resulting from energy savings. Table 26 summarises the appropriate FICOSTEF values.

Table 26 FICOSTEF values obtained

GWP	FICOSTEF USD/t of GWP Costs	
	3%	5%
3%	-124.45	-97.05
5%	-150.86	-117.64

5.6.2 *Calculation of FUCOSTEF values*

On the basis of FICOSTEF values and the values derived from the analysis of indirect effects it was possible to calculate the net economic cost of the mitigation option. For FUCOSTEF values, discount rates of 3% and 5% have again been used. It can be seen that the assumptions regarding discount rate, income elasticity and the valuation of environmental effects all have a significant influence on the resulting values. Table 27 below summarises these results.

Table 27 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%	-124.45	-201.31	-221.56	-246.30	-294.10
Cost: 3%. GWP: 5%	-150.86	-244.03	-268.58	-298.57	-356.51
Cost: 5%. GWP: 3%	-97.05	-160.20	-176.91	-197.32	-236.75
Cost: 5%. GWP: 5%	-117.64	-194.20	-239.19	-239.19	-286.99

5.7 Conclusions

In this report we have analysed the indirect costs and benefits related to greenhouse gas mitigation option of replacing incandescent lamps by CFLs in Hungarian households and communal buildings. This study was based on an earlier assessment of direct costs of greenhouse gas mitigation. The research followed the guidelines of Markandya (1998).

The key indirect costs and benefits relating to the analysed mitigation option were found to include saved emissions of electricity generation, hidden implementation costs and benefits, costs and benefits related to waste disposal, changed mercury pollution, and the saved cost of labour and leisure time. In these cases costs and benefits can be calculated in monetary terms. In other cases, only qualitative analysis is possible. Clearly therefore, the FUCOSTEF results reached do not contain all economic impacts. However, these results provide a strong indication that the inclusion of indirect costs is likely to reduce the net costs. Since these costs were negative on the basis of the FICOSTEF analysis in any case, we can conclude that the case for the implementation of the project has been strengthened – all else being equal.

5.8 References

Környezetstatisztikai adatok 1996. (Environmental statistics data). Központi Statisztikai Hivatal

Magyar Statisztikai Évköny 1993. (Statistical Yearbook of Hungary). Központi Statisztikai Hivatal

dr. Barótfi. I. ed. (1993). Energia felhasználói kézikönyv (Handbook of Energy Usage). Környezet-technika Szolgáltató Kft.

Vajda. Gy. (1981). Energetika I.. Akadémiai Kiadó. Budapest

Markandya. A. (1998). The Indirect Costs and Benefits of Greenhouse Gas Limitations. Bath. Uni8versity of Bath Mertoeconomica.

Ürge-Vorsatz. D. and Medián (1997). Market Penetration and Market Potentials of Compact Fluorescent Lamps in Hungary. Survey Report. Budapest. Medián.

Vorsatz. D. (1996). Exploring US Residential and Commercial Electricity Conservation Potentials: Analysis of the Lighting Sector. Environmental Science and Engineering; and Energy and Resources Group. Los Angeles and Berkeley. UCLA and UC Berkeley.

5.9 Appendices

Appendix 1: Number of CFLs to be installed and the resulting energy savings

Years	Residential		Public		Total energy Saved
	Implementation	Saved energy	Implementation	Saved energy	
	Lamps	TJ	Lamps	TJ	TJ
1998	0	0.00	0	0.00	0.00
1999	984500	112.05	88150	22.85	134.90
2000	984500	224.10	88150	45.70	269.80
2001	984500	336.15	88150	68.55	404.70
2002	984500	448.20	88150	91.40	539.60
2003	984500	560.25	88150	114.25	674.50
2004	0	560.25	0	114.25	674.50
2005	0	560.25	0	114.25	674.50
2006	0	560.25	0	114.25	674.50
2007	0	560.25	0	114.25	674.50
2008	0	560.25	0	114.25	674.50
2009	984500	560.25	88150	114.25	674.50
2010	984500	560.25	88150	114.25	674.50
2011	0	448.20	0	91.40	539.60
2012	0	336.15	0	68.55	404.70
2013	0	224.10	0	45.70	269.80
2014	0	224.10	0	45.70	269.80
2015	0	224.10	0	45.70	269.80
2016	0	224.10	0	45.70	269.80
2017	0	224.10	0	45.70	269.80
2018	0	224.10	0	45.70	269.80
2019	0	112.05	0	22.85	134.90
2020	0	0.00	0	0.00	0.00

