EUROPEAN COMMISSION
Programme «LIFE+2007»

Developing Local Plans for Climate Change Mitigation by 2020

(CLIM-LOCAL2020)

LIFE07 ENV/GR/000282

ACTION 4

CBA report

Table of Contents

1. General approach

The aim of action 4 is to provide a sound analytical basis for the selection of those GHG emission reduction options that minimize the economic cost and maximize the social welfare. Such an analysis will assist decision makers in identifying the "least cost" set of measures for reducing local GHG emissions and thus contributing to the national reduction effort within the framework of the Kyoto Protocol.

For this type of decision situations cost benefit analysis (CBA) has been shown to be a suitable evaluation tool that may lead to higher quality financial, operational and political decisions. CBA provides the methodological background for an overall evaluation of projects and policies by taking into account all cost and benefit parameters, both those referring to the investment party itself (private cost or benefit), as well as those attributed to the external economic and natural environment (external cost or benefit). Consequently, the CBA methodology is capable of identifying those actions with the larger net social benefit, thus limiting market distortions stemming from the exclusion of external cost in the current market energy prices. Furthermore, by attributing monetary values to the environmental pressures generated by the scheduled interventions, CBA provides a uniform basis for the integration of the environmental and social dimension in the climate change mitigation policy However, to date, CBA has been rarely used in the evaluation procedure of the various GHG emission abatement options due to uncertainties and methodological problems inherent to the external cost estimations. For this reason, decision makers usually prefer other techniques in order to deal with these kinds of problems, such as multicriteria analysis, decision analysis, cost effectiveness analysis/ CEA (a special sort of CBA where usually only the net financial costs associated with the interventions under consideration are taken into account) etc. However, these latter techniques also present difficulties/ disadvantages such as arbitrariness during the determination of criteria weights and exclusion of the effect of environmental impacts in the preference of decision makers.

Ideally, from an economic point of view, decision makers would like to reduce GHG emissions by implementing "win–win" abatement options (i.e. interventions presenting an economic benefit for end-users without the provision of any economic subsidies or other similar policies). In case that this is not possible or adequate, decision makers would tend to look for low cost interventions that are simultaneously associated with significant indirect benefits (i.e. additional improvements in environmental quality through the reduction of other pollutants, creation of new jobs, rationalization of the energy system etc.).

In the context of this LIFE project, a methodological framework has been developed to assist decision makers to these kinds of decisions. Specifically, a two step procedure has been formulated, aiming at identifying those mitigation measures that reduce GHG emissions, have significant other environmental benefits and on the same time do not impose great direct costs to the economy and to the consumers.

In the first stage, the GHG emission reduction measures specified in Action 3 of the LIFE project are evaluated on the basis of a CEA, thus identifying "win–win" actions that could be implemented by energy consumers without any economic support. These actions should be in the core of any integrated local GHG emissions reduction policy. Next, the measures are re-evaluated using an integrated CBA, in order to identify measures that could be also considered as "win-win" options if their environmental externalities are translated into monetary terms. Thus, CBA provides the basis for completing the initial "win–win" set of measures. For this analysis, the findings of recent studies on external cost estimations undertaken at a European level have been used.

2. Methodological framework

2.1. Stages of CEA and CBA

CBA is basically a decision tool which evaluates projects or measures by comparing their costs and benefits. It is one of the techniques intended to improve the quality of decisions by converting all the cost and benefit elements (financial, environmental and social) arising from a specific activity/ project into monetary units. If the activity/project shows a net benefit, it is worth approving, while different activities/projects can be ranked on the basis of their net benefits. CBA evaluates different projects on the basis of their social costs, which reflect all costs to society, including private costs and externalities. However, by its nature, the assessment of environmental externalities is difficult and uncertain. Thus, in many cases, a cost effectiveness analysis (CEA) is conducted, where only financial costs and no indirect positive and negative costs are considered. In this, CEA is a special sort of CBA where all financial costs/benefits of a portfolio of projects are assessed in relation to a policy goal.

The CBA and CEA processes comprise the following general methodological stages:

- *Definition of technological project parameters and evaluation assumptions*. All the technical characteristics of the project under evaluation, such as capacity, efficiency, qualitative and quantitative characteristics of inputs and outputs etc., are recorded in detail. In addition, the evaluation period is specified and a discount rate is selected in order to reduce the various cost and benefit elements to a common base.

