Economic Evaluation of Sectoral Emission Reduction Objectives for Climate Change

Economic Evaluation of Carbon Dioxide Emission Reduction in the Household and Services Sectors in the EU

Bottom-up Analysis

Final Report
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Preface

On its way to its current form this report has received significant input from a considerable number of experts. In particular, a panel of experts in Brussels discussed a draft version of the report on March 29, 2000 (see Annex 2 for a list of names), and made a number of specific and more general comments and suggestions. The authors would like to thank these people for their valuable inputs into this study. For this "Final Report" it was attempted to consider their suggestions wherever possible.

EXECUTIVE SUMMARY

Within the EU, the household and private and public services sectors are an important source of carbon dioxide, accounting for 39% of total carbon dioxide emissions in 1990 and 30% of total greenhouse gas emissions. Greenhouse gases other than CO_2 contribute for less than 1% to total greenhouse emitted.
Indirect emissions related to the use of electricity play an important role in this sector. Emission from the energy supply use that can be allocated to the household and services sector contributes to about 46% of the total emissions of this sector.

Description of the sectors

There are approximately 140 million dwellings in the EU in 1995. It is expected that the number of dwellings will rise to 156 million in 2010. Almost 20% of the energy is consumed in the household sector. The average energy consumption of a dwelling in a country depends among others on many country specific circumstances. Important are: climate, building construction, building regulation and age distribution profile of dwellings. About one tenth (12%) of the energy in the EU is consumed in the services sector. The energy consumption of a services building depends very much on the standard of insulation, air conditioning, ventilation systems and the appliances used. The five most important energy-functions are heating, cooling, transport of air, heat and cold, lighting and office equipment. Energy demand for these energy-functions can vary considerably depending on the characteristics of the buildings. To examine (specific) CO_2 emission reduction options and their consequences it is often useful to break the services sector down into a number of sectors, e.g. health, education, government (excluding defence), sports and entertainment, services offices, communications and transport, hotels and catering, retail, warehousing etc.

Frozen technology reference level

The emission reduction potential for 2010 is calculated using an emission reference level based on frozen technology development. In the frozen technology reference level it is assumed that there is no energy improvement obtained and that no reduction of specific energy consumption occurs. In the frozen technology reference level the emissions of the household sector in 2010 are about 12% higher than the 1990 emissions, 750 Mt compared to 841 Mt of CO_2-equivalent. The increase is caused by the projected increase of households in the EU15. The frozen technology reference level in the services sector is about 57% higher in 2010 than in 1990, and increases from 438 Mt of CO_2-equivalents in 1990 to almost 687 Mt in 2010. The large increase is because of the projected larger role of the services sector in the economies of the EU15, increased demand for cooling and increased use of appliances.

Emission reduction options

There are numerous of options to reduce emissions in the household and services sector. For practical reasons the most important options, in terms of reduction potential, are identified and characterised. Remaining 'small' options are grouped in the options 'miscellaneous' and 'development'. The main household emission reduction option categories are the insulation of existing buildings, energy-efficient new buildings, advanced heating systems and energy efficient electric appliances. The main emission reduction option categories in the services sector are the improvement of the building shell, new efficient buildings, more efficient cooling systems, building energy management systems, improved lighting systems and improved electric office appliances. Improved refrigeration systems and use of alternative foams are options to reduce emissions of fluorinated gases.

Table 1 and 2 give an overview of the options for the household and services sector respectively, with data on reduction potentials and costs for the EU15. The specific costs are calculated using a real interest rate of 4%, using the lifetime of the option, i.e. installation or equipment.

In 2010 emission reduction potential of 315 Mt of CO_2–equivalent is identified; about 190 Mt in the household sector and about 126 Mt in the services sector. In both sectors improving energy performance of existing houses has a large reduction potential. In the services sector improved cooling systems also do have a large emission reduction potential. A further 360 Mt of CO_2–equivalent is avoided because electricity is consumed in 2010 with a lower emission factor than in 1990 (see also the energy supply sector report). Total direct and indirect emission reduction amounts therefore to 677 Mt of CO_2-equivalent.

Table 1. EU15-average costs and potential (Mt of CO_2–equivalent) for emission reduction in the household sector.

Pollutant	Measure Name	Emission reduction	Investment	Yearly costs	Lifetime[1/]	Specific abatement costs
		Mt CO2 eq.	euro/tCO2 eq.	euro/tCO2 eq.	year	euro/tCO2 eq.
CO2	Energy efficient TV and video equipment	1	0	-310	15	-194
	Very energy efficient refrigerators and freezers	0.5	0	-317	15	-187
	Efficient lighting: Best Practice (partly implemented)	1	178	-323	8	-181
	Efficient lighting: Best Practice (fully implemented)	2	178	-326	8	-178
	Miscellaneous options (cheap tranche)	11	0	-235	15	-165
	Miscellaneous options (moderate costs tranche)	11	138	-235	15	-156
	Efficient refrigerators and freezers: Best Practice	3	6686	-368	15	-57
	Retrofit houses: wall insulation [2/]	28	2269	-129	50	-42
	Retrofit houses: roof insulation	26	1600	-169	20	-29
	Subtotal: Cost range < 0 euro / t CO2 eq.	**83**				
	New energy efficient residential houses: Best Practice	12	1815	-200	20	-11
	Subtotal: Cost range 0 < 20 euro / t CO2 eq.	**12**				
	Efficient washing machines, clothes dryers, dishwashers: Best Practice	1	11227	-275	15	7
	Retrofit houses: (highly) insulated windows	49	2344	-177	20	10
	Advanced heating systems: condensing boilers	15	2038	-140	15	50
	Subtotal: Cost range 20 < 50 euro / t CO2 eq.	**66**				
	Geothermal heat production	0.2	406	-28	25	58
	New very energy efficient residential houses: Zero Energy	3	3056	-200	20	71
	Solar thermal	8	4879	-52	15	272
	Advanced heating systems: heat pumps [/3]	16	3884	73	15	432
	Subtotal: Cost range > 50 euro / t CO2 eq.	**28**				
HFC	Domestic refrigeration: hydrocarbons	1	32.5	0	15	3
	Subtotal: Cost range: 0 < 20 euro / t CO2 eq.	**1**				
	Total potential emission reduction	**190**				

[1/] The lifetime of some options (e.g. retrofitted (uninsulated) walls and efficient appliances) are chosen at the upper part of the range [De Beer et al, 1994]

[2/] An equally divided mix of the options insulating cavity (cheap) and external solid wall insulation (expensive) was chosen.

[/3] Based on average fuel/electricity use. Replacing electric heating systems may reduce specific costs down to zero for the 4% discount rate case.

Table 2. EU15-average costs and potential (Mt of CO_2–equivalent) for emission reduction in the services sector.

Pollutant	Measure Name	Emission reduction	Investment	Yearly costs	Lifetime[1/]	Specific abatement costs
		Mt CO2 eq.	euro/tCO2 eq.	euro/tCO2 eq.	year	euro/tCO2 eq.
CO2	Efficient office equipment: Best Practice	3	0	-278	5	-178
	Building Energy Management Systems (BEMS): electricity	3	0	-278	10	-178
	Efficient space cooling equipment	1	377	-277	15	-172
	Efficient lighting: Best Practice level 1	2	651	-278	8	-159
	Very efficient lighting: Best Practice level 2	1	1200	-277	8	-144
	Building Energy Management Systems (BEMS): space heating and cooling	42	0	-153	10	-129
	Retrofit services buildings: wall insulation	14	2269	-157	50	-26
	Retrofit services buildings: roof insulation	13	1600	-162	20	-8
	Subtotal: Cost range < 0 euro / t CO2 eq.	**80**				
	Retrofit services buildings: (highly) insulated windows	31	2344	-168	20	35
	New energy efficient services buildings: Energy efficiency level 1	9	4059	-159	20	146
	New very energy efficient services buildings: Energy efficiency level 2	3	6495	-159	20	312
	Subtotal: Cost range 20 < 50 euro / t CO2 eq.	**43**				
HFC	Stationary air conditioning DX (distributed technology): leak reduction[2/]	1	52.1	32.7	15	37
	Stationary air conditioning chiller: HC and NH3 [2/]	1	221.9	21.7	15	42
	Commercial refrigeration: leakage reduction	2	82.5	41.5	15	49
	Subtotal: Cost range 20 < 50 euro / t CO2 eq.	**3**				
	Total potential emission reduction	**126**				

[1/] The lifetime of some options (e.g. retrofitted (uninsulated) walls and efficient appliances) are chosen at the upper part of the range [De Beer et al, 1994]

[2/] This reduction option covers both the household and the services sector. However, no sectoral breakdown is available.

Summary of Household and Services sectors

Table 3 summarises the frozen technology reference level in the household and services sector and shows the position if all the options in Table 3 and all options in the energy supply sector were adopted.

Table 3. Summary of direct and indirect emission levels with and without implementation of the complete reduction potential of household and services sector (Mt CO_2-equivalent)

	1990		2010 reference		2010 with measures	
	households	services	households	services	households	services
Carbon dioxide	749	413	841	647	448	367
Methane	0	10	0	10	0	10
Nitrous oxide	0	11	0	8	0	8
Fluorinated gases	-	-	2	6	0	3
Total	**750**	**435**	**843**	**671**	**449**	**388**
	1184		**1514**		**837**	

Figure 1 and Figure 2 show the share in emission reduction in the household and services sector categorised in four costs brackets.

Figure 1. Households: 1990/1995 base year direct and indirect emissions per greenhouse gas (left), 2010 frozen technology reference level and reduction potentials per cost bracket (right)

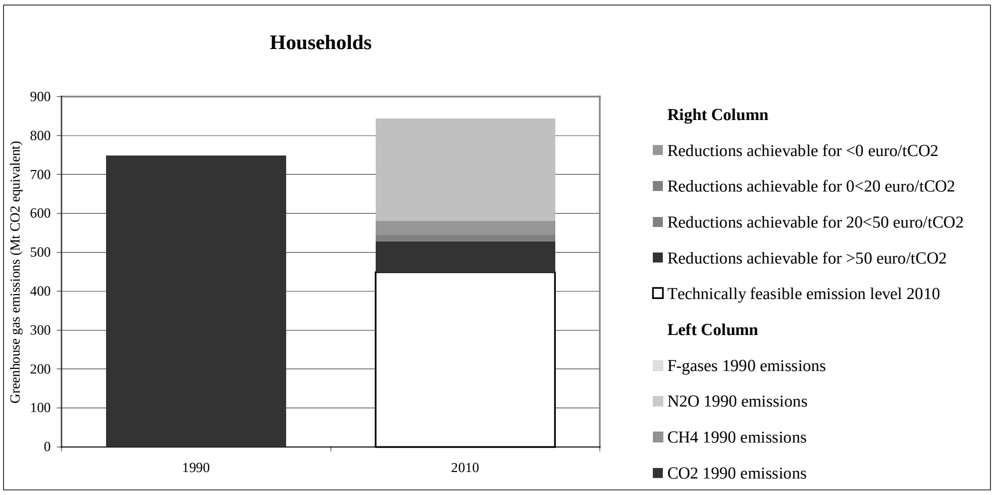
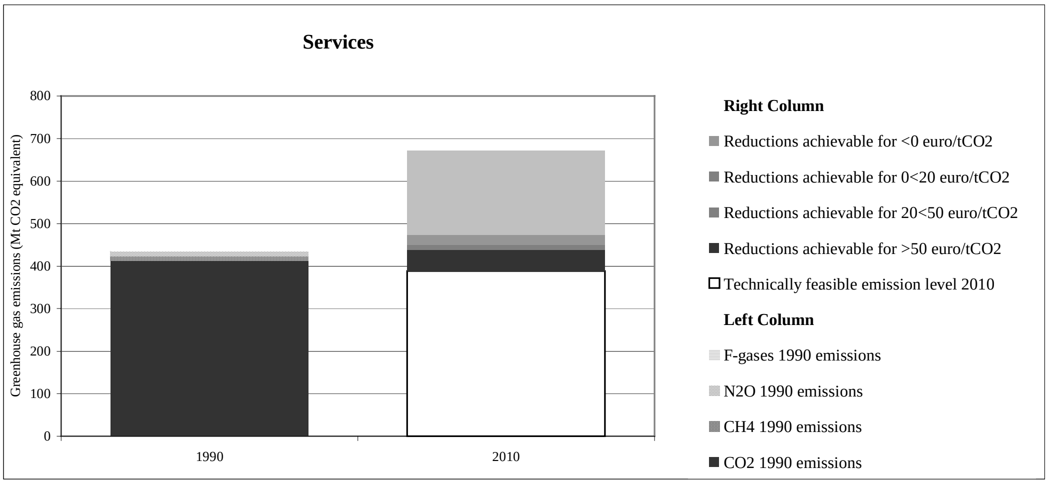


