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TNO report

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Impact of Solar Control Glazing on energy and CO_2 savings in Europe

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Executive Summary

The Energy Performance of Buildings Directive, EPBD, requires all Member States to improve their Building Regulations at 5-yearly intervals. Energy use and CO_2 production of air conditioning is getting more and more important as the rise in global temperatures and higher aspirations of comfort increase the share of air-conditioned buildings.

Therefore, the four major European manufacturers of architectural glass joined in GEPVP induced an independent study for calculation of the energy and CO_2 savings in the 25 EU Member States as a result of the use of existing high performance solar control glazing in those air-conditioned buildings which would not normally contain this glass.

This report quantifies the impact of application of solar control glazing in existing and new buildings with air conditioning on energy savings and CO_2 reduction to be achieved in 2020. The calculation method used corresponds to the EPBD standard developed for determination of heating and cooling loads of buildings. Information on building stock, material properties and meteorological data comes from European studies and statistics.

Sets of two calculations form the basis for determination of the energy savings:

– in one calculation, heating and cooling energy is calculated for the building with reference glazing, which is already present for existing buildings or is expected to be applied for future buildings (period 2007-2020);
– in the other calculation, heating and cooling energy is calculated for the same building with solar control glazing.

Subtraction of the energy performance resulting from the two calculations reveals the energy savings for heating and cooling. Subsequently, CO_2 reduction is derived from the energy savings.

Figures on energy savings and CO_2 reduction have been calculated for the 25 EU Member States for four scenarios:

– Scenario 1: application of solar control glazing in all future air-conditioned buildings under the assumption that the percentage of air conditioning in the new buildings (built between 2007 and 2020) is twice as high as in present buildings;
– Scenario 2: as Scenario 1 but with the suggestion that the application of solar control glazing may cause air conditioners to be left out for all new buildings except for South Europe;
– Scenario 3: application of solar control glazing in all existing and future air-conditioned buildings, i.e. combining Scenario 1 with the existing buildings with air conditioners;
– Scenario 4: as Scenario 3 with vast increase of air conditioning in both existing and future buildings to present USA levels of 65% for residential and 80% (100% for South Europe) for non-residential buildings.

The overview below presents the figures summed for the EU25 Member States in the year 2020. CO_2 reduction has also been presented as contribution to the Commission's objective on primary energy savings as described in the Action Plan for Energy Efficiency: 20% in the year 2020. For the building sector, the EU target corresponds to about 300 Mt/year CO_2 reduction.

Scenario	Energy savings for heating in 2020 [TJ]	Energy savings for cooling in 2020 [TJ]	CO_2 reduction in 2020 [kt]	Contribution to EU target for CO_2 reduction for buildings in 2020
1	-3282	68794	4502	1.5%
2	-3282	104550	6594	2.2%
3	16241	204173	15913	5.3%
4	139815	980675	82031	27%

Relating the figures to the Commission's objective for all sectors, i.e. 780 Mt/year CO_2 reduction, shows that application of solar control glazing can contribute up to 10% of the target for 2020.

The South of Europe contributes the most to the potential of solar control glazing for CO_2 reduction: 50 – 75% depending on the scenario. The mid-European countries are second with 10 – 20%. There is also interesting potential up to 10% for Poland and the United Kingdom.

The present report contains interesting information, not only for the glass industry but also for policymakers as the appealing contribution to the EU target can be achieved with available products with minimal maintenance and without adaptation of the installation infrastructure to match.

Contents

1 Introduction

1.1 Issue of impact of solar control glazing on energy and CO_2 savings

Groupement Européen des Producteurs de Verre Plat, GEPVP, comprises the four major European manufacturers of architectural glass, i.e. Glaverbel, Guardian, Pilkington and Saint Gobain Glass. Together these companies have a turnover in Europe of approximately 4 billion euros, and represent 95% of European flat glass manufacturing capacity.

GEPVP believes that insufficient attention has been paid by policymakers and legislators to the significance of air conditioning as a producer of CO_2 from buildings. This is partly due to the fact that the majority of air-conditioned buildings are in the southern European countries, where historically regulations on energy efficiency have not been strong, and partly due to the fact that air conditioning has been perceived as being present in only a small minority of buildings. However, this is beginning to change. The Energy Performance of Buildings Directive, EPBD, requires all Member States to improve their Building Regulations at 5-yearly intervals. Air conditioning will be taken into account in a better way with respect to energy use and CO_2 production. At the same time, the rise in global temperatures and higher aspirations of comfort will increase the number of buildings in which air conditioning will be installed.