- *Determination of the project cost and benefit components*. The analysis involves initially the recording of private cost and benefit components, which determine the financial return of the project/ measure examined. Specifically, these cost components usually refer to initial (investment) expenditures, maintenance and operation cost, cost of labor, cost for replacement etc. Similarly, the benefit components comprise potential revenues arising from the operation of the project, from energy savings etc. Usually, it is relatively easy to determine both components on the basis of market data and existing experience. On the contrary, costs and benefits resulting from changes in environmental quality or from impacts on other social goods are much more difficult to measure, especially when it comes to non-tradable goods, such as human health, biodiversity, exhaustion of natural resources etc. To this purpose, special techniques, derived from the neoclassic economic theory of welfare, or data derived from pertinent studies are used.

- *Calculation of evaluation indicators*. Time allocation of cost and benefit components over the life cycle of the project under examination greatly affects the analysis results. An evaluation can only be made by incorporating timing considerations by tracing the incidence over time of costs and benefits and by using an appraisal method that takes this into account. As already mentioned, CEA involves a comparison of financial cost flows and GHG emission reductions occurring at different points in time. On the other hand, CBA assumes more aggregated cost flows including the associated externalities, which also occur during the project's life cycle. In both cases, cost flows can be compared through the net present value (NPV):

$$\mathrm{NPV} = \sum_{t=0}^{T} \frac{C_t}{(1+r)^t}$$

where r is the discount rate, C_t is the net cost at time t (financial cost in the case of CEA and social cost in the case of CBA) and T is the evaluation period of the measure.

Apart from NPV, other evaluation indicators can also be used for the comparison of GHG emissions reduction measures, such as the internal rate of return (IRR), the benefit–cost ratio (B/C) and the levelised costs. All these indicators basically provide similar project rankings. As explained above, NPV determines the present value of net costs by discounting the flows of costs and benefits back to the base year. The IRR is defined as the rate of return on an investment, which will equate the net present value of an investment with zero benefits. The B/C is defined as the ratio of benefits and costs associated with a specific project. Both the IRR and B/C indicators are neutral to the scale of costs, as well as to the GHG emission reductions achieved by the measure. On the other hand, the NPV criterion gives a clear view of the overall economic performance of the measure without taking into account in this evaluation the reduction of GHG emissions achieved. Finally, in the case of levelised costs per unit of GHG emission reductions, annual costs as well as GHG emission reductions are transformed to constant annual flows over the lifetime of the measure.

Within the cost of the specific LIFE project, GHG emission reduction measures are compared on the basis of their B/C ratio. This indicator was considered more suitable for the specific decision situation as the results of the analysis are simple to communicate to decision makers (measures with a B/C greater than one show net benefits and thus are preferred to the rest), while the scale of the investments and GHG emission reductions are not considered at this stage of measures' prioritization. The scale of investments needed will be one of the criteria to be considered during the prioritization of measures within the context of Action 5. Regarding the scale of GHG emission reductions per measure, it was thought that it should not form an exclusion factor for some measures to be applied in municipal buildings, schools etc. (sectors where the overall GHG emission reduction potential is much smaller than the one in the residential or private sector) since the Local Action Plan to be formulated should present a relative balance between all sectors.

- *Sensitivity analysis*. Sensitivity analysis tries to identify the parameters that most affect the outcome of a project evaluation. Experience shows that very often, the final project's outcome differs significantly from the one initially expected. Usually, parameters which may significantly alter the project's overall attractiveness are the discount rate adopted, the initial investment cost and the estimated externalities associated with non-tradable goods (i.e. human health, biodiversity, historical monuments etc.). For all these factors, sensitivity analyses should be undertaken in order to examine the reliability of the analysis.

2.2. Estimation of environmental externalities

It is widely recognized that energy production and use is a significant source of environmental deterioration, imposing economic costs to the society. These costs, which are not taken into account in the current price system, constitute the external costs, or the externalities, of the reference energy source or technology. Therefore, it is clear that the realization of interventions aiming at energy conservation and GHG emissions abatement will limit the environmental impacts arising from the production and use of energy causing external benefits (and in some cases external costs) to the society. Hence, in order to incorporate effectively the environmental and social dimension in policy decisions, it is necessary to take into account not only private costs but also the external costs/benefits associated with each particular activity.

It is relatively simple to measure environmental externalities related to tradable goods (e.g. agricultural crops). For non-tradable goods (e.g. human health, ecosystems), a number of problems arise. In the last decade, there has been significant effort to assign values to similar goods by using the methods of welfare economics. Particular emphasis was given to the energy sector in an attempt to ascertain to what extent the failure of the market mechanism to assess environmental impact leads to the distortion of energy prices and, consequently, to a non-efficient use of energy resources. In an attempt to provide a sound methodological framework and to conduct a number of national implementation studies in all European Union Member States with the same methodology, the European Union commissioned a research project (ExternE). The results of this project show that the cost attributed to the environmental impacts of conventional fuels is very high and may be of a similar or even greater order of magnitude as their private cost. Despite the high degree of uncertainty and the fact that several environmental impacts are still not possible to evaluate, the above results constitute a much better approximation, compared to private cost figures, and are already being used in the elaboration of energy policies and in CBA studies.