Figure 2. Services: 1990/1995 base year direct and indirect emissions per greenhouse gas (left), 2010 frozen technology reference level and reduction potentials per cost bracket (right)



CONTENT

1. INTRODUCTION

The household and private and public services sectors are important contributors to CO_2 emissions in the European Union. Emissions are caused by direct use of fuel (mainly for heating purposes) and indirectly by electricity consumption. Table 1.1 gives an overview of the greenhouse gas emissions in the household and services sector.

Table 1.1. 1990 and 2010 frozen technology reference level direct and indirect emissions from household and services sector (in sector (in Mt CO_2-equivalent).

Household sector		1990					2010				
		CO2	CH4	N2O	F-gases	Total	CO2	CH4	N2O	F-gases	Total
Austria	AUT	13	0	0	0	13	15	0	0	0	16
Belgium	BEL	26	0	0	0	26	29	0	0	0	29
Germany	DEU	236	0	0	0	236	233	0	0	0	233
Denmark	DNK	12	0	0	0	12	13	0	0	0	13
Spain	ESP	33	0	0	0	33	42	0	0	0	42
Finland	FIN	11	0	0	0	12	17	0	0	0	17
France	FRA	90	0	0	0	90	112	0	0	0	112
United Kingdom	GBR	151	0	0	0	151	171	0	0	0	171
Greece	GRC	14	0	0	0	14	18	0	0	0	18
Ireland	IRL	9	0	0	0	9	11	0	0	0	11
Italy	ITA	106	0	0	0	106	116	0	0	0	116
Netherlands	NLD	35	0	0	0	35	45	0	0	0	45
Portugal	PRT	6	0	0	0	6	10	0	0	0	10
Sweden	SWE	7	0	0	0	7	9	0	0	0	9
European Union	EU	749	0	0	0	750	841	0	0	2	843

Services sector		1990					2010				
		CO2	CH4	N2O	F-gases	Total	CO2	CH4	N2O	F-gases	Total
Austria	AUT	6	0	0	0	7	9	0	0	0	10
Belgium	BEL	13	0	1	0	14	21	0	1	0	22
Germany	DEU	163	3	2	0	167	173	3	1	2	178
Denmark	DNK	8	0	0	0	8	10	0	0	0	10
Spain	ESP	23	1	1	0	25	52	1	1	0	54
Finland	FIN	6	0	0	0	6	11	0	0	0	12
France	FRA	37	3	1	0	41	71	3	1	1	76
United Kingdom	GBR	73	1	1	0	75	131	1	0	1	134
Greece	GRC	9	0	1	0	10	26	0	0	0	26
Ireland	IRL	4	0	0	0	4	9	0	0	0	9
Italy	ITA	37	0	4	0	41	69	0	2	1	73
Netherlands	NLD	21	0	0	0	21	36	0	0	0	37
Portugal	PRT	5	0	0	0	6	17	0	0	0	18
Sweden	SWE	7	0	0	0	8	11	0	0	0	11
European Union	EU	413	10	11	0	435	647	10	8	6	671

Source: Primes (1999); UNFCCC (1999); sector study on fluorinated gases; this study.

Non-CO_2 greenhouse gases

This report only describes reduction options for CO_2 emissions while the other greenhouse gases (methane, nitrous oxide and fluorinated gases) are covered by separate reports (see http://europa.eu.int/comm/environment/enveco). Direct emissions of CH_4 and N_2O are negligible for both sectors. The emissions in the table are mainly indirect emissions from energy supply that are allocated to both sectors. Direct emissions from fluorinated gases are mainly related to refrigeration and air conditioning and show a strong increase. Emission mechanisms and control options are described in the report on fluorinated gases. The results for non-CO_2 greenhouse gases are incorporated in the overview tables as presented in this report (e.g. Table 1 of the Executive Summary).

2. OPTIONS TO REDUCE CARBON DIOXIDE EMISSIONS FROM THE HOUSEHOLD SECTOR

2.1 INTRODUCTION

Short description of the sector
Almost one fifth (20%) of the energy in the EU is consumed in the household building sector [IEA, 1996]. In most European countries the share in final energy consumption of heating (and cooling) is about 90%, while appliances and lighting consume the remainder (10%) [PRIMES, 1999].

There are approximately 140 million dwellings in the EU in 1995. It is expected that the number of dwelling will rise to 156 million in 2010 [MURE].
Over a period of 2-3 years about 175000 dwellings are removed from the stock due to demolitions and change of use. This equals less than 0.2%. This low rate of demolition is due to the fact that most European countries focus on renovation since the 1970s [Ashford, 1998].

The average energy consumption of a dwelling in a country depends among others on many country specific circumstances. Important are: climate, building habits, building regulation and age distribution profile of dwellings. These items are discussed below.

During the past decades a considerable reduction of the heating demand of newly built dwellings has already been achieved. This is mainly due because after the first oil crisis (begin 1970s) much attention was paid to thermal insulation. In several European countries there are governmental laws which set minimum requirements for insulation. On the other hand, the use of air conditioning systems in the domestic sector has been increasing the past decade and it is expected that this trend will continue in the future.
The overall energy demand of electric appliances has increased the past decade. This is mainly due to more and new equipment (e.g. PCs). To combat this trend at the European level, several guidelines to promote energy efficient equipment have been developed and have been put in force (labelling system).

Climate
The heating and cooling demand of a dwelling depends on the climate. In a cold climate the heating demand is higher than in a warm climate and vice versa. In this report three climate zones are distinguished based on the amount of degree-days (Table 2.1).

The impact of several energy saving options depends on the climate. We used the average number of degree-days in the climate zone to make corrections for the impact of these options.

Table 2.1 Climate zones and degree-days

Climate zone	Countries	# of degree days	Average # of degree days
Cold	Finland, Sweden	# > 4000	4330
Moderate	Austria, Belgium, Denmark, Germany, United Kingdom, France, Ireland, Luxembourg, The Netherlands	2500 < # < 4000	2978
Warm	Greece, Italy, Portugal, Spain	# < 2500	1785

Source: [EC, 1996; Schipper, 1985]

Building construction

The construction method differs per country. Low energy demand was first achieved in buildings using the traditional or modified North American and Scandinavian wood frame construction. In particular, Sweden performed a pioneer function in the early 1980s where dwellings with low energy demand were already common practice. Later on these low energy requirements have also been realised in buildings using Western European massive wall construction techniques. During the early 1990s, the European leadership position in implementing state-of-the-art building efficiency has even been taken over by countries using traditional masonry or other massive weight bearing walls, such as Denmark, Germany and Switzerland [Krause et al., 1998].

Building regulations

Almost all European countries have building regulations. In most countries there is an obligation for a certain insulation level for newly built dwellings [STOA, 1998]. Due to these regulations the energy demand of new dwellings is considerably lower than that of the existing stock.

Age distribution profile of dwellings

Finally another factor that influences the energy consumption is the age distribution profile of dwellings, because old dwellings or dwellings from a particular building period (before 1975) are often poorly insulated or not insulated at all. This profile differs per country. United Kingdom is skewed towards the older properties compared to for instance Ireland and the Netherlands [Ashford, 1998]. The age distribution profile is used to determine the impact of various energy saving options (e.g. insulation).

2.2 EMISSIONS

2.2.1 Emission mechanisms

To fulfil the heating, cooling, lighting and electric appliances requirements ultimately mainly techniques based on burning of fossil fuels, are used.

An approach to reduce energy consumption and therefore CO_2-emissions is the so-called "Trias Energetica strategy". This strategy has three golden rules, which are in order of importance:

1. Reduce energy demand
2. Use renewable sources
3. Use efficient energy supply technologies

In this report we concentrate on rule 1 and 3, because emission reduction options like renewables and CHP are treated in the sector report on energy supply, which is prepared in the framework of this project.

2.2.2 Emission in EU-15

Table 2.2 shows the 1990 energy use in the EU in the household sector. The energy use is split up for heating and cooling demand and electric appliances. The table shows also the 1990 and 1995 emissions of CO_2 [Primes, 1999].

Table 2.2. Final energy use (fuel and electricity) in 1990 for heating & cooling demand and electric appliances, and emission of CO_2 in 1990 and 1995 for the household sector.

	Total	Heating and cooling	Electric appliances	CO2 emission	CO2 emission
Country	1990	1990	1990	1990	1995
	PJ	PJ	PJ	Mt CO2	Mt CO2
AUT	287	263	25	9	9
BEL	349	322	27	19	19
DEU	2542	2324	218	130	129
DNK	164	140	24	5	6
ESP	388	360	28	13	14
FIN	230	203	26	6	6
FRA	1678	1554	124	71	72
GBR	1743	1542	201	88	81
GRC	160	143	16	5	7
IRL	92	87	5	7	5
ITA	1345	1244	102	69	66
NLD	415	371	45	19	23
PRT	109	91	18	2	3
SWE	286	248	38	5	4
EU	9790	8892	898	447	444

Source: Primes (1999)

2.2.3 Introduction

A literature study was conducted to find out which measures enable CO_2 emission reductions in the building sector (domestic and services buildings). The outcome was a list of measures, which can be categorised in 10 main groups. An overview is given in Annex 1.

Within the scope of this investigation this list is too detailed, so only the most important measures are described in this paper. Insulation in existing buildings, energy-efficient new buildings, advanced heating systems and energy efficient electric appliances appeared to be very significant options.

Limitations

This study aims at giving a first indication for the CO_2 emission reduction measures in the household sector. Possible follow-up studies can fine-tune the used data (see also recommendations, needs for information). As just stated the presented options are by no means exhaustive. Also the trend of increasing sizes of dwellings in Europe is not taken into account. Due to the fact that there is little country specific information available to what extent measures are already implemented, there are probably greater differences between countries in term of potentials than the results indicate at this moment (average penetration levels are assumed in case specific country information is not available).