Therefore, GEPVP induced an independent study for calculation of the energy and CO_2 savings in each of the 25 EU Member States as a result of the use of existing high performance solar control glazing, i.e. solar control glass in conjunction with low emissivity glass in a double glazed unit, in those air-conditioned buildings which would not normally contain solar control glass.

Results of this study, carried out by TNO, have been presented in this report. The study covers dwellings and non-residential buildings, new buildings as well as existing buildings having their windows replaced. Calculations have been made for developments over the next 15 years (until 2020) and for the 25 EU Member States.

The outcome has been placed in the context of the Commission’s Action Plan for Energy Efficiency ([1]). The EU objective is to save 20% of the primary energy consumption by 2020, corresponding to 390 Mtoe/year[1] and 780 Mt/year CO_2 reduction. About 41% of the total energy consumption is related to buildings. Energy statistics to support EU policies and solutions ([2]) indicate that the building sector produces somewhat less CO_2 per unit of oil equivalent than the other sectors, i.e. mainly industry and transport. Assuming the same target energy saving of 20% for all sectors and conversion from Mtoe into Mt CO_2 as indicated in [2], the 2020 target for CO_2 reduction for buildings is about 300 Mt/year.

1.2 Approach

Determination of the energy and CO_2 savings has been based on the European methods for assessment of the energy performance as being elaborated for the Energy Performance of Buildings Directive. Heating and cooling loads of buildings as

[1] Mtoe = Megaton oil equivalent.

calculated according to this EN ISO 13970 method ([3]) have been incorporated in a calculation tool.

This tool has been provided with sheets containing input data for the calculations as well as output sheets for final processing. There are input data on country information, description of buildings including operation of installations, building stock, glazing properties and meteorological data. Final processing involves conversion of heating and cooling loads for the various situations into energy savings and further CO_2 savings for clusters of countries and individual Member States. Input and output details of the tool are described in Chapter 2.

Four scenarios of penetration of air conditioning have been studied using the calculation tool for quantification. Additional sensitivity analyses give information on the accuracy of the figures presented. The scenarios and the savings to match are presented in Chapter 3.

TNO’s work has been followed by a small GEPVP Working Group. Members contributed to the study with specific data on glazing properties, market information for the European countries as well as references to available European data and studies.

2 Calculation method and tool

2.1 Monthly method from EN ISO 13790 for window energy calculations

2.1.1 Reference to the calculation method

Within the set of standards for the Energy Performance of Buildings Directive, EN ISO 13790: 2007 ([3]) describes the calculation of heating and cooling loads of buildings. The final version of this standard is being prepared by TNO and will be published in 2007. The standard integrates different levels of detail:

- the document has been structured to maximize the common use of procedures, conditions and input data, irrespective of the calculation method;
- a monthly (and seasonal) method for heating and cooling has been provided;
- a simple hourly method for heating and cooling, to facilitate easier introduction of hourly, daily or weekly patterns (e.g. controls, user behaviour), has been included;
- for dynamic simulation methods, procedures concerning boundary conditions and input data have been included, that are consistent with the boundary conditions and input data for more simplified methods;
- the whole document has been scrutinised to check its applicability within the context of building regulations, which require a minimum of ambiguities and subjective choices; where needed, possibilities are offered for national choices, depending on the purpose or application of the calculations (see list above) and on type or complexity of the building.

An inventory among the EU Member States reveals that the monthly method will be used by the majority of the Member States for calculating the energy performance for heating and cooling. Some of these Member States will allow a detailed method for complex buildings. The main reason for choosing the monthly method is its robustness, reproducibility and transparency.

The monthly method from EN ISO 13790: 2007 is currently used as basis for drafting an ISO standard on the energy rating of windows. Scope of this ISO standard ([4]), being handled in ISO TC163 SC2 WG 11, is to draft a simplified procedure to assess the energy performance of fenestration systems for rating of windows, doors and skylights, including frame, sash, glazing and shading components. The standard is to take into account the heating and cooling energy use in buildings, internal and external climatic conditions and relevant building characteristics. Within this WG, consisting of several partners from USA, Canada, Europe and Japan), TNO is responsible for the proper link with EN ISO 13790.

The same monthly method for determination of heating and cooling loads of buildings has been incorporated in the calculation tool created for the study in this report.