In order to assess the externalities (external costs and benefits) arising from the realization of the interventions under consideration, the most recent results of the ExternE project are used (*European Commission 2008, "Cost assessment for sustainable energy systems", Technical report of the CASES project*). It should be noted that the results obtained for Greece constitute the most integrated scientific attempt aiming to estimate the externalities of the Greek energy sector. It must be also noted that the range of environmental impacts and, consequently the external cost, largely depends on the geographical location of the emission sources, a factor that also determines the type and number of the environmental pollution receptors.

The most important environmental benefit resulting from the measures investigated is the reduction of air emissions due to the reduction of electricity and conventional fuels use. The emissions taken into consideration are primarily conventional air pollutants, i.e. sulfur dioxide (SO_2), nitrogen oxides (NO_x), particulate matter (PM_{10}) and non-methane volatile organic compounds (NMVOC), as well as GHG emissions (CO_2, CH_4, N_2O). These air emissions cause significant impacts on the human and natural environment, such as:

- Impact on public health (increase of morbidity and mortality rates);
- Impact on agriculture;
- Impact on buildings and historical monuments;
- Impact on forests and ecosystems.

The ExternE studies have quantified in monetary terms a large number of environmental impacts associated with energy production and consumption, examining a wide range of technologies and energy fuels. According to the findings of these studies, the most important components of the externalities associated with the production and use of energy, are mortality (due to air pollution) and the global warming effect. Many other environmental externalities associated with energy production and consumption seem to be less important, while some others (e.g. land use change, production of other waste products etc.) have not been quantified within the context of these studies and, therefore, are not included in this analysis, thus underestimating the total environmental benefits associated with the realization of the various interventions. Furthermore, it should be noted that the uncertainty of all these estimations is very high and the reference studies present alternative approaches and methodologies, which lead to considerably divergent values. In this analysis, generally conservative estimations were adopted in order to ensure that the environmental benefits arising from the realization of the measures examined were not overestimated.

The monetary values used for the assessment of externalities were as follows:

- CO_2: 19 Euro/t
- CH_4: 399 Euro/kg
- N_2O: 5890 Euro/kg
- SO_2: 5081 Euro/kg
- NO_x: 2418 Euro/kg
- PM_{10}: 15774 Euro/kg
- NMVOC: 532 Euro/kg
- Electricity consumption: 21.14 Euro/MWh for 2010, 19.93 Euro/MWh for 2015, 17.92 Euro/MWh for 2020 (the latter value was assumed to remain constant for the years after 2020)

3. Results

The GHG emissions reduction measures defined (in the context of Action 3) and examined for the greater Volos area, taking into account existing and projected energy consumption and emissions profile, fall into the following main categories:

- Buildings
- Road transportation
- Water supply and wastewater management
- Solid waste management
- City operation

The total GHG emissions reduction potential is estimated (for 2020) at 96,000 t CO_2 eq approximately (about 12% of GHG emissions estimated for the greater Volos area in 2007, excluding EU-ETS installations). *Building*-related interventions account for the majority (about 61%) of the estimated potential for 2020 (**Figure 1** and **Table 1**). Interventions targeting emissions from *road transportation* (including capital intensive measures as the construction of tram) contribute about 19% of the estimated potential for 2020. Interventions related to *Solid Waste Management* account for 4% of the estimated potential, while the rest 16% is almost equally divided between *Water supply and wastewater management* and *City operation* (street lighting and trees planting).