Insulation of existing buildings

In a standard dwelling in the Western European climate, the largest heat losses appear through walls and windows, about 21% and 29% of the total heat losses respectively [Krause et al., 1998].

For this reason the following retrofit measures were chosen:

- wall insulation
- replacing single and double glazing by advanced insulating windows
- because it is simpler and cheaper than wall and window insulation the option of roof installation is also included (about 11% of the total heat losses)

Energy-efficient new buildings

It is already possible to build dwellings with a (very) low energy demand with the same comfortable living standards as for average energy consuming dwellings. In many European countries a considerable number of new dwellings will be built during the period 2000 – 2010. Therefore it is of great importance to increase the implementation rate of (very) low energy demand dwellings.

Advanced heating systems

There are several advanced proven heating systems on the market, which could contribute to considerable savings of fossil fuels. The application of these systems, such as condensing boilers and heat pumps will contribute significantly to CO_2 emission reduction. From the point of view of costs the natural moment of replacement is preferable.

Electric appliances
It is expected that the energy consumption of electric appliances (including lighting, cold, wet and brown appliances[1]) will continue to grow rapidly (as in the past decade) [Huiskamp, 1998]. Therefore measures in this field are necessary. One way of doing so is to stimulate the purchase of very efficient appliances.

Overview of options
Table 2.3 shows the options that were chosen for analysis in this study. Also it is indicated what the additional penetration potential is assumed to be until 2010 (on top of autonomous developments) and to which section of the sector the measure can be applied. The penetration is limited by factors like the replacement rate of equipment (e.g. 15 years for condensing boilers and most appliances) and by an assumed (historically observed) maximum retrofit rate of existing dwelling of 3% per year.

Table 2.3. Overview of selected options in this study

Option	Additional potential penetration in the period 2000-2010	Section of sector
Building shell - Wall insulation - Roof insulation - (Highly) insulated windows	 20% 20% up to full penetration	Existing dwellings
Low energy dwellings Zero energy dwellings	50% 10%	New dwellings
Advanced heating systems - Condensing boilers - Heat pumps	 30% 20%	Individual dwellings without district heating
Electric appliances: - Compact fluorescent lamps - Efficient refrigerators, freezers (best practice 1999) - Efficient refrigerators, freezers (Economic and technical potential) - Efficient washing machines, dishwashers, clothes dryers (best practice 1999) - Efficient televisions (best practice 1999)	 55% 70% 35% 70% 70%	All dwellings

[1] Cold appliances: Refrigerators, fridge-freezers and freezers; Wet appliances: washing machines, dishwashers and clothes dryers; Brown appliances: televisions, etc.

2.2.4 Option 1: Improving building shell: wall insulation

2.2.4.1 Description

Heat losses of existing poorly insulated houses can be reduced through insulation. Particularly retrofit wall insulation can save substantial quantities of energy since the heat loss per unit of wall surface can be reduced substantially and the current penetration level of retrofit wall insulation is low. By wall insulation of uninsulated houses the heat losses through the wall are reduced by around 30% [Ashford, 1998; MURE]. It could be expected that the total saving of the energy demand for space heating across Europe's domestic building stock would be in the order of 20% from insulation alone [Ashford, 1998].

An indication of energy savings and costs are shown in Table 2.4.

Table 2.4. Energy savings and costs of wall insulation of existing dwellings

	Energy saving* [$MJ/m^2/yr.$]	Investment cost [$euro1990/m^2$]
Insulating a cavity wall	285	10
Insulating a solid wall (external)	400 – 600	75 - 100
Insulating a solid wall (internal)**	400 – 600	25

* dependent on number of degree-days
** this option is not used in the analysis, the measure would result in a smaller living area
Source: Joosen (1999)

2.2.4.2 Autonomous development

The uninsulated building stock in 1995 is known from literature or estimated. The estimation is based on values in literature [Huiskamp, 1999 and Krause et al., 1998]. Approximately 50% of the total building stock of countries in the cold and moderate climate zone was uninsulated or poorly insulated in 1995[2]. In countries with a warm climate this is estimated to be about 90%. For 2010 is assumed that the already retrofitted building stock will increase (about 10%), based on renovation rates in the last decade [Huiskamp, 1999].

2.2.4.3 Further energy efficiency improvement

First the number of households and their corresponding energy use for heating are calculated for 1995 and 2010 [PRIMES, 1999]. The number of dwellings is assumed to be the same as the number of households. Other literature data [UN, 1997; VROM, 1998; EC, 1993] confirm that this assumption is sufficiently accurate for this analysis. Subsequently the average heating demand per dwelling is estimated. The heating demand for an uninsulated dwelling is based on information from the MURE database (energy consumption of old and/or intermediate aged houses), and proportional adjusted to PRIMES data. The energy savings per m^2 wall surface are known (see Table 2.4). The average exterior wall surface per dwelling is assumed to be 40 m^2. [Joosen, 1999]. On this basis

[2] Comment of some reviewers: lower percentage for countries in the cold climate zone.

the saving by wall insulation, equally distinguished in solid and cavity wall construction, can be calculated per dwelling.

Subsequently the European average space heating demand of an uninsulated dwelling and the corresponding energy saving by wall insulation are determined (respectively 1.39 and 0.42 TOE per dwelling). The saving percentage is 30% of the space heating demand of an uninsulated dwelling. The space heating demand of uninsulated dwelling varies from low in a country with a warm climate to high in a country with a cold climate. By applying the saving percentage the estimated saving potentials are automatically climate corrected. It is also taken into account that countries with a low space heating demand for an uninsulated dwelling (due to for instance higher building standards) have a relative lower saving potential.

As the next step an estimate is made of the extra amount of retrofitted dwellings. In option 1 it is assumed that 20% of the walls are insulated in addition to the expected level of the already renovated building stock in 2010. This is based on the assumption that 3% of the uninsulated building stock can be handled per year. Finally the total saving potential is calculated by multiplying the number of dwellings with the saving per dwelling.

Note that the use of average values is useful for the purpose of this study, but in practice both energy savings and costs will vary significantly due to local circumstances.

2.2.4.4 Costs

Per m^2 wall the costs for wall insulation are around 75 to 100 $euro_{1990}$ (external solid construction) and 10 $euro_{1990}$ (cavity construction) [Joosen, 1999]. Furthermore it is assumed that there is 40 m^2 wall per dwelling and that 50% of the building stock has a solid construction and 50% a cavity construction. This results in an average cost per dwelling of about 1950 $euro_{1990}$ (3500 $euro_{1990}$ per dwelling in case of solid construction and 400 $euro_{1990}$ per dwelling in case of cavity construction).

2.2.5 Option 2: Improving building shell: roof insulation

2.2.5.1 Description

Roof insulation is cheaper and simpler to implement than wall insulation. The energy saving depends on both the roof type and the heat demand of the room beneath the roof (low heat demand results in low energy saving, high heat demand results in high energy saving).
Energy savings of roof insulation are estimated to be between 155 and 320 MJ per m^2 roof surface [Joosen, 1999]. The costs of roof insulation are between 15 and 40 $euro_{1999}$ per m^2 roof surface [Reydellet, 2000; Joosen, 1999].

2.2.5.2 Autonomous development

Due to the fact that roof insulation is economical favourable the expectation is that the percentage of building stock without some sort of roof insulation is in northern European countries lower than the percentage without wall insulation. In some countries this is indeed the case (less than 11 % of the building stock without some sort of roof insulation in the UK, [Ashford, 1998]). In other countries the amount of roof insulated dwellings is comparable with wall insulated dwellings (in the Netherlands 60% of the overall building stock has roof insulation compared to 62% wall insulation in 1998, [Huiskamp, 1999]).
As for wall insulation it is also assumed for roof insulation that approximately 50% of the total building stock of most countries in the cold and moderate climate zone was uninsulated or poorly insulated in 1995. In countries with a warm climate this is estimated to be about 90%.
For 2010 it is assumed that the already retrofitted building stock will increase (about 10%), based on renovation rates in the last decade [Huiskamp, 1999].

2.2.5.3 Further energy efficiency improvement

The same method is used as for wall insulation (see paragraph 2.2.4). The energy savings per m^2 roof surface are known: between 155 and 320 MJ. The average roof surface per dwelling is assumed to be 60 m^2. [Joosen, 1999]. So the saving by roof insulation, taking the average of low and high energy savings, can be calculated per dwelling. Subsequently the European average space heating demand of an uninsulated dwelling and the corresponding energy saving by roof insulation have been determined (respectively 1.39 and 0.45 TOE per dwelling). The saving percentage is 32% of the space heating demand of an uninsulated dwelling.
As the next step, an estimate is made of the extra amount of retrofitted dwellings. In option 2 it is assumed that 20% of the roofs are insulated in addition to the expected level of the already renovated building stock in 2010. This is based on the assumption 3% of the uninsulated building stock can be handled per year.
Finally the total saving potential is calculated by multiplying the number of dwellings with the saving per dwelling.

2.2.5.4 Costs

The costs of roof insulation vary considerable from 13 euro$_{1990}$ upto 35 euro$_{1990}$ per m^2 roof surface. Do-it-yourself and attic insulation are the cheapest options. The average cost per dwelling are estimated to be around 1475 euro$_{1990}$, based on the assumptions that the average roof surface is 60 m^2.

2.2.6 Option 3: Improving building shell: windows

2.2.6.1 Description

Another important insulation measure is the replacement of single windows or double pane windows by highly insulated windows (Argon-filled low e-window (U-value glass 1,1 W/m^{2}K)) and superwindows (U-value glass 0.3-0.4 W/m^{2}K^3).[4]

Option 3 concerns renovation of existing dwellings. Application of highly insulated windows in new dwellings is part of option 4a and 4b.
An indication of the savings and costs of insulated windows compared with single windows are shown in Table 2.5.

Table 2.5. Additional energy savings and cost of highly insulated windows compared with single windows

	U-value*) [W/m^{2}K]	Energy saving [MJ/m^2/yr]	Costs**) [euro$_{1990}$ /m^2]
Single pane	5		
Double pane	3	790	90-100
Argon-filled low-e window	1,5	1105	100-120
Superwindow	1	1200	About 175

Source: Krause et al. (1998); Joosen, (1999); Laffont and Janssen, (2000)
*) U-value – heat transmission coefficient. The lower this value is, the smaller is the heat loss. **Including losses through frame**
**) Including installation costs in an existing frame

The available saving potential through applying insulating glazing has been researched extensively within a DGXVII sponsored project conducted by FachinformationsZentrum Karlsruhe (FIZ) and the Comite Permanent des Industries du Verre de la Communauté Economique Europeenne (CPIV). As part of the THERMIE programme action a report is published entitled ‘Major Energy Savings, Environmental and Employment Benefits by Double-Glazing and Advanced Double-glazing Technologies’ [Ashford, 1998]. According to this study approximately 60% of all windows in the EU are single glazed. In the domestic sector the implementation rate of insulated windows in countries with a moderate and cold climate is likely to be higher than 40% in 1998 (e.g. about 80% in Germany within its pre-1990 borders [Krause et al., 1998] and the Netherlands [Huiskamp, 1999][5]). In general the replacement of glazing is linked to the natural moment of replacement of frames. In most countries double panes nowadays represent the standard offer. This means that energy saving opportunities related to low-e glazing are hardly exploited [Laffont, 2000]. At the moment there is a strong evolution in the German, Belgium, French and

[3] Balance U value, taking into account not only heat losses, but also solar gains. In this report the term superwindow is used for the highest technical feasible insulating window.
Since ten years windows with triple glazing (U-value glass 0.76 W/m^{2}K) are available. For instance standardly implemented in ‘Passiv Hauser’ in Germany.
[4] The option to insulate a single pane window by placing a second window on it in the old frame has not been considered in this study. Background: only under specific circumstances this option is preferable above double panes. (These circumstances are: only applicable for small windows (2 m^2), façade and/or (leaded) window has to be intact and limited budget available.)
[5] Also Finland and Sweden have very likely a much higher implementation rate than 40%, double glazing is a standard since decades.