Appendix 2: Environmental benefits of emissions saved

Year	Elasticity = 1		Elasticity = 0,35	
	benefits, low	benefits, high	benefits, low	benefits, high
	Total ($'000)			
1998	0	0	0	0
1999	526	767	1061	1629
2000	1051	1533	2122	3259
2001	1577	2300	3183	4888
2002	2103	3066	4243	6518
2003	2628	3833	5304	8147
2004	2628	3833	5304	8147
2005	2628	3833	5304	8147
2006	2628	3833	5304	8147
2007	2628	3833	5304	8147
2008	2628	3833	5304	8147
2009	2628	3833	5304	8147
2010	2628	3833	5304	8147
2011	2103	3066	4243	6518
2012	1577	2300	3183	4888
2013	1051	1533	2122	3259
2014	1051	1533	2122	3259
2015	1051	1533	2122	3259
2016	1051	1533	2122	3259
2017	1051	1533	2122	3259
2018	1051	1533	2122	3259
2019	526	767	1061	1629
2020	0	0	0	0

Appendix 3: Environmental impacts

Year	Implementation (new)	Total CFLs implemented	Saved waste	Saved money on disposal	Discharged CFLs	Mercury in discharged CFLs	Hazardous waste	Disposal cost of CFLs (-)	Total cash flow
	bulbs (000)	bulbs (000)	tons	$ (000)	bulbs	kg	t	USD	USD
1998	0	0	0	0	0	0	0	0	0
1999	1072650	1072650	0	0	0	0	0	0	0
2000	1072650	2145300	26816	123863	0	0	0	0	123863
2001	1072650	3217950	53633	247725	0	0	0	0	247725
2002	1072650	4290600	80449	371588	0	0	0	0	371588
2003	1072650	5363250	107265	495450	0	0	0	0	495450
2004	0	5363250	134081	619313	0	0	0	0	619313
2005	0	5363250	134081	619313	0	0	0	0	619313
2006	0	5363250	134081	619313	0	0	0	0	619313
2007	0	5363250	134081	619313	0	0	0	0	619313
2008	0	5363250	134081	619313	0	0	0	0	619313
2009	1072650	6435900	134081	619313	1072650	3003	160898	74318	544995
2010	1072650	7508550	160898	743176	1072650	3003	160898	74318	668858
2011	0	7508550	187714	867038	1072650	3003	160898	74318	792721
2012	0	7508550	187714	867038	1072650	3003	160898	74318	792721
2013	0	7508550	187714	867038	1072650	3003	160898	74318	792721
2014	0	7508550	187714	867038	0	0	0	0	867038
2015	0	7508550	187714	867038	0	0	0	0	867038
2016	0	7508550	187714	867038	0	0	0	0	867038
2017	0	7508550	187714	867038	0	0	0	0	867038
2018	0	7508550	187714	867038	0	0	0	0	867038
2019	0	7508550	187714	867038	1072650	3003	160898	74318	792721
2020	0	7508550	187714	867038	1072650	3003	160898	74318	792721