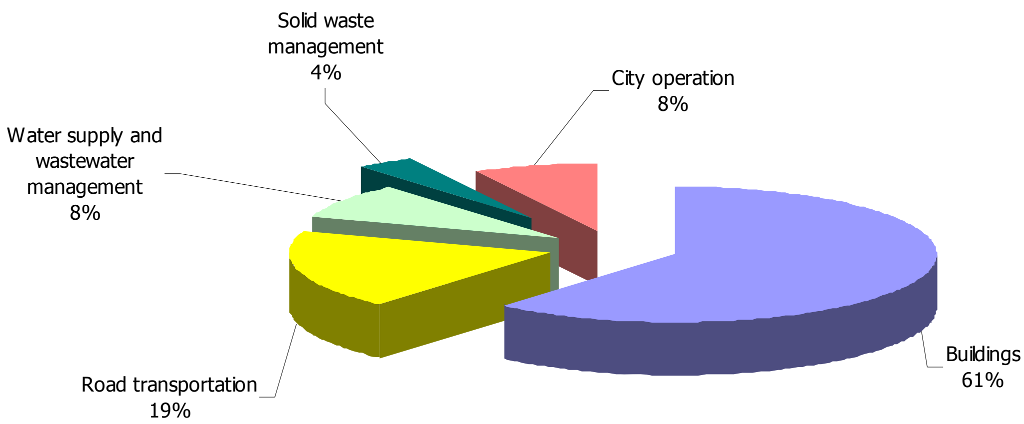

Figure 1. GHG emissions reduction potential (in t CO_2 eq) for 2020 per category

The allocation of the estimated GHG emissions reduction potential for 2020 per implementing authority/agent is presented in **Figure 2** (and **Table 1**). However, it should be mentioned that part of the potential attributed to the Municipality of Volos and the Public sector (as responsible for the implementation of the measure) can only be realised through the active participation of the local population (e.g. construction of bicycle lane, tram, paper recycling, etc).

45% of the estimated potential can be achieved by measures undertaken by residents. Measures implemented by the Municipality of Volos together with DEYAMV (in charge of the operation of the waste supply system and wastewater treatment facility) correspond to 25% of the estimated potential. The rest 30% of the potential can be achieved by measures from the rest of the tertiary sector (13% for private sector and 17% for the Public sector).

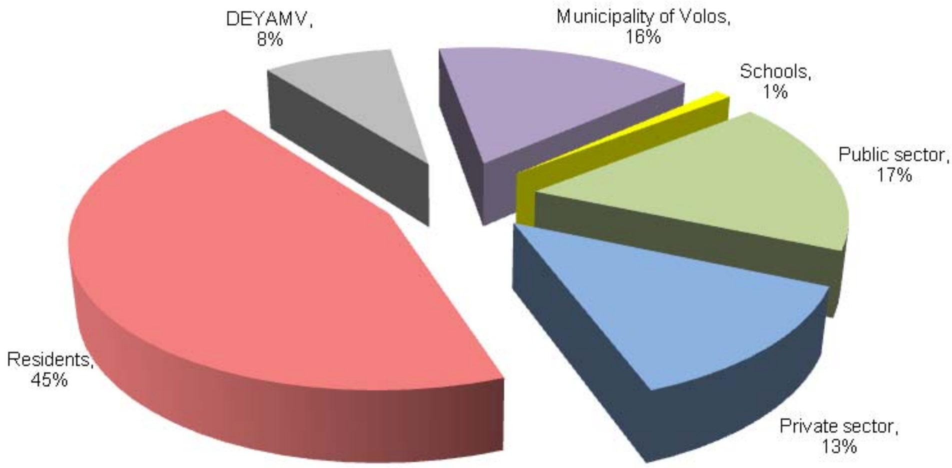

Figure 2. GHG emissions reduction potential (in t CO_2 eq) per implementing authority/agent

The B/C ratio obtained for the CEA and CBA analysis is shown in **Tables 2 and 3**. The discount rate used was 6%.

Out of 91 cases examined (combinations of GHG emission reduction measures and sectors), 41 have a B/C > 1 in CEA (only private costs and benefits considered). When externalities are included in the analysis (CBA), 14 more measures show a B/C > 1. Finally, when some sensitivity analyses were performed (e.g. regarding investment and operational cost), especially with respect to measures showing a B/C slightly lower than 1 in CBA, 2 more measures are also included in the list of those presenting net benefits. Thus, 57 out of 91 measures have a B/C > 1 in CEA or CBA and will form the focus of the Local Action Plan for GHG emissions reductions. These measures represent 75% of the estimated GHG emissions reduction potential for the greater Volos area in 2020.

The allocation of the emissions reduction potential of the measures examined according to the estimated benefit to cost ratio in CEA and CBA and the implementing authority/agent is presented in **Figure 3**. The following should be noted:

- Measures with a benefit to cost ratio greater than 1 in the CEA (i.e. win-win measures) account for 57% of the estimated GHG emissions reduction potential for 2020 (96,000 t CO_2 eq) potential. Another 18% of this potential can be achieved through measures with a benefit to cost ratio greater than 1 in the CBA (i.e. including external costs and benefits) while the rest 25% of the potential cannot be considered as feasible in the context of the present analysis. Almost half of the emissions reduction potential of measures with a benefit to cost ratio less than 1 (in both CEA and CBA) is attributed to a single measure (i.e. the construction of tram for the city of Volos). Obviously, such an investment that affects the infrastructure of the whole area should be subject to a broader assessment and not only to environmental effectiveness.