Dutch market where low-e insulated window are becoming more and more a standard product. Sweden and Finland have had double glazing as a standard for decades and triple glazing is the present standard.

2.2.6.2 Autonomous development

In most European countries there are regulations for the insulation degree for newly built dwellings. In France, The United Kingdom, Italy and Spain highly insulated windows are not yet required for new dwellings. For the existing building stock there are generally no standards (exception German regulation) [Laffont, 2000]. The number of existing dwellings with uninsulated windows is estimated based on values in literature [Ashford, 1998; Huiskamp, 1999, and Krause et al., 1998]. The autonomous development in 2010 is based on the expectation that the number of dwellings with insulated windows will increase (about 20%), based on implementation rates of the past decade.
The energy savings per m^2 window surface are known (see Table 2.5). It is assumed that the average window surface per dwelling is 21 m^2 [Joosen, 1999; MURE]. On this basis the average energy saving if the single or double pane windows are replaced by Argon filled low-e windows or superwindows can be calculated. Just as in option 1 (wall insulation) it is assumed that the number of households is equal to the number of dwellings.

2.2.6.3 Further energy efficiency improvement

Option 3 consists of replacement of the remaining single windows in 2010 which are not covered by the autonomous development. It is assumed that 50% is replaced by double glazing, 40% by Argon-filled low-e glazing and 10% by superwindows. This leads to a European average energy saving of 34.5% of the space heating demand per uninsulated dwelling.

2.2.6.4 Costs

The figures from Table 2.5 are used. Per dwelling the cost for implementation of double-glazing is 1995 $euro_{1990}$, Argon-filled low-e window is 2310 $euro_{1990}$, for implementation of superwindows 3675 $euro_{1990}$ [Krause et al., 1998; Joosen, 1999, Laffont and Janssen, 2000]. For option 3 these figures lead to average cost of 2289 $euro_{1990}$ per dwelling[6].

2.2.7 Option 4a and b: Low & zero energy buildings

2.2.7.1 Description

Low energy dwellings

[6] These costs are based on information of Dutch installers and the glazing industry, some reviewers think these costs will be higher.

So-called superinsulated prototype dwellings have been built over the last 15 years in both Europe and North America. Their energy requirement for space heating is typically about 30-50 kWh/m^2, this is about 40% lower than the average standard for new buildings.
This is mainly achieved by the following measures:
- Highly insulated building shell (U-value floor and external walls 0.20 W/m^{2}K, roof 0.15 W/m^{2}K).
- Argon filled low-e windows
- Ventilation rates are reduced to average air exchange rates of 0.3 per hour using demand-orientated ventilation systems. (Air quality benefit is higher than that provided by uncontrolled infiltration of the same average magnitude: when the building is fully occupied, ventilation provides more than the average per hour rate and vice versa) [Krause et al., 1998].

A recent project of the WWF in the Netherlands shows that it is already possible to realise low energy dwellings (about 30 kWh/m^2) on a commercial basis.

Zero-energy dwellings
The advances in component technology (e.g. superwindows, vacuum insulation) combined with improved design tools will allow to realise dwellings with no or a very low space heating requirement (0-15 kWh/m^2). Here, space heating related energy use is more or less limited to the electricity demand for operating ventilation systems and controls (few hundred kWh in a well-designed system).
An example of recent demonstration project is: townhouses in Darmstadt-Kranichstein in Germany with a space heating requirement of 10-15 kWh/m^2.

The field experience suggests that present building technology alone would allow the construction of completely passive-solar dwellings in Southern Europe [Krause et al., 1998].

2.2.7.2 Autonomous development

The autonomous development in 2010 is based on the assumptions that:
- The change of number of households between 1995 and 2010 is the same as the number of newly built dwellings. Demolition rates are so low that they can be neglected (less than 0.2% per year [Ashford, 1998*;* MURE, *year*]).
- New dwellings built in the period 2000 – 2010 have 44% lower energy space heating demand than new dwellings in 1990, among others due to strict building regulations.

2.2.7.3 Further energy efficiency improvement

We estimated as realistic technical potential that 50% of the new dwellings will be low-energy (option 4a) and 10% will be zero-energy (option 4b).

Option 4a Low energy dwellings

The half of the newly build dwellings is built according the standard of low energy. Compared to the autonomous scenario in 2010 the energy demand per dwelling is reduced by 25%.

Option 4b Zero energy dwellings

Ten percent of the new building stock is built as zero-energy dwellings. Compared to the autonomous development in 2010 the energy demand per dwelling is reduced by 55%.

2.2.7.4 Costs

The costs calculations are based on extra cost per dwelling found in literature. These additional investment costs are [Krause et al., 1998]:

- 2908 $euro_{1990}$ for a low energy dwelling
- 6786 $euro_{1990}$ for a zero energy dwelling.

The latter figure represents the average of high and low cost zero-energy dwellings.

2.2.8 Option 5: Advanced heating systems: condensing boilers

2.2.8.1 Description

A considerable amount of the fossil fuel combustion products consists of water vapour. Condensing boilers use a heat exchanger to condense the water vapour and extract the heat. Hence, the latent heat of the water vapour is made use of and the efficiency of the boiler is improved.

2.2.8.2 Current practice option

In most European countries the current efficiency of gas-fired heating equipment is about 70% (higher heating value), the efficiency of equipment based on other fuels is lower [MURE].

In some countries the share of condensing boilers is already considerable. In the Netherlands for instance about the half of the building stock is already heated by condensing boilers [Huiskamp, 1999]. In other European countries the implementation level is much lower [STOA, 1998].

2.2.8.3 Implementation of option

To calculate the energy savings the following assumptions have been made:

- A condensing boiler achieves 25% improvement of the heat efficiency of the heating equipment (from 70% to 95% based on higher heating value).
- The option is only applied to individual dwellings without district heating.

Option 5 assumes a 30% replacement of heating equipment by condensing boilers. The extent of replacement is limited for technical reasons. For instance condensing boilers cannot directly replace heating equipment based on oil (pollution) and furthermore the place of the condensing boiler is crucial (enough draft).

2.2.8.4 Costs

The investment cost including installation of a condensing boiler is approximately 1968 $euro_{1990}$ [Joosen, 1999]. The additional costs relative to a conventional boiler in 1997 are 913 $euro_{1990}$. The additional annual maintenance cost is about 16 $euro_{1990}$. Yearly maintenance of a boiler is certainly necessary to provide a properly functioning heating system.

2.2.9 Option 6: Advanced heating system: heat pumps

2.2.9.1 Description

A heat pump transports heat of a low temperature level to a high temperature level. Heat is extracted from the environment (soil, air, ground water, exhaust air from dwelling, sewage) upgraded using a compressor and delivered to either a radiator or warm air heating system. An indication of the energy saving per dwelling is: 75% (final energy) and 30% to 50% (primary energy).

2.2.9.2 Autonomous development

In excess of 2.5 million heat pumps are currently installed in the size range from 1 kW to 8 MW. Small heat pumps are used in single family dwellings and the larger installations in multi-family dwellings and small district heating schemes. The biggest opportunity for CO2 savings is the 20% of the EU housing stock currently electrically heated by direct radiators, storage heaters or electric boilers.

2.2.9.3 Further energy efficiency improvement

For the calculation of energy saving the following assumptions have been made:

- A heat pump with a Coefficient of Performance of 3.0 has been assumed.
- The option is only applied to individual dwellings without district heating.
- There is a fuel switch from traditional fuel heated dwellings to electric driven heat pump heated dwellings.

Option 6 assumes that - relative to the autonomous development - 20% of the conventional heating equipment is replaced by heat pumps.

A substantial higher reduction of CO_2 emission can be obtained when heat pumps are applied in households currently electrically heated by direct radiators, storage heaters or electric boilers.

2.2.9.4 Costs

The costs of this option vary considerable dependent on the market segment where the heat pump is applied (e.g. existing or new dwelling, in project or not, large / small heat demand of dwelling). The investment costs are assumed to be 8930 $euro_{1990}$ for an individual heat pump. The operational cost are 2,5% of the investment costs, i.e. 225 $euro_{1990}$ per heat pump.
However, these costs can be half as high in case one single ground source is used for several new dwellings built closely to each other.

2.2.10 Option 7: Lighting: Compact fluorescent lamps

2.2.10.1 Description

The energy consumption of lighting is a substantial part of the total energy consumption of the domestic sector. In the investigated European countries the share of lighting varies from 12% to 32% in terms of the energy consumption of electric appliances.

Compact fluorescent lights (CFLs) are essentially folded fluorescent tubes. Nowadays there is an extensive assortment in shape and fitting. This means that in many cases the light bulbs can be replaced by CFLs. A CFL has three advantages compared to a standard light bulb:

1. At the same light production they use much less electricity (at least 60%),
2. Longer lifetime (10000 burning hours instead of 1250),
3. They are cheaper (higher purchase price counterbalances electricity savings and longer lifetime)

2.2.10.2 Autonomous development

The country profiles of domestic lighting in Europe are based on values in literature [Palmer et al., 1998] and in the MURE II database. For the autonomous development in 2010 is assumed that:

- The demand for lighting in 2010 increases by 11% compared to 1995 (assumed same ratio as rise in number of households).
- The use of CFL in households increases by about 10%.
- Reduction of 60% of the energy consumption for lighting.

2.2.10.3 Further energy efficiency improvement

Options 7a and 7b assume a higher penetration level than the autonomous scenario in 2010, with an additional penetration of 15% and 40% respectively. These implementation levels are based on the assumption that in 2010 a price reduction is achieved so that also replacement of bulbs with few operation hours will become cost-effective.

2.2.10.4 Costs

The payback time is dependent on the annual operating hours as well as the relative bulb prices and the cost of electricity. Assuming:

- an average price of 13 $euro_{1990}$ for a 20W CFL and
  0.7 $euro_{1990}$ for a 60WGLS bulb
- CFL has a lifetime of 10000 burning hours, the lifetime of a GLS is 8 times shorter
- a 20W CFL replaces a 60W GLS bulb used for 3.5 hours a day

results in additional investment cost of 0.018 $euro_{1990}$ /saved kWh/year. This is equivalent to a simple payback time of about 2 years.
This means taking lifetime costs into account, an ecolamp giving an equivalent of 60 Watts would be 52% cheaper than a normal lamp.

Of course for bulbs used only an hour a day this simple payback period is much longer (exceeding 7 years) [Palmer et al., 1998].

2.2.11 Option 8 Efficient cold appliances

2.2.11.1 Description

Cold appliances (refrigerators, freezers etc.) use 20% to 58% of the energy consumption of all electric appliances [MURE]. A European labelling system is introduced to make customers more aware of energy efficiency.

2.2.11.2 Autonomous development

The current Best Practice appliances with respect to energy consumption are [Energy guide]:
- Refrigerators with an annual energy consumption of 150 kWh
- Freezers with an annual energy consumption of 208 kWh.