Appendix 4: Total environmental benefits due to air pollutant emission savings

Years	Elasticity = 1		Elasticity = 0.35	
	Benefits. low USD	Benefits. high USD	Benefits. low USD	Benefits. high USD
1998	0	0	0	0
1999	525640	766550	1060836	1629466
2000	1051279	1533099	2121672	3258931
2001	1576919	2299649	3182507	4888397
2002	2102558	3066198	4243343	6517862
2003	2628198	3832748	5304179	8147328
2004	2628198	3832748	5304179	8147328
2005	2628198	3832748	5304179	8147328
2006	2628198	3832748	5304179	8147328
2007	2628198	3832748	5304179	8147328
2008	2628198	3832748	5304179	8147328
2009	2628198	3832748	5304179	8147328
2010	2628198	3832748	5304179	8147328
2011	2102558	3066198	4243343	6517862
2012	1576919	2299649	3182507	4888397
2013	1051279	1533099	2121672	3258931
2014	1051279	1533099	2121672	3258931
2015	1051279	1533099	2121672	3258931
2016	1051279	1533099	2121672	3258931
2017	1051279	1533099	2121672	3258931
2018	1051279	1533099	2121672	3258931
2019	525640	766550	1060836	1629466
2020	0	0	0	0

6 Summary and Conclusions

6.1 Empirical Results

The inclusion of the indirect effects that could be quantified into the economic analysis is significant to the net economic cost of each option – as Table 28 below shows. Results for the direct costs (Financial Cost Effectiveness (FICOSTEF)) are shown alongside the full (direct and indirect) costs (FUCOSTEF). The FUCOSTEF results are portrayed according to the assumptions made with regard to the values of environmental damages, (characterised as *high* and *low*) and the value of mortality impacts that are adjusted for differing GDP per capita levels by using income elasticities of 0.35 and 1.

Table 28 Comparison of FICOSTEF and FUCOSTEF values, US$/t of GWP

Mitigation Option	FICOSTEF	FUCOSTEF	FUCOSTEF	FUCOSTEF	FUCOSTEF
		E=1, low	E=1, high	E=0.35, low	E=0.35, low
Installation: insulating windows	5.87	-10.77	-19.72	-28.67	-52.37
Low-flow faucets/shower-heads	-42.79	-157.35	-166.75	-171.87	-194.83
Active solar water heating systems	144.6	22.4	2.1	-119.5	-166.9
Compact fluorescent lights	-124.45	-201.31	-221.56	-246.3	-294.1

Effects on employment and other environmental impacts proved to be quantifiable and it is solely these impacts that are included in the results presented above. The qualitative assessment of the other indirect effects suggests that these are not as important in cost effectiveness terms as employment and environmental effects. In the case of each of the four options considered it is apparent that inclusion of indirect effects reduces the net economic cost of the option significantly. Depending on the assumptions made, in two cases a net cost is transformed into a net benefit.

The quantifiable indirect effects have been disaggregated in Table 29 below. Data shown is based on an income elasticity rate of 0.35 for the mortality valuation. The adoption of an income elasticity value of 1 would clearly reduce these monetary values. Both low and high estimations of environmental benefits are included. A 3% discount rate is used.

Table 29 Net present value of quantified indirect effects for the chosen mitigation options (Million USD)

	Employment Benefit	Environmental Benefit		Total Indirect Costs
		(low)	(high)	
Installation: insulating windows	116.4	292.0	572.3	408.4/688.7
Active solar water heating systems	93.1	47.6	73.1	140.7/166.2
Low-flow faucets/shower-heads	2.2	227.8	267.3	230.0/269.5
Compact fluorescent lights	19.9	54.3	83.4	74.2/103.3

From those considered, the mitigation option aimed at the installation of insulating windows has the highest indirect cost effect. Both employment and environmental benefits of the project are the highest identified in the study. Other options differentiate themselves according to effect. Water saving devices on faucets have a high environmental benefit and a low employment benefit. This is because the production of such devices requires only a few people while environmental benefits include water savings as well as the savings of energy resources. Active solar water heating devices have a high employment effect because the manufacturing of these equipment requires a significant additional labour force.

The determination of the importance of each indirect effect through monetary quantification has to be viewed with some caution. A brief note on each is provided below. Monetarisation of the health (mortality) effects on employment and the environmental effects both need to quantified in terms of value ranges and are likely to be subject to on-going scrutiny. Indeed, the *Guidelines* suggest that as long as these values (for mortality in particular) remain uncertain it may be prudent to describe these effect in qualitative terms only. Additionally, in many instances data availability is the most serious constraint on further quantitative analysis.