- As already mentioned, about 45% of the emissions reduction potential (about 43,000 t CO_2 eq) can be achieved through actions undertaken by residents. The share of the win-win measures to this potential is high and accounts for about 77% of the estimated potential for the resident sector. This win-win potential corresponds to 60% of the total win-win potential identified. This high potential should be addressed to the local population through appropriate awareness campaigns.

- High shares of win-win potential have been also estimated for *DEYAMV* and *Private sector (Services – Trade)*: 98% and 72% respectively. In the case of DEYAMV this share is attributed to the utilization of existing or planned infrastructure to produce electricity through small hydroelectric plants.

- The majority of measures attributed to the Municipality of Volos present a benefit to cost ratio greater than 1 only when CBA is applied. The associated potential of these measures account for 77% of the total potential (including measures for *Schools*).

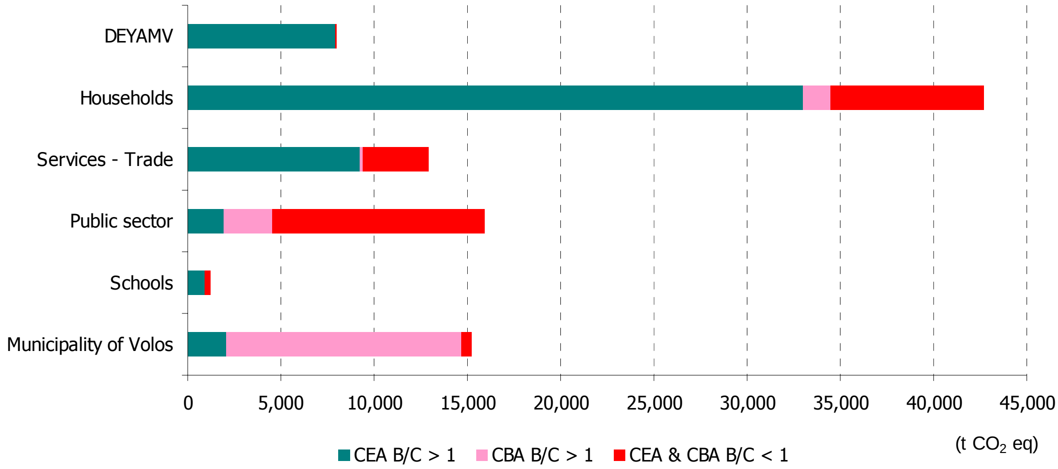

Figure 3. CEA and CBA results and GHG emissions reduction potential (in t CO_2 eq) for 2020 per implementing authority/agent

These measures will be the target of Action 5 (prioritization of measures), while the rest represent low-priority options. However, since it is clear that the final classification of measures into priority categories is a political decision, it is possible that a limited number of deviations from this procedure may take place.

Table 1. GHG emissions reduction potential for 2020 (in t CO_2 eq)

	Benefit / Cost ratio	Local Government		Public sector (incl. DEYAMV)	Private sector	Residents
		Municipal	Schools			
	A. BUILDINGS					
A.1	Insulation of roof & external walls	92	151	90	3,310	7,938
A.2	Green roofs					164
A.3	Replacement of window/door frames & glazing	38	70	19	1,422	1,569
A.4	Replacement of low efficiency A/C units	67	No info	31		1,488
A.5	External shading	48		3	503	
A.6	Ceiling fans	10	Not relevant	141		633
A.7	Replacement of low efficiency diesel boilers	29	19	3	290	343
A.8	Regular maintenance of boilers					1,146
A.9	Intelligent indoor temperature management system					3,262
A.10	Solar collectors for space & water heating				23	508
A.11	Increased penetration of natural gas use			4	978	1,275
A.12	Thermosiphonic solar systems			96	84	13,610
A.13	Solar cooling			40		
A.14	Photovoltaics	144	810	323	691	3,566
A.15	Energy efficient office and home electrical appliances	52	16	626	2,081	542
A.16	Replacement of low efficiency bulbs	106	108	501	2,026	2,140
A.17	Light control automation systems	6	28	101	58	89
A.18	Non-technical energy conservation measures	7	6	30	876	1,404
A.19	Cogeneration			2,575		
A.20	Installation of Building Management Systems (BMS) - new construction	4		4		
A.21	Bioclimatic buildings - new construction	60			151	99