To estimate the energy consumption by 2010 in the autonomous development trajectory it is assumed that:
- The share of the energy consumption of cold appliances in 1995 is based on information from the MURE database.
- The amount of energy consumption due to cold appliances increases according the growth in the MURE database.
- The average of energy consumption per cold appliance stays the same.

2.2.11.3 Further energy efficiency improvement

Option 8a: All best practice
This measure consists of reducing the average level of energy consumption to the best practice level in 1999. It is assumed that 65% of the total stock will be replaced by best practice equipment.

Option 8b: Economic and technical potential (ETP)
In case new techniques are used, such as vacuum insulation, energy savings by 80% can be achieved compared to the average energy consumption in 1995 [Boardman et al, 1997a; Boardman et al, 1997b]. It is assumed that 5% of the total stock will be replaced by equipment with such a high efficiency.

2.2.11.4 Costs

The additional investment costs of best practice cold appliance are [Energy Guide]:

- for refrigerators 170 $euro_{1990}$ per GJ electricity saved per annum
- for freezers 240 $euro_{1990}$ per GJ electricity saved per annum

According to PRIMES the additional investment costs for cold appliances vary between 185 and 231 $euro_{1990}$ per annual saved GJ electricity for cold appliances.

The costs of option 8b (ETP) are still unknown, but will be higher than for option 8a.

2.2.12 Option 9: Efficient wet appliances

2.2.12.1 Current practice option

Wet appliances (washing machines, dishwashers and clothes dryers) account for 14% to 28% of the energy consumption of all electric appliances [MURE]. A labelling system is introduced to make customers more aware of energy efficiency.

2.2.12.2 Autonomous development

The current Best Practice machines with respect to energy consumption are [Energy Guide]:

- Washing machines with an annual energy consumption of 200 kWh
- Dishwashers with an annual energy consumption of 132 kWh
- Gas-fired dryers use 39% less energy than electric dryers.
  Heat pump clothes dryers have an annual energy consumption of 250 kWh (energy reduction by approximately 50%) [Holsteijn et al, 1999]

To estimate the energy consumption by 2010 in the autonomous development trajectory it is assumed that:

- The share of the energy consumption of wet appliances in 1995 is based on information from the MURE database.
- The amount of energy consumption due to wet appliances increases according the growth of appliances in use according to the MURE database. For the Netherlands it is expected that the growth of clothes dryers will continue [Huiskamp1997, Huiskamp, 1998].
- The average of energy consumption per wet appliance is assumed to remain unchanged compared to 1995.

2.2.12.3 Further energy efficiency improvement

Option 9: All best practice

This measure aims to reduce the average level of energy consumption to the best practice level in 1999. It is assumed that - by gradual replacement - a 70% implementation rate of best practice equipment will be achieved by 2010.

Economic and technical potential
The economic and technical potential is almost the same as the best practice level for washing machines and dishwashers [Boardman et al., 1997a].
Heat pump clothes dryers have an energy saving potential of around 50% [Holsteijn et al., 1999]

2.2.12.4 Costs

The additional costs of best practice wet appliance are:
- for washing machines 982 $euro_{1990}$ per GJ electricity saved per annum
- for dishwashers there is not a clear relation between energy efficiency and price [Energy Guide diskette].
- 215 $euro_{1990}$ for a gas-fired dryer and 405 $euro_{1990}$ for a heat pump dryer.

2.2.13 Option 10: Efficient brown appliances

2.2.13.1 Description

Due to the fact that detailed data are only available for televisions this option is restricted to this type of brown appliances [MURE]. Televisions use 4% to 13% of the energy consumption of electric appliances.

2.2.13.2 Autonomous development

The current best practice television (with respect to energy efficiency) has an average energy consumption of 38 kWh per year [MURE].

To estimate the energy consumption by 2010 in the autonomous development trajectory it is assumed that:
- The share of the energy consumption of brown appliances in 1995 is based on information from the MURE database.
- The amount of energy consumption due to brown appliances increases according the growth in the MURE database.
- The average of energy consumption per brown appliance stays the same as in 1995.

2.2.13.3 Further energy efficiency improvement

Option 10: All best practice
The goal of this measure is to reduce the average level of energy consumption to the best practice level in 1999. The assumed implementation level of best practice equipment is 70% based on the lifetime of 15 years.

The additional costs of best practice television are expected to be negligible in 2010.

2.2.14 Option 11: Miscellaneous efficient appliances

2.2.14.1 Description

The preceding sections described specific appliances. A number of appliances is only partially covered, e.g. appliances for hot water production and cooking and a range of small electric appliances.

2.2.14.2 Autonomous development

We assume that autonomous development of the energy efficiency for these appliances is 1% per year.

2.2.14.3 Further energy efficiency improvement

We assume that additional savings of 30% are possible at typical investment costs of 20 euro per GJ (see, e.g. [De Beer et al., 1994]).

3. OPTIONS TO REDUCE CARBON DIOXIDE EMISSIONS FROM THE SERVICES SECTOR

3.1 INTRODUCTION

Short description about the sector

The services sector comprises the subsectors health, education, government (excluding defence), sports and entertainment, commercial offices, communications and transport, hotels and catering, retail, warehousing, craftmanship etc. About one tenth (12%) of the energy in the EU is consumed by the services sector [IEA, 1996]. The energy consumption of a services building depends very much on the conditions to provide a good indoor-climate and on the equipment to perform specific tasks.

The five most important energy-functions are:

1. Heating: to establish a comfortable indoor temperature
2. Cooling: to establish a comfortable indoor temperature
3. Transport: to transport fresh air from outside to the desired place and to transport thermal energy (heat or cold) to the desired place
4. Lighting: to provide sufficient sight for performing tasks
5. Equipment: to perform or support tasks (e.g. computers, photo copiers etc.)

Energy demand for these activities can vary considerably depending on the characteristics of the buildings. To examine (specific) CO_2 emission reduction measures and their consequences it is often useful to break the services sector down of the subsectors mentioned above. [Lillicrap and Ashford, 2000; ECN, 1999]). Each of these sectors has specific characteristics which can often dictate the most effective CO_2 emission reduction measures. Typical savings are in the range of 25% of energy use for comprehensive refurbishment in some sectors.

The heating demand of buildings is currently declining. For newly built buildings this is among others due to governmental laws concerning energy efficiency. For the existing stock this is due to renovation projects. The expectation for 2010 is that this trend will continue.

For the energy demand of cooling three tendencies are observed:

1. Increase of the amount of appliances, leading to more internal heat generation and therefore, to higher cooling loads.
2. Increase of energy efficiency of lighting and appliances, leading to internal heat generation and therefore lower cooling loads.
3. Increased comfort demands, causing higher cooling loads.

The sum of theses three trends is expected to lead to an increase of energy demand for cooling in the future.

The energy demand of office appliances has increased the past decade. This is mainly caused by more and introduction of new equipment. Although there is also the trend of techniques becoming more energy efficient, the expectation for autonomous development in 2010 is that there will be an overall increased energy demand for appliances.

It should furthermore be noted that, in contrast to the domestic sector, there is very little quantified information on building stock in the services sector at the European level. For this reason, the uncertainties of the model calculations are higher for the services sector than for the household sector.

3.2 EMISSIONS

3.2.1 Emission mechanisms

The energy demands of the five important energy-functions (heating, cooling, transport, lighting and equipment) are mainly fulfilled by techniques that are based on the burning of fossil fuels.

To reduce the burning of fossil fuels and their CO_2-emissions the so-called “Trias Energetica strategy” can be used. The three golden rules according to this strategy are in order of importance:

1. Reduce energy demand
2. Use renewable sources
3. Use efficient energy supply technologies

As for the household sector, we focus for the services sector on rule 1 and 3, because emission reduction options like renewables and CHP are treated in the sector report on energy supply, which is prepared in the framework of this project.

Table 3.1. Final energy use (fuel and electricity) in 1990 for heating & cooling demand and electric appliances, and emission of CO_2 in 1990 and 1995 for the services sector].

	Total	Heating and cooling	Electric appliances	CO2 emission	CO2 emission
Country	1990 PJ	1990 PJ	1990 PJ	1990 Mt CO2	1995 Mt CO2
AUT	82	73	9	3	3
BEL	140	125	15	7	14
DEU	1554	1384	170	82	51
DNK	139	125	14	3	2
ESP	217	193	25	8	16
FIN	98	87	11	2	1
FRA	678	606	71	23	32
GBR	630	560	70	24	43
GRC	65	55	10	3	4
IRL	40	35	4	2	6
ITA	292	250	42	9	15
NLD	405	343	62	19	27
PRT	44	39	5	2	3
SWE	191	171	20	6	4
EU	4574	4042	531	193	222

Source: Primes (1999)

Table 3.1 shows the 1990 energy use in the EU in the services sector. The energy use is split up for heating and cooling demand and electric appliances. The table shows also the1990 and 1995 emissions of CO_2 [Primes, 1999].

3.3 EMISSION REDUCTION OPTIONS

3.3.1 Introduction

A literature study was conducted to find out which measures in the entire building sector (domestic and services) lead towards CO_2 emissions reduction. The outcome was a list of measures, which can be categorised in 10 main groups. An overview is given in Annex 1.

Within the scope of this investigation this list is too detailed, so the more important measures from this list are selected. Due to the shorter periods of occupancy in the services sector compared to the domestic sector good energy management deserves special attention.

Limitations

Compared with the domestic sector there is much less detailed information available of the services sector. This lack of information is confirmed by various information sources [Ashford, 1998; Krause et al., 1998]. For this reason the CO_2 reduction potential in the services sector is based on saving percentages concerning the overall measure instead of saving percentages concerning the measure at building level.

Wherever transferable, the results for the domestic sector are used. To account for the specific situation in the services sector, corrections are made based on information found in the literature.

This study aims at giving a first indication for the CO_2 emission reduction measures in the services sector. Possible follow-up studies can fine-tune the used data (see also recommendations, need for information). As just stated the presented options are by no means exhaustive. It should be noted that there are probably greater differences between countries in terms of potentials than the results indicate at this moment (cause: average penetration levels are assumed in case specific country information is not available).

Due to the lack of data in PRIMES Luxembourg is excluded from this study. Industrial buildings are part of the sector industry. Therefore they are outside the scope of this chapter.

Renovation

The measures to reduce the heating energy demand are in principle the same as in the domestic sector. Heat losses can be reduced through, amongst others:

- Wall and roof insulation
- Replacing single glazing by advanced insulating windows.
- Improved insulation of buildings
- Better control systems

As a consequence of improved insulation, additional ventilation might become necessary in order to maintain a good indoor climate (e.g. avoid draught problems) perhaps extra ventilation will become necessary.

New buildings
Buildings with a (very) low energy demand compared to the current standard are already realised. It is expected that a considerable number of new buildings will be built in many European countries during the period 2000-2010. It is important that a significant amount of these new buildings has a (very) low energy demand. The long lifetime of the building shell (about 50 years) is a decisive argument for this measure.

Building Energy Management Systems (BEMSs)
Building Energy Management Systems can avoid and reduce the energy demand of a building by switching off energy-functions (heating, cooling, transport, lighting and appliances) when they are not required. BEMS's automatically control window blinds to prevent unwanted irradiation. These BEMSs are especially important in the services sector where there is lower occupancy [STOA, 1999; Ashford, 1998].