2.1.2 Building energy balance

In EN ISO 13790, the monthly energy need for space heating is calculated according to:

$$Q_{\mathrm{H,nd}} = Q_{\mathrm{H,ht}} - \eta_{\mathrm{H,gn}} \cdot Q_{\mathrm{H,gn}} \quad (1)$$

where for each month:

$Q_{H,ht}$ is the total heat transfer by transmission and ventilation of the building;

$Q_{H,gn}$ are the total solar and internal heat gains of the building;

$\eta_{H,gn}$ is the dimensionless gain utilization factor.

The monthly energy need for space cooling is calculated according to:

$$Q_{C,nd} = Q_{C,gn} - \eta_{C,ls} \cdot Q_{C,ht} \tag{2}$$

where for each month:

$Q_{C,ht}$ is the total heat transfer by transmission and ventilation of the building;

$Q_{C,gn}$ are the total solar and internal heat gains of the building;

$\eta_{C,ls}$ is the dimensionless utilization factor for heat losses.

2.1.3 *Heat balance elements*

Leaving out the indices H for heating and C for cooling, the total heat transfer of the building is given by:

$$Q_{ht} = Q_{tr} + Q_{ve} \tag{3}$$

where for each month:

Q_{tr} is the total heat transfer by transmission of the building;

Q_{ve} is the total heat transfer by ventilation of the building.

The total heat gains of the building are given by:

$$Q_{gn} = Q_{int} + Q_{sol} \tag{4}$$

where for each month:

Q_{int} is the sum of the internal heat gains of the building;

$Q_{sol\ e}$ is the sum of the solar gainsof the building.

Gain utilization factor $\eta_{H,gn}$ and heat loss utilization factor $\eta_{C,ls}$ are function of the heat balance ratio γ, being Q_{gn}/Q_{ht}, and a numerical parameter that depends on the thermal inertia of the building. Figures 1 and 2 illustrate the gain and heat loss utilization factor for the heating respectively cooling load calculation of the building.

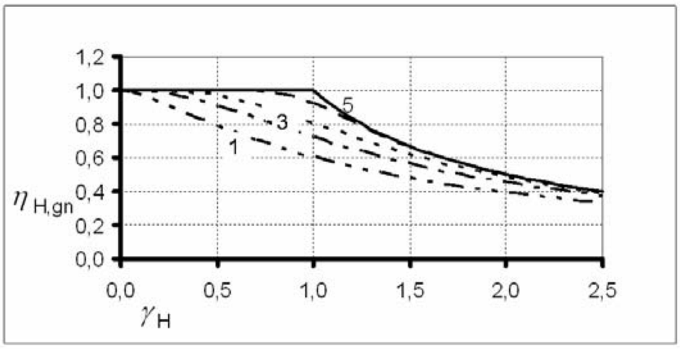

Figure 2.1 Illustration of gain utilization factor for heating mode, for 8 hours (low inertia, key 1), 1 day, 2 days, 1 week and infinite (high inertia, key 5) time constants.

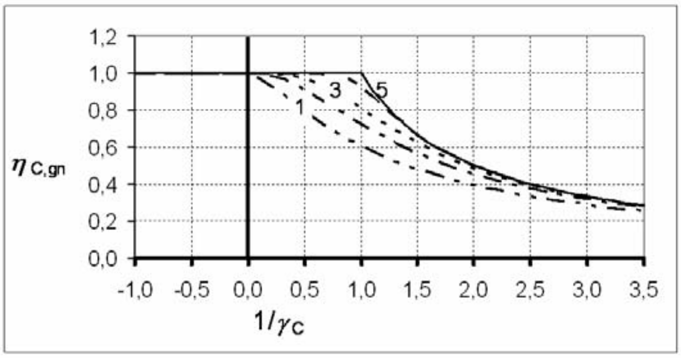

Figure 2.2 Illustration of loss utilization factor for cooling mode, for 8 hours (low inertia, key 1), 1 day, 2 days, 1 week and infinite (high inertia, key 5) time constants.

2.1.4 *Calculation at window level*

Use of the monthly calculation method for the window energy balance gives the following energy performance per m^2 window area A_w for heating:

$$Q_{H,nd,w} = Q_{H,ht,w} - \eta_{H,gn} \cdot Q_{H,gn,w} \tag{5}$$

For cooling it is:

$$Q_{C,nd,w} = Q_{C,gn,w} - \eta_{C,ls} \cdot Q_{C,ht,w} \tag{6}$$

Leaving out the indices H and C, the window energy terms are as follows:

$$Q_{ht,w} = U_w \cdot (\theta_i - \theta_e) \tag{7}$$

and

$$Q_{gn,w} = g_w \cdot I_{sol} \tag{8}$$

where:

- U_w is the U-value of the window, in W/(m^{2}K);
- g_w is the dimensionless total solar energy transmittance of the window;
- $\theta_i - \theta_e$ is the difference between internal and external temperatures on a monthly basis, in K;
- I_{sol} is the solar irradiance, the total monthly energy of the solar irradiation per m^2 window with given orientation and tilt, in MJ/m^2.