Benefit / Cost ratio		Local government		Public sector (incl. DEYAMV)	Private sector	Residents
		Municipal	Schools			
	B. TRANSPORT					
B.1	Replacement of old municipal passenger cars with hybrid ones	19				
B.2	Renewal of heavy duty vehicles fleet	67				
B.3	Renewal of garbage truck fleet	140				
B.4	Renewal of DEYAMV vehicle fleet			6		
B.5	Municipal bicycle rental system	326				
B.6	Extension of bicycle lane network	781				
B.7	Extension of the pedestrian walkways	116				
B.8	New car parking stations	2,058				
B.9	Urban buses - new low emissions compact buses			504		
B.10	Urban buses - redesign of bus lines			586		
B.11	Tram construction			10,179		
B.12	Eco-driving	11		66	450	2,061
B.13	Car pooling					819
	C. WATER SUPPLY AND SANITATION					
C.1	Reduction of water consumption through advertising campaigns and/or billing policy. which will result in energy demand reduction of the following services: (a) exploitation of water resources (water wells) & operation of water distribution network and (b) operation of sewage conveyance and pumping system & operation of sewage treatment plant			78		
C.2	Leakage minimization in water distribution network and residential connections			No quantification		
C.3	Reduction of water supply share coming from water wells (especially deep wells) by the utilization of surface water resources			No quantification		
C.4	Optimization of water supply system through the installation of "smart" valves, division of water network into additional distribution zones. etc.			299		
C.5	Installation of electromagnetic water meters of direct reading to improve leakage monitoring					

Benefit / Cost ratio		Local government		Public sector (incl. DEYAMV)	Private sector	Residents
		Municipal	Schools			
C.6	Changes in the electromechanical equipment (pumps, etc) and generally upgrading of the water pumping stations to increase operating equipment efficiency			33		
C.7	Minimization of parasitic inflow into the sewer system that causes operational problems in transporting and treating sewage			217		
C.8	Upgrading of the electromechanical equipment of sewage treatment plant with the aim of reducing local and linear losses			57		
C.9	Changes in the electromechanical equipment (pumps, etc) and generally upgrading of the sewage pumping stations to increase operating equipment efficiency			49		
C.10	Optimization of sewage treatment plant (STP); the measures to be specified by energy audit (resetting of control system, put switch 'off' when not in operation, leakage repair, reprogramming of load/consumption)			No quantification		
C.11	Shift electrical load to off-peak, improve power factor (STP)			No quantification		
C.12	Simple control systems (STP)			No quantification		
C.13	Further sludge treatment – possible further energy recovery (STP)			2,587		
C.14	Utilization of potential energy in surface waters to produce electricity– application of renewable energy systems, autonomous and interconnected			4,663		
	D. MUNICIPAL SOLID WASTE MANAGEMENT					
D.1	Additional paper recycling	1,417				
D.2	Biodegradable waste recycling	1,969				
	E. CITY OPERATION					
E.1	Replacement of low efficiency bulbs in street lighting	1,555				
E.2	Automation in street lighting	5,875				
E.3	Tree planting/ green areas	270				
	F. OTHER					
F.1	Mediterranean Games' Infrastructure – Mediterranean Village			No quantification		
F.2	Rehabilitation of Glavani land property			No quantification		
F.3	Rehabilitation of fish market			No quantification		

Table 2. Results of CEA (only private costs and benefits are considered)

Benefit / Cost ratio		Local Government		Public sector (incl. DEYAMV)	Private sector	Residents
		Municipal	Schools			
	A. BUILDINGS					
A.1	Insulation of roof & external walls	0.99	0.48	2.31	1.43	1.02
A.2	Green roofs					0.93
A.3	Replacement of window/door frames & glazing	0.35	0.26	0.36	0.35	0.11
A.4	Replacement of low efficiency A/C units	0.45	No info	0.45		0.20
A.5	External shading	1.50		0.40	1.46	
A.6	Ceiling fans	0.35	Not relevant	1.79		0.43
A.7	Replacement of low efficiency diesel boilers	0.94	0.94	2.56	3.16	2.06
A.8	Regular maintenance of boilers					1.04
A.9	Intelligent indoor temperature management system					0.39
A.10	Solar collectors for space & water heating				0.40	0.26
A.11	Increased penetration of natural gas use			3.51	1.24	0.98
A.12	Thermosiphonic solar systems			1.80	1.89	1.32
A.13	Solar cooling			0.86		
A.14	Photovoltaics	1.01	1.01	1.01	1.01	1.05
A.15	Energy efficient office and home electrical appliances	0.10	0.06	0.28	0.16	0.13
A.16	Replacement of low efficiency bulbs	0.89	0.87	1.03	2.12	2.24
A.17	Light control automation systems	0.56	0.39	2.14	1.05	0.14
A.18	Non-technical energy conservation measures	NO IC	NO IC	NO IC	NO IC	4.48
A.19	Cogeneration			0.86		
A.20	Installation of Building Management Systems (BMS) - new construction	0.73		0.73		
A.21	Bioclimatic buildings - new construction	0.87			0.87	0.46