Cooling
The energy demand for cooling contributes significantly to the energy consumption of services sector. The demand for cooling services is expected to grow in the near future. Therefore attention has to be paid towards this option.

Table 3.2. Overview of selected options in this study

Option	**Additional potential penetration in the period 2000 – 2010**	**Section**
Building shell - Wall insulation - Roof insulation - (Highly) insulated window	 20% 20% up to full penetration	 Existing buildings
New energy efficient buildings	50 + 10%	New buildings
Efficient cooling systems	70%	All buildings
Building Energy Management Systems (BEMSs)	70%	All buildings
Efficient lighting systems	60 + 10%	All buildings
Efficient office appliances	50%	All buildings

Equipment
During the past few years the energy demand for equipment has rapidly increased. The expectation according literature [Hallenga et al., 1998] is that this still will be the case for at least the coming 5 years. The increase is mainly caused by the growth of the penetration of equipment and the introduction of new types of equipment. Fortunately there is also the tendency of the improve-

ment of the energy efficiency of equipment, which lowers the overall rise in energy consumption to some extent.

Overview of options
The selected options are shown in Table 3.2. Also the additional penetration rate compared to the autonomous development in 2010 is given and the part of the sector to which the option can be applied is named.

3.3.2 Option 1 : Improving building shell: wall insulation

3.3.2.1 Description

In poorly insulated or uninsulated buildings there are enormous heat losses through the building envelope. One measure with great effect is wall insulation. The impact of the application of wall insulation depends very much on the age distribution profile of buildings, the renovation level etc. Only little information is available on these aspects which decisively influence the energy use of the services sector. The results of the measures assumed for the domestic sector are translated to the services sector by correcting for the relative lower heat losses through walls in the services sector and taking into account other characteristics.

3.3.2.2 Autonomous development

The energy demand for heating in 1995 and 2010 is taken from the PRIMES database. It is assumed that the specific energy consumption for space heating decreases by the same percentage between 1990 and 2010 as in the domestic sector. Depending on the country this results in an energy reduction relative to the reference energy demand for heating in 2010 of about 1% to 5%. (The variation is caused by differences in average energy consumption per building in the same climate zone). This energy reduction will be achieved through the common rate of renovation (about 10%).

3.3.2.3 Further energy efficiency improvement

Option 1 consists of 20% extra retrofitting compared to the expected level of already retrofitted building stock in 2010. This is based on the assumption that 3% of the uninsulated building stock can be handled per year and 10% of the building stock has already been renovated during the period 2000 and 2010.
For calculation of this option also the energy saving percentages of the domestic sector have been used. At the country level this leads to 1% to 3.5% energy reduction of space heating.

In the literature it is estimated that potential of thermal insulation (including roof and floor insulation) is about 7.5% of the total energy consumption. This confirms our results [Ashford, 1998].

3.3.2.4 Costs

For the cost per saved GJ the same value is taken as in the domestic sector. In practice, costs may be lower in the services sector due to reduced prices for larger insulated surfaces.

The costs vary from 60 $euro_{1990}$/savedGJth/yr to 465 $euro_{1990}$/saved GJth/yr. This cost range is mainly caused by differences in climate conditions; in a colder country the energy reduction is higher than in a warmer country, while the insulation cost per building is the same.

3.3.3 Option 2: Improving building shell: Roof installation

3.3.3.1 Description

Another measure to reduce heat losses of the building shell is roof insulation. The same method as for option 1 has been used for option 2. The estimates have been based on the available information for the domestic sector but adaptations have been made to account for the relatively lower heat transmission. The cost of option 2 has been based on the costs of roof insulation in the domestic sector.

3.3.3.2 Autonomous development

The data of energy demand for space heating in 1995 and 2010 are extracted from the PRIMES database. It is assumed that the specific energy consumption for space heating decreases by the same percentage between 1990 and 2010 as in the domestic sector. This results in a lower energy demand for space heating at country level of 0% to 5%. Cause of this reduction is the autonomous implementation of renovation projects.

3.3.3.3 Further energy efficiency improvement

Option 2 consists of 20% extra retrofitting compared to the expected level of already retrofitted building stock of the services sector in 2010. This is based on the assumption that 3% of the building stock can be insulated per year of which 10% has already been planned to be insulated during the period 2000 and 2010 (i.e. total 30%: 20% extra (option 2), 10% (autonomous development)). At the country level this leads to an additional energy reduction of space heating by 1% to 4%.

3.3.3.4 Costs

The cost per saved GJ is assumed to be the same as in the domestic sector, i.e. between 40 and 330 $euro_{1990}$/savedGJth/yr. This variety is mainly caused by difference in climate conditions; in a colder country the energy reduction is higher than in a warmer country, while the insulation cost per building is the same.

3.3.4 Option 3: Improving building shell: Windows

3.3.4.1 Description

The replacement of single pane windows by double pane windows, Ar-filled low-e windows or superwindows represents a considerable energy saving potential.
Due to lack of detailed information for the services sector the same method as in option 1 has been used. This means that for a great deal we relied on information of the domestic sector. Subsequently we corrected the saving percentages for the relatively lower heat transmission losses in the services sector compared to the domestic sector. For the data (reduction of energy use and additional costs) of double pane windows, Ar-filled low-e windows and superwindows we refer to the report of the options to reduce carbon dioxide in the household sector.

3.3.4.2 Autonomous development

The data of energy demand for space heating in 1995 and 2010 are extracted from the PRIMES database.
It is assumed that the specific energy consumption for space heating decreases by the same percentage between 1990 and 2010 as in the domestic sector. This means that at country level the energy demand for space heating is lowered by 2.5 % to 8%. This reduction is caused by the autonomous implementation of renovation projects.

3.3.4.3 Further energy efficiency improvement

Option 3 consists of replacement of the remaining single windows in 2010 adjusted for the autonomous development. Furthermore, it is assumed that 50% of this remaining window amount is replaced by double-glazing, 40% by Argon-filled low e-glazing and 10% by superwindows.
For calculation of this option also the findings of energy saving potentials of the domestic sector have been used. This leads to 2.5% to 8% (compared to autonomous scenario in 2010) energy reduction of space heating at country level.

3.3.4.4 Costs

The costs per saved GJ are taken the same as in the domestic sector. In practice they may be lower due to reduced prices for larger insulated surfaces.
The costs for this option ((highly) insulated windows) vary from 65 $euro_{1990}$/savedGJth/yr to 480 $euro_{1990}$/savedGJth/yr in investment terms only.
This variation is caused, as in option 1 by the large variation in climate across the EU.

3.3.5 Option 4: New energy efficient buildings

3.3.5.1 Description

The energy intensity of space heating in new buildings is already lower than in existing buildings. A typical current energy demand for space heating of a services building in the moderate climate zone is around 320 MJ/m^2.
In many European countries buildings have been realised with very low heating requirement: e.g. in France, Spain, and the United Kingdom services offices have been built using around 200 MJ/m^2 or less for heating (Ademe, 1993).
Based on this information it is assumed that it is possible to bring the average energy use for space heating of new services building in 2010 down to a level of 30% of average 1995 buildings (about 100 MJ/m^2). This can be achieved by applying good insulated building shell, heat recovery systems and energy efficient heating systems (heat pumps).

3.3.5.2 Autonomous development

The data for space heating of the services sector both for 1995 and for 2010 are extracted from the PRIMES database. The number of new buildings is assumed to be identical with the difference between 1995 and 2010. This is based on the assumption there is the assumption that the demolition rate can be neglected. The characteristic heating demand in a building in moderate climate will be around 200 MJ/m^2.

3.3.5.3 Further energy efficiency improvement

We assume that 50% of the new buildings have 30% lower energy use for space heating compared to the autonomous development in 2010 (from 200 MJ/m^2 to 140 MJ/m^2) and 10% of the new buildings have 50% lower energy use (100 MJ/m^2).

3.3.5.4 Costs

The cost per floor space for new services buildings with a heat demand of about 140 MJ/m^2 is estimated to be 15 $euro_{1990}/m^2$, for new services building with a heat demand of about 100 MJ/m^2 the cost are estimated to be 40 $euro_{1990}/m^2$. [Novem Website, 2000].

3.3.6 Option 5: Efficient cooling systems

3.3.6.1 Description

The energy consumption for air conditioning has become significant in the services sector (13% of electricity demand [Blok et al., 1996]). Three tendencies are observed in the energy demand for cooling:

- Increase of the amount of equipment, causing higher cooling loads
- Increased comfort demands, causing higher cooling loads
- Increase of energy efficiency of lighting and equipment, causing lower cooling loads.

When these tendencies are taken in consideration it is expected that there will be an increased demand for cooling. There are generally two ways for energy conservation in this area: reducing the need for cooling and by improving the efficiency of the cooling system. The demand for air conditioning can be reduced and sometimes eliminated by using natural shading in building design, natural shading by planting trees, improvement of ventilation and by efficiency improvement of other office equipment. The efficiency of the air conditioning system itself can be improved by improving the efficiency of the chiller, improved heat exchange, improved controls, switching to systems using a heat pump, adequate system design and improved maintenance [Levine, 1995]. Important are also the increased use of heat exchangers and economiser, which switch the air conditioning system to the use of outdoor air when the outdoor temperature is low enough to cool the building. The technical energy saving potential comes up to 40% based on most efficient models on the market [Levine, 1995].

Other important developments are storage of thermal energy in building mass (‘night ventilation’) and seasonal storage of thermal energy (for cooling and heating). Utilising the thermal storage capacity can cut cooling energy demand by 30-70% [Bevington and Rosenfeld, 1990].

3.3.6.2 Autonomous development

For the autonomous scenario in 2010 it is assumed that the energy consumption for cooling is 13% of the electricity demand.

3.3.6.3 Further energy efficiency improvement

The additional saving potential is estimated to amount to about 40% compared to the autonomous development in 2010. It is assumed that this potential can be applied to 70% of the cooling demand in the services sector.

3.3.6.4 Costs

The cost of this option are estimated to be 11 $euro_{1990}$/GJ [Beer et al, 1994].

3.3.7 Option 6: Building Energy Management Systems

3.3.7.1 Description

Building energy management systems (BEMSs) automatically regulate the operation of all energy demands (heating, cooling, transport, lighting and equipment). The BEMS saves energy and water demands by producing accurate and proper comfort levels depending on climate conditions. They are especially realising energy conservation by switching off energy-services when rooms are not occupied. Particularly for the services sector, where many offices are empty for over 75% of the time, this is an essential source of energy saving. The introducing of BEMSs has been widely trailed and monitored in the public building sector (among others through the CADDET programme). It is estimated that savings in the range up to 20% in space heating energy consumption could be

realised if wider use of BEMSs were made in the public and services sectors [Ashford, 1998; NWS, *year*].
For electric appliances such as lighting and ventilation an additional saving of 10% is expected [Ashford, 1998].

3.3.7.2 Autonomous development

The amount of energy demand for space heating and electricity appliances are based on data from the PRIMES database.

3.3.7.3 Further energy efficiency improvement

Option 6 consists of 20% saving of space heating in 2010 and 10% saving of electricity appliances in 2010. The assumed maximum penetration level is 70% of the overall building stock.

3.3.7.4 Costs

The costs of BEMSs vary enormously. The payback time is usually very short. Therefore additional costs are not taken into account.