6.2 Employment Effects

The quantified effects of the projects on employment that have been reported are positive for each project. However, it is important to note that only gross wage rates have been used in the analysis to date. We await more detailed information on average tax rates to calculate net rates. Use of net wage rates will, of course, lower the social benefits.

Health effects of increased employment dominate the employment effects. This suggests that some further attention should be given to the epidemiology of the health effects and their valuation in order to further establish the credibility of these valuations.

So far, analysis of the employment effects has not produced quantification of the negative employment effects that might arise from substitutability between energy sources. It is expected that with further analysis of employment patterns this may become possible. Undoubtedly, the inclusion of these negative effects will significantly reduce the positive effects reported in these studies.

6.3 Environmental Effects

The environmental effects that have been quantified suggest significant pollution reduction and resulting health and other benefits. The range of damage values has been utilised, providing a form of sensitivity analysis. This element appears to be a significant and robust addition to the analysis.

6.4 Sustainability

As perhaps we would expect, the reported effects of the projects on sustainability have been positive. However, the small scale of the projects that have been considered has made quantification of these effects difficult. A more complete inventory of renewable and non-renewable resources would certainly facilitate greater scope for comparison in this regard.

6.5 Income Distribution and Poverty

None of the projects considered were on a sufficiently large scale to generate substantial or significant distributional effects. As with the analysis of sustainability impacts, it became clear that the major constraint relating to analysis of this effect is likely to be the availability and quality of relevant data.

6.6 Macro-Economic Effects

Again, the small scale of the projects considered meant that no significant effects were noted in this category. It is suggested that a project with larger scale effects, e.g. the imposition of an energy tax, could usefully be undertaken in a future study.

6.7 Adjustments to Financial Costs

Quantification of the external effects, as highlighted above, enabled estimations of the financial costs to be supplemented. In addition, some exploration of the possible need for shadow pricing helped to raise important issues regarding resource pricing in Hungary – with policy implications for this area. However, water pricing as a policy measure, as discussed in the low-flow faucet project, suffers from data paucity that prevents full quantification.

6.8 Conclusions and Areas for Future Work

This study has shown the potential, as well as the current practical limitations, of the methodology. The value of the employment created has been estimated by adding gains in income effects with health effects. The environmental effects that have been quantified suggest that the reduction of pollution and associated health effects would be significant. The options that have been investigated are too small-scale to generate distributional impacts or macro-economic effects but the estimated effects on sustainability are positive and significant.

6.8.1 Policy conclusions

The principal policy conclusion that can be drawn from the analysis thus far is that it is imperative to consider indirect effects. It is possible that inclusion of indirect effects will make the net economic cost of an option negative thereby making it much more easy to „sell" as a policy measure – though the assumptions will have to be made explicit and therefore defensible. It is important for policy makers to note that whilst there is a general pattern of lower economic costs derived from this analysis, the reductions are not uniform and individual effects need to be examined for each option. The marginal cost curve is likely to have to be re-positioned and re-ordered since it is possible that this analysis will encourage a wider range of mitigation options to be considered than to date in the implementation of the principles of the Kyoto Protocol.

6.8.2 Suggestions for further work

1. 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 countries in transition. Valuation methodologies for morbidity and other environmental impacts also need to be further developed.
2. Scientific research is required to measure the effects of air pollution on crops and on forest growth.
3. General equilibrium studies of environmental sustainability would allow measures of the value of the indirect contribution to sustainability of climate change policies. This type of environmental macro-economic analysis is not well developed at present but is critical in the context of sustainable development policy.

4. Studies are required for a wider variety of mitigation options perhaps on a larger scale, e.g. the application of fiscal instruments, that would perhaps allow analysis of other indirect effects.
5. The production of adequate and sufficient statistics needs to be an international priority in this area of research and policy formulation if all indirect effects are to be quantified properly.