	Benefit / Cost ratio	Local government		Public sector (incl. DEYAMV)	Private sector	Residents
		Municipal	Schools			
	B. TRANSPORT					
B.1	Replacement of old municipal passenger cars with hybrid ones	1.02				
B.2	Renewal of heavy duty vehicles fleet	0.20				
B.3	Renewal of garbage truck fleet	0.30				
B.4	Renewal of DEYAMV vehicle fleet			0.07		
B.5	Municipal bicycle rental system	1.50				
B.6	Extension of bicycle lane network	0.96				
B.7	Extension of the pedestrian walkways	0.76				
B.8	New car parking stations	0.85				
B.9	Urban buses - new low emissions compact buses			0.86		
B.10	Urban buses - redesign of bus lines			1.20		
B.11	Tram construction			0.28		
B.12	Eco-driving	1.62		3.57	1.65	1.65
B.13	Car pooling					2.73
	C. WATER SUPPLY AND SANITATION					
C.1	Reduction of water consumption through advertising campaigns and/or billing policy. which will result in energy demand reduction of the following services: (a) exploitation of water resources (water wells) & operation of water distribution network and (b) operation of sewage conveyance and pumping system & operation of sewage treatment plant			1.19		
C.2	Leakage minimization in water distribution network and residential connections			No quantification		
C.3	Reduction of water supply share coming from water wells (especially deep wells) by the utilization of surface water resources			No quantification		
C.4	Optimization of water supply system through the installation of "smart" valves, division of water network into additional distribution zones. etc.			1.00		
C.5	Installation of electromagnetic water meters of direct reading to improve leakage monitoring					

Benefit / Cost ratio		Local government		Public sector (incl. DEYAMV)	Private sector	Residents
		Municipal	Schools			
C.6	Changes in the electromechanical equipment (pumps, etc) and generally upgrading of the water pumping stations to increase operating equipment efficiency			0.80		
C.7	Minimization of parasitic inflow into the sewer system that causes operational problems in transporting and treating sewage			1.31		
C.8	Upgrading of the electromechanical equipment of sewage treatment plant with the aim of reducing local and linear losses			1.72		
C.9	Changes in the electromechanical equipment (pumps, etc) and generally upgrading of the sewage pumping stations to increase operating equipment efficiency			0.22		
C.10	Optimization of sewage treatment plant (STP); the measures to be specified by energy audit (resetting of control system, put switch 'off' when not in operation, leakage repair, reprogramming of load/consumption)			No quantification		
C.11	Shift electrical load to off-peak, improve power factor (STP)			No quantification		
C.12	Simple control systems (STP)			No quantification		
C.13	Further sludge treatment – possible further energy recovery (STP)			1.05		
C.14	Utilization of potential energy in surface waters to produce electricity– application of renewable energy systems, autonomous and interconnected			1.10		
	D. MUNICIPAL SOLID WASTE MANAGEMENT					
D.1	Additional paper recycling	1.00				
D.2	Biodegradable waste recycling	0.66				
	E. CITY OPERATION					
E.1	Replacement of low efficiency bulbs in street lighting	0.91				
E.2	Automation in street lighting	0.93				
E.3	Tree planting/ green areas	Not defined				
	F. OTHER					
F.1	Mediterranean Games' Infrastructure – Mediterranean Village			No quantification		
F.2	Rehabilitation of Glavani land property			No quantification		
F.3	Rehabilitation of fish market			No quantification		

Table 3. Results of CBA (both private costs/ benefits and environmental externalities are considered)

Measures with B/C > 1 in private economic analysis
Measures with B/C > 1 when environmental externalities are included
Measures with B/C > 1 when environmental externalities are included & sensitivity analyses are performed