3.3.8 Option 7: Efficient lighting systems

3.3.8.1 Description

The share of energy for lighting accounts for about 38% of the total electricity consumption of the services sector [Blok et al., 1996].
Lighting in the services sector is mainly provided by three systems: incandescent lamps, fluorescent lighting and high-intensity discharge lighting. The following measures can conserve a considerable amount of energy:

- Incandescent lamps can be replaced by efficient fluorescent lamps (CFLs). CFLs can yield the same amount of light using 60-80% of the energy compared to ordinary incandescent lamps.
- The luminaire efficiency of all lamp types can be improved using better reflectors.
- A lighting control system detecting occupancy of a room or operating daylight or time independent can reduce the amount of burning hours.

The saving potential of the first two measures is determined to be 30% (Option 7a) [Ashford, 1998]. The total saving potential of all three measures is estimated to be 55% (Option 7b) [Blok et al, 1996]. It should be noted that the last measure overlaps with the electricity saving of introducing a BEMS.

3.3.8.2 Autonomous development

It is assumed that the share of electricity demand for lighting remains unchanged between 1995 and 2010. The data used originate from the PRIMES database.

3.3.8.3 Further energy efficiency improvement

It is assumed that the implementation degree of option 7a (30% savings) is 60% and that of option 7b (30% savings) is 10%.

3.3.8.4 Costs

The cost of the 55% saving option (option 7b) is estimated to be about 35 $euro_{1990}$/GJ saved electricity/yr. [Blok et al., 1996]. The cost of the 30% saving option (option 7a) will be lower around 19 $euro_{1990}$/GJ saved electricity/yr.

3.3.9 Option 8: Efficient office appliances

3.3.9.1 Description

Appliances use 35% of the total electricity consumption in the services sector [Blok et al., 1996]. Most of these appliances are typical office-appliances such as computers, monitors, printers and photocopiers. Office-appliances account for one of the fastest growing end-users in the services building sector [Hallenga et al., 1998]. Computers are responsible for the largest part of the energy consumption. Energy reduction can be achieved by power down management and LCD screens.

3.3.9.2 Autonomous development in 2010

It is assumed that the share of electricity demand for electric appliances remains unchanged between 1995 and 2010. The data used originate from the PRIMES database.

3.3.9.3 Further energy efficiency improvement

The technical energy saving potential of applying the combination of power management and LCD screens is about the 50% - 75% of the energy demand for appliances. The penetration degree is estimated to be 50%.

3.3.9.4 Costs

It could be expected that power management would be available by 2010 without additional costs. The current additional costs of LCD screens compared to standard screens are about 406 $euro_{1990}$ per screen. It could be expected that these costs are about 200 $euro_{1990}$ per screen in 2010.

4. CONCLUSIONS

In 2010 an emission reduction potential of 311 Mt of CO_2 has been identified for both sectors; about 189 Mt in the household sector and about 123 Mt in the services sector. From the report on fluorinated gases an emission reduction potential of 1 resp. 3 Mt of CO_2-eq. is derived for HFCs in refrigeration and air conditioning. From the energy supply sector report a reduction potential of about 8 Mt CO_2 is derived for solar thermal installations.

In both sectors the improvement of the energy performance of existing buildings offers large emission reduction potentials. In the services sector improved cooling systems also offer a large emission reduction potential. A further 360 Mt of CO_2–equivalent is avoided because of reduction options applied in the energy supply sector (for electricity production, see also energy supply sector report). Total direct and indirect emission reduction amounts therefore to 677 Mt of CO_2-equivalent.

Table 4.1. EU15-average costs and potential (Mt of CO_2–equivalent) for emission reduction in the household sector[7].

Pollutant	Measure Name	Emission reduction	Investment	Yearly costs	Lifetime[1/]	Specific abatement costs
		Mt CO2 eq.	euro/tCO2 eq.	euro/tCO2 eq.	year	euro/tCO2 eq.
CO2	Energy efficient TV and video equipment	1	0	-310	15	-194
	Very energy efficient refrigerators and freezers	0	0	-317	15	-187
	Efficient lighting: Best Practice (partly implemented)	1	178	-323	8	-181
	Efficient lighting: Best Practice (fully implemented)	2	178	-326	8	-178
	Miscellaneous options (cheap tranche)	11	0	-235	15	-165
	Miscellaneous options (moderate costs tranche)	11	138	-235	15	-156
	Efficient refrigerators and freezers: Best Practice	3	6686	-368	15	-57
	Retrofit houses: wall insulation [2/]	28	2269	-129	50	-42
	Retrofit houses: roof insulation	26	1600	-169	20	-29
	Subtotal: Cost range < 0 euro / t CO2 eq.	**83**				
	New energy efficient residential houses: Best Practice	12	1815	-200	20	-11
	Subtotal: Cost range 0 < 20 euro / t CO2 eq.	**12**				
	Efficient washing machines, clothes dryers, dishwashers: Best Practice	1	11227	-275	15	7
	Retrofit houses: (highly) insulated windows	49	2344	-177	20	10
	Advanced heating systems: condensing boilers	15	2038	-140	15	50
	Subtotal: Cost range 20 < 50 euro / t CO2 eq.	**66**				
	Geothermal heat production	0	406	-28	25	58
	New very energy efficient residential houses: Zero Energy	3	3056	-200	20	71
	Solar thermal	8	4879	-52	15	272
	Advanced heating systems: heat pumps [/3]	16	3884	73	15	432
	Subtotal: Cost range > 50 euro / t CO2 eq.	**28**				
HFC	Domestic refrigeration: hydrocarbons	1	32.5	0	15	3
	Subtotal: Cost range: 0 < 20 euro / t CO2 eq.	**1**				
	Total potential emission reduction	**190**				

[1/] The lifetime of some options (e.g. retrofitted (uninsulated) walls and efficient appliances) are chosen at the upper part of the range [De Beer et al, 1994]

[2/] An equally divided mix of the options insulating cavity (cheap) and external solid wall insulation (expensive) was chosen.

[/3] based on averagy fuel/electricity use, replacing electric heating systems may reduce costs down to zero costs

[7] Some reviewers consider the chosen lifetimes of several options (retrofitted (insulated) walls and efficient appliances) to be too high.

Table 4.2. EU15-average costs and potential (Mt of CO_2–equivalent) for emission reduction in the services sector.

Pollutant	Measure Name	Emission reduction	Investment	Yearly costs	Lifetime[1/]	Specific abatement costs
		Mt CO2 eq.	euro/tCO2 eq.	euro/tCO2 eq.	year	euro/tCO2 eq.
CO2	Efficient office equipment: Best Practice	3	0	-278	5	-178
	Building Energy Management Systems (BEMS): electricity	3	0	-278	10	-178
	Efficient space cooling equipment	1	377	-277	15	-172
	Efficient lighting: Best Practice level 1	2	651	-278	8	-159
	Very efficient lighting: Best Practice level 2	1	1200	-277	8	-144
	Building Energy Management Systems (BEMS): space heating and cooling	42	0	-153	10	-129
	Retrofit services buildings: wall insulation	14	2269	-157	50	-26
	Retrofit services buildings: roof insulation	13	1600	-162	20	-8
	Subtotal: Cost range < 0 euro / t CO2 eq.	**80**				
	Retrofit services buildings: (highly) insulated windows	31	2344	-168	20	35
	New energy efficient services buildings: Energy efficiency level 1	9	4059	-159	20	146
	New very energy efficient services buildings: Energy efficiency level 2	3	6495	-159	20	312
	Subtotal: Cost range 20 < 50 euro / t CO2 eq.	**43**				
HFC	Stationary air conditioning DX (distributed technology): leak reduction[2/]	1	52.1	32.7	15	37
	Stationary air conditioning chiller: HC and NH3 [2/]	1	221.9	21.7	15	42
	Commercial refrigeration: leakage reduction	2	82.5	41.5	15	49
	Subtotal: Cost range 20 < 50 euro / t CO2 eq.	**3**				
	Total potential emission reduction	**126**				

[1/] The lifetime of some options (e.g. retrofitted (uninsulated) walls and efficient appliances) are chosen at the upper part of the range [De Beer et al, 1994]
[2/] This reduction option covers both the household and the services sector. However, no sectoral breakdown is available.

NB: the investment costs for the options Building Energy Management Systems space heat and cooling and Building Energy Management Systems electricity vary considerably, but are relatively low. In the calculations the investment costs are assumed to be zero.

Table 4.1 and 4.2 give an overview of the investment costs, the yearly costs (sum of operation and maintenance costs and savings), average specific avoidance costs and potential for options applicable in the household and services sector. The specific costs are calculated using a real interest rate of 4% and using the technical lifetime of the option, i.e. installation or equipment.

This report only deals with CO_2 emissions while the other greenhouse gases (notably fluorinated gases) are covered by a separate report. However, the results for non-CO_2 greenhouse gases are displayed in Table 4.1 and 4.2.

Figure 4.1 and Figure 4.2 show the share in emission reduction by the household and services sector in four costs brackets.

Figure 4.1. Households: 1990/1995 base year direct and indirect emissions per greenhouse gas (left), 2010 frozen technology reference level and reduction potentials per cost bracket (right)

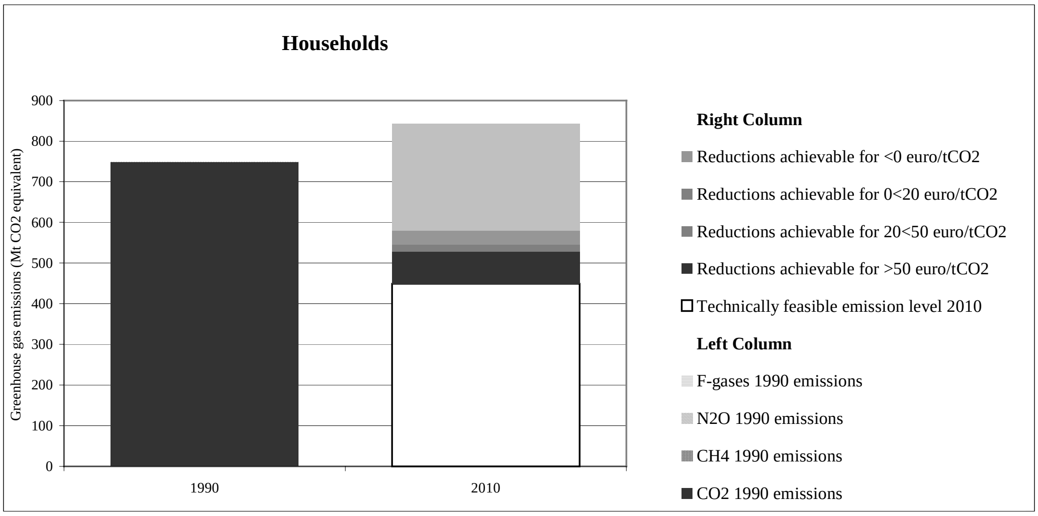
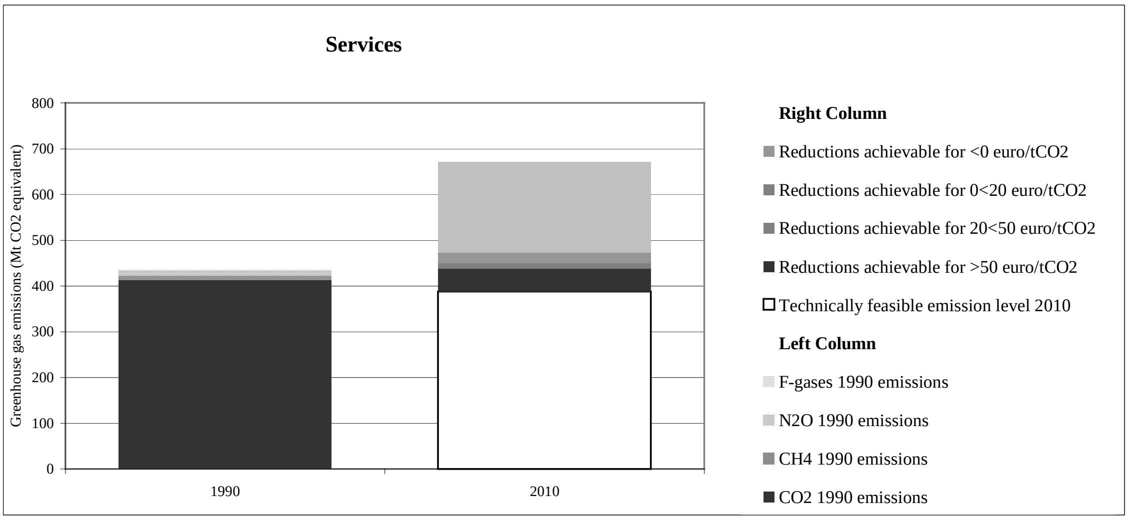