The calculation process involves:

1 From selected climate and window orientation: assigning of matching ($\theta_i - \theta_e$) and I_{sol} per month.
2 From the window properties: assigning U_w, g_w and A_w.
3 From selected building and occupancy: assigning of matching $\eta_{H,gn}$ and $\eta_{C,ls}$ per month.

2.1.5 *Validation of the calculation tool*

The monthly calculation method has been validated against four reference cases as described in prEN 15265 ([5]). These reference cases present an office room with a west oriented window and different combinations of building inertia, internal heat gain and g-value. Reference values for heating and cooling load of the room come from calculations using different dynamic mathematical models.

Table 1 presents calculation results of the tool in comparison to the reference values.

Table 1 Comparison of heating and cooling loads for an office room from the calculation tool with reference calculations according to prEN 15265.

Case	Construction	Internal gain W/m²	g-value		Tool kWh	Reference kWh	Difference
1	Light	20	0.20	$Q_{H,nd}$	832	748	11%
				$Q_{C,nd}$	249	234	7%
2	Heavy	20	0.20	$Q_{H,nd}$	791	723	10%
				$Q_{C,nd}$	189	201	-6%
3	Light	0	0.20	$Q_{H,nd}$	1430	1369	5%
				$Q_{C,nd}$	40	43	-6%
4	Light	20	0.72	$Q_{H,nd}$	617	567	9%
				$Q_{C,nd}$	1648	1531	8%

The comparison shows that the calculation tool is in line with the reference calculations. Maximum difference is about 10%.

2.2 Structure and contents of the calculation tool

Figure 3 describes the structure of the MS Excel based calculation tool, called EUCO2, Version 1.00. The tool core contains the calculation routine as described in Section 2.1. These calculations are performed for multiple combinations of country clusters coupled to climate, building type, building age and type of glazing. Hence, a matrix is defined for all combinations to be calculated. Afterwards, calculation results are processed to reveal totals of energy use and CO_2 production as well as the savings.

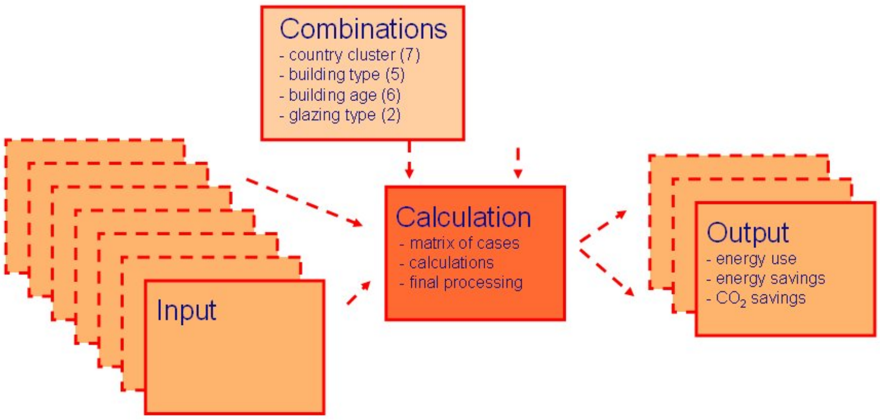

Figure 2.3 Structure of the tool for calculation of the heating and cooling load of buildings.

2.2.1 Definition of country clusters coupled to climate

Calculations are performed for seven different clusters of countries, each of the clusters having its own set of meteorological data. Table 2 presents the distribution of the EU Members States over the country clusters. There are three Central regions. ‘Central maritime’ and ‘Central continental’ contain old (EU15) Member States, whilst ‘Central’ contains four new Member States. The Central continental and Central regions have the same reference climate, but are treated separately because of different basic data concerning the performance and distribution of the building stock.

Table 2 Distribution of the EU Member States over the country clusters, including number of inhabitants (x million).