Benefit/ Cost ratio		Local government		Public sector (incl. DEYAMV)	Private sector	Residents
		Municipal	Schools			
	A. BUILDINGS					
A.1	Insulation of roof & external walls	1.05	0.51	2.48	1.62	1.11
A.2	Green roofs					1.03
A.3	Replacement of window/door frames & glazing	0.38	0.28	0.39	0.40	0.12
A.4	Replacement of low efficiency A/C units	0.52	No info	0.52		0.24
A.5	External shading	1.76		0.46	1.70	
A.6	Ceiling fans	0.40	Not relevant	2.11		0.53
A.7	Replacement of low efficiency diesel boilers	1.00	1.00	2.82	3.27	2.13
A.8	Regular maintenance of boilers					1.15
A.9	Intelligent indoor temperature management system					0.42
A.10	Solar collectors for space & water heating				0.44	0.29
A.11	Increased penetration of natural gas use			3.72	1.30	1.02
A.12	Thermosiphonic solar systems			1.93	2.05	1.58
A.13	Solar cooling			1.03		
A.14	Photovoltaics	1.05	1.05	1.05	1.05	1.10
A.15	Energy efficient office and home electrical appliances	0.12	0.07	0.34	0.19	0.15
A.16	Replacement of low efficiency bulbs	1.05	1.02	1.22	2.51	2.61
A.17	Light control automation systems	0.65	0.46	2.52	1.34	0.17
A.18	Non-technical energy conservation measures	NO IC	NO IC	NO IC	NO IC	5.43

Benefit / Cost ratio		Local government		Public sector (incl. DEYAMV)	Private sector	Residents
		Municipal	Schools			
A.19	Cogeneration			1.56		
A.20	Installation of Building Management Systems (BMS) - new construction	0.81		0.81		
A.21	Bioclimatic buildings - new construction	1.12			0.97	0.49
	B. TRANSPORT					
B.1	Replacement of old municipal passenger cars with hybrid ones	0.34				
B.2	Renewal of heavy duty vehicles fleet	0.29				
B.3	Renewal of garbage truck fleet	0.43				
B.4	Renewal of DEYAMV vehicle fleet			0.07		
B.5	Municipal bicycle rental system	1.59				
B.6	Extension of bicycle lane network	1.01				
B.7	Extension of the pedestrian walkways	0.80				
B.8	New car parking stations	0.88				
B.9	Urban buses - new low emissions compact buses			0.90		
B.10	Urban buses - redesign of bus lines			1.22		
B.11	Tram construction			0.29		
B.12	Eco-driving	1.77		3.88	1.75	1.75
B.13	Car pooling					2.85
	C. WATER SUPPLY AND SANITATION					
C.1	Reduction of water consumption through advertising campaigns and/or billing policy. which will result in energy demand reduction of the following services: (a) exploitation of water resources (water wells) & operation of water distribution network and (b) operation of sewage conveyance and pumping system & operation of sewage treatment plant			1.25		
C.2	Leakage minimization in water distribution network and residential connections			No quantification		
C.3	Reduction of water supply share coming from water wells (especially deep wells) by the utilization of surface water resources			No quantification		

Benefit / Cost ratio		Local government		Public sector (incl. DEYAMV)	Private sector	Residents
		Municipal	Schools			
C.4	Optimization of water supply system through the installation of "smart" valves. division of water network into additional distribution zones. etc.			1.03		
C.5	Installation of electromagnetic water meters of direct reading to improve leakage monitoring					
C.6	Changes in the electromechanical equipment (pumps. etc) and generally upgrading of the water pumping stations to increase operating equipment efficiency			0.94		
C.7	Minimization of parasitic inflow into the sewer system that causes operational problems in transporting and treating sewage			1.65		
C.8	Upgrading of the electromechanical equipment of sewage treatment plant with the aim of reducing local and linear losses			2.16		
C.9	Changes in the electromechanical equipment (pumps. etc) and generally upgrading of the sewage pumping stations to increase operating equipment efficiency			0.28		
C.10	Optimization of sewage treatment plant (STP); the measures to be specified by energy audit (resetting of control system. put switch 'off' when not in operation. leakage repair. reprogramming of load/consumption)			No quantification		
C.11	Shift electrical load to off-peak. improve power factor (STP)			No quantification		
C.12	Simple control systems (STP)			No quantification		
C.13	Further sludge treatment – possible further energy recovery (STP)			1.29		
C.14	Utilization of potential energy in surface waters to produce electricity– application of renewable energy systems. autonomous and interconnected			1.38		
	D. MUNICIPAL SOLID WASTE MANAGEMENT					
D.1	Additional paper recycling	1.57				
D.2	Biodegradable waste recycling	1.11				
	E. CITY OPERATION					
E.1	Replacement of low efficiency bulbs in street lighting	1.08				
E.2	Automation in street lighting	1.07				
E.3	Tree planting/ green areas	1.48				

Benefit / Cost ratio	Local government		Public sector (incl. DEYAMV)	Private sector	Residents
	Municipal	Schools			
F. OTHER					
F.1 Mediterranean Games' Infrastructure – Mediterranean Village			No quantification		
F.2 Rehabilitation of Glavani land property			No quantification		
F.3 Rehabilitation of fish market			No quantification		