Figure 4.2. Services: 1990/1995 base year direct and indirect emissions per greenhouse gas (left), 2010 frozen technology reference level and reduction potentials per cost bracket (right)



5. RECOMMENDATIONS

This study indicates that there is large scope for further energy efficiency improvement in the household and services sector. This leads to recommendations for R&D in both sectors (see below). Moreover, this study comes to the conclusion that more detailed information is required for the model calculations, especially to account for country specific aspects. In the following, the findings are given in more detail.

Suggestions for new options in household sector

- The limitation of the cooling demand and the energy efficient supply of cooling services will be an important option in the future. This option will especially be especially relevant for southern European countries.
- Implementation of non-electric heat pumps, i.e., gas-fired absorption heat pumps could be an interesting option. Also the development of improved electric heat pumps is of major importance.
- As the insulation degree of dwellings is improved energy efficient ventilation systems become more and more important.
- Hot fill equipment for washing machines
- Development of appliances that are more efficient than ‘1999 best practice’ appliances
- Increased penetration of floor insulation and upgrading of insulation.

Suggestions for additional options in services sector

- Advanced heating systems (e.g. heat pumps) have not been taken into account in this study for two reasons. Firstly, priority is given to lowering the energy demand of a building (renovation projects, energy-advanced buildings). Secondly, it is expected that considerable saving potential have already been realised by improved control systems.
- Advanced energy techniques, like vacuum insulation.
- Other options, e.g. floor insulation and upgrading of insulation etc.

Needs for more detailed information

- More country-specific data to what extent measures are already penetrated is of great importance. For instance the number of dwellings that has been renovated.
- More accurate data and projections of the building stock.
- More information about maximum penetration of options.
- Data of number of offices and other buildings in the services sector, area (m^2) and their age distribution profile.
- Projections of building stock for the nearby future and renovation rates.
- Characteristics of energy demand of the various energy-functions (heating, cooling, transport, lighting and appliances) at country level.

- Information of energy consumption, development in energy consumption and (specific) CO_2 reduction measures and their consequences at more detailed level, preferable per sub-sector (Health, Education, Government, Sports and Entertainment, Commercial offices, Communications and Transport, Hotels and Catering, Retail, Warehousing etc).

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ANNEX 1 LIST OF ENERGY SAVING MEASURES

I Space heating and cooling (comfortable indoor temperature)

I.1 Improving building shell
- wall and ceiling insulation
- windows
- doors and window frames
- tubes insulation (in rooms, which have no or low heat demand)
- measures to reduce draft (tochtwering en kierdichting)

I.2 Advanced heating systems (Switching of energy carriers (and using more energy-efficient heating systems))
- condensing boilers
- heat pumps
- low temperature systems

I.3 Energy storage
- seasonal storage of thermal energy (e.g. aquifer)
- energy storage in phase changing materials
- cold storage
- passive cooling (e.g. night ventilation, sunshading use of building mass)
- passive solar energy

I.4 Heat recovery on ventilation air

II Transport (to transport fresh air to the desired place and to transport thermal energy (heat or cold) to the desired place)

II.1 Ventilation on demand (with occupation-sensors)

II.2 Low Energy ventilation systems
- Energy efficient fans
- Natural (driven) ventilation

II.3 Optimal tuning of pumps and fans (with software, sensors and variable speed drives)

III Lighting

III.1 Increased usability of day-light (daylight transport systems

III.2 Increased efficiency of lighting systems

- switch from tungsten lamps to compact fluorescent lamps
- improvement in the efficiency of traditional fluorescent tubes

III.3 Increased tunability of lighting systems

IV Hot water

IV.1 Reduce hot water demand

- hot water production near the faucet
- use water saving faucets and showers
- use thermostatic faucets

IV.2 Advanced heating systems (Switching of energy carriers (and using more energy-efficient heating systems))

- see also I.2
- heat pump boiler

IV.3 Using waste heat

- use waste heat from fridge or deep freeze
- heat recovery on waste-water

V Cooking Only Residential buildings

V.1 Improve traditional cooking systems

- Improving the heat (or energy-) transfer between cooking device and cooking pot (max 40% improvement) (e.g. cooker with built-in heating element)
- Reduce cooking time (e.g. high pressure, high temperature cooking)
- Insulating the cooking pot
- Thermostatic tuning of cooking device (delivering no more heat then needed)

V.2 Advanced cooking systems

- Microwave heating
- Induction heating

Electricity appliances

VI **COLD** A) Refrigerator, B) Deep freeze — Only Residential buildings

VI.1 Improve traditional systems

- Vacuum insulation
- Increased door insulation (applied on the outside/inside)
- Increased cabinet insulation (with increase of appliance height/with constant exterior appliance dimensions (loss of volume)

- Decreased door leakage
- Increase evaporator surface
- Increased condenser surface
- Increased evaporation heat capacity
- Increased condenser heat capacity
- Improved compressor efficiency

VI.2 Advanced systems

- Stirling cooling
- Absorption cooling

VI.3 Use of waste/environmental heat/cold

- Exergetic cascade (use of waste-heat from refrigerator for instance hot water)
- Use of environmental cold

VI.4 Replace or repair faulty working systems — Only Existing Residential buildings

VII **WET** A) Washing machine — Only Residential buildings

VII-A.1 Improve traditional washing systems

- Improved water level control [proven technology]
- Longer time, lower temperature, including biostep (or alternatively, improved mechanical action) [proven]

- Basic improvement thermal efficiency [proven]
- Reduction of tub-drum clearances, larger drum
- Improved rinsing efficiency, 3 rinses [proven]
- Basic improvement motor efficiency [proven]
- Extended motor efficiency improvement [experimental]
- Extended water economy improvement [experimental]

VII-A.2	Advanced washing systems	
	Heat pump washing machine	
	Ultrasonic washing	
VII-A.3	Heat recovery	Heat exchanger concept for district heating, central heating, etc.
VII-A.4	Improve and tune operation	
	Buying smaller machines (to fit household size better), 15-20% downscaling (improved loading efficiency smaller households	
	Lower programme temperature (through detergent improvements)	
	Reduced detergent loss (e.g. tub valve)	
	Automatic/improved detergent dosage (dual component)	
	Use of Eco-button	
	Improved textiles	
VII-A.5	Infrastructural options	
	Use of hot-fill, wherever appropriate (e.g. in case of non-electric hot water supply and reasonably short supply lines)	
	Topic spin speed, which does not relate to the energy consumption of the washing machine but to the energy consumption of tumble driers, and night-time use, which refers to the sound level of the machine and features of programme pre-set	
	B) Drier	Only Residential buildings
VII-B.1	Advanced drying systems	
	High speed spin drying	
	Heat pump dryer	
	Microwaves dryer	
	No dryer (ultrasonic washing)	
VII-B.2	Heat recovery	
	Heat recovery, condensing dryer	
VII-B.3	Improve and tune operation	
	Improved textiles	

C) Dishwasher — Only Residential buildings

VII-C.1 Improve traditional washing systems
- Lower hot rinse (spoel) temperature of 55 C [proven technology]
- Lower wash temperature of 55 C and 10 minutes longer wash cycle [proven]
- Alternating spraying of top and bottom spray arm [proven]
- Cross-flow heat exchanger between water in- and outlet
- Improved thermal efficiency, reduce thermal bridges
- Weight reduction of heated machine parts
- Condenser for drying without additional heat [proven]
- Improved motor and pump efficiency
- Improved water level control
- Reuse of last rinse water

VII-C.2 Advanced dishwashing systems
- Heat pump dishwasher
- Acoustic dish washer

VII-C.3 Improve and tune operation
- Improved detergents (cold water)

VII-C.4 Infrastructural options
- Hot-fill and alternative heat sources

VIII **BROWN** (TV, VSR, audio, PC etc) — Only Residential buildings

VIII.1 Reduction of standby consumption
VIII.2 Improved techniques (e.g. lcd screens, improved transformators)

IX **Office equipment** (copiers, faxes) — Only Commercial buildings

IX.1 Reduction of standby consumption
IX.2 Improved techniques (e.g. lcd screens, improved transformators)

X **Integrated options**

X.1 Building climate control system
X.2 Energy management system
X.3 Integrated approaches to energy efficient building
X.4 Reduce energy requirement of the building itself

ANNEX 2 LIST OF WORKSHOP PARTICIPANTS

Participants at Experts Workshop "Industry" and "Services and Household sector", March 30 1999, DG Environment, Brussels

Name	**Organisation**
Experts	
Paul Ashford	Caleb Management Services Limited (EUROACE)
Rob Bradley	Energy specialist
Valérie Callaud	EUROPIA, Deputy Secretary General
Giovanni Cinti	Italcementi Group, C.T.G. S.p.A
Christine De Laeter	Dow Benelux NV Powerplant
Aymon de Reydellet	SAINT GOBAIN ISOVER, Environnement et risques industriels
Mats Fredriksson	Texaco
Graham Funnell	UK Steel Association
Anu Karessuo	Finnish Forest Industries Federation Environmental Manager
Paul Laffont	SAINT GOBAIN GLASS Dir. Environnement et Normalisation
Lars Nilsson	Lund University Department of environmental and energy systems studies
Erik Nordheim	European Aluminium Association
Stephan Singer	WWF European Policy Office
Helmut Warsch	Siemens
Consultants	
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Kornelis Blok	Ecofys Energy and Environment
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Peter Horrocks	ENV.D.3, Air quality, urban environment, noise, transport & energy
Daniel Johansson	European Commission ENTR.D.4 ICT & electronic commerce
Marco Loprieno	ENV.A2 Climate change unit
Stefan Lorenz-Meyer	ENTR.E.2
Åsa Malmstrom	ENTR.G.5
Aphrodite Mourelatou	European Environment Agency Energy and Environment project manager
Annika Nilsson	Commission DG ENV D.3
Norbert Theis	DG ENTR.E.3
Matti Vainio	ENV B.2, Economic analyses and employment