North		**South**	
- Finland	5.2	- Cyprus	0.8
- Sweden	9.0	- Greece	10.7
		- Italy	58.1
		- Malta	0.4
Central maritime		- Portugal	10.6
- Belgium	10.4	- Spain	40.4
- Denmark	5.5		
- Ireland	4.1	**Baltics**	
- Luxemburg	0.5	- Lithuania	3.5
- Netherlands	16.5	- Latvia	2.3
- United Kingdom	60.6	- Estonia	1.3
- France	60.9		
		Poland	
		- Poland	38.5
Central continental			
- Austria	8.2	**Central**	
- Germany	82.4	- Czech Republic	10.3
		- Hungary	10.2
		- Slovakia	5.4
		- Slovenia	2.0

Table 3 defines the link between country clusters and reference meteorological data. The data have been derived from Meteonorm Version 5.0 ([6]), additionally taking into account data on climate change as reported by the Intergovernmental Panel on Climate Change (IPPC; [7]). For the majority of the calculations, external temperatures have been assumed to increase according to the mid range projection of the IPPC report expecting a 2°C temperature rise at the end of the century. In the sensitivity study reported in Section 3.6, external temperatures increase at the top and bottom of the ranges identified in [7], corresponding to 0.6°C and 3.5°C temperature increase by the year 2100.

Table 3 Link between country clusters and reference meteorological data.

Country cluster	Location of reference meteorological data
North	Stockholm
Central maritime	London
Central continental	Munich
South	Rome
Baltics	Riga
Poland	Warsaw
Central	Munich

2.2.2 *Definition of building types and building stock*

Calculations are performed for five different building types, both residential and non-residential buildings, like offices and schools. Table 4 defines the building types by way of floor, wall, window and roof area.

Building stock has been composed from residential and non-residential buildings from five periods, i.e. before 1975 and periods 1975 – 1990, 1991 – 2002, 2002 – 2006 and 2007-2020. For the period before 1975, distinction has been made between refurbished and non-refurbished buildings. For the majority of the calculations, it is assumed that the net growth in floor area is 1% per year equally distributed over building types and country clusters. In more detail, the annual demolition rate is assumed to be 1%, and 2% per year is new built. Table 5 defines the distribution of floor area over the building ages, building types and country clusters for the situation in 2006 and Tabel 6 for the situation in 2020. In the sensitivity study reported in Section 3.6, construction rate of new buildings is varied between 1% and 3% per year, whereas the annual demolition rate remains 1%.

Information for the Tables 4, 5 and 6 comes from Ecofys studies for Eurima and EuroACE ([8], [9] and [10]).

Table 4 Definition of building types.

Building type	**Dwelling**	**Apartment building small**	**Apartment building large**	**Non-residential small**	**Non-residential large**
Function: - 1 = residential - 2 = office, school, etc.	1	1	1	2	2
Length of the building [m]	10	70	210	70	210
Width of the building [m]	5	10	15	15	25
Height of the floor [m]	2.7	3.0	3.0	3.0	3.0
Number of floors	2	3	10	3	10
Footprint (floor area) [m^2]	50	700	3150	1050	5250
Roof area [m^2]	75	700	3150	1050	5250
Total wall area including windows [m^2]	108	810	7200	900	7800
Used (heated/cooled) building area [m^2]	113	1890	28350	2835	47250
Window area - East [m^2]	6.8	95	1350	126	1763
Window area - South [m^2]	6.8	95	1350	126	1763
Window area - West [m^2]	6.8	95	1350	126	1763
Window area - North [m^2]	6.8	95	1350	126	1763
Glass/façade for building length	0.1	0.3	0.4	0.4	0.5
Glass/façade for building width	0.3	0	0.4	0	0.5
Glass/floor	27%	18%	17%	16%	13%

Table 5 Distribution of floor area (x million m2).over the building ages, building types and country clusters for 2006.

	Dwelling	Apartment building small	Apartment building large	Non-residential small	Non-residential large	Total
North						
<1975 non-refurbished	67	25	13	15	25	145
<1975 refurbished	266	99	54	60	101	581
1975-1990	102	37	21	23	39	222
1991-2002	86	32	17	20	33	187
2002-2006	43	16	9	10	16	94
Central maritime						
<1975 non-refurbished	911	247	133	154	365	1810
<1975 refurbished	2125	577	311	359	852	4223
1975-1990	840	228	122	142	336	1668
1991-2002	633	172	92	107	254	1258
2002-2006	187	51	27	32	75	371
Central continental						
<1975 non-refurbished	521	141	76	88	209	1036
<1975 refurbished	1216	330	178	206	487	2417
1975-1990	480	130	70	81	192	955
1991-2002	362	99	53	61	145	720
2002-2006	107	29	16	18	43	212
South						
<1975 non-refurbished	599	385	207	160	208	1558
<1975 refurbished	599	385	207	160	208	1558
1975-1990	748	480	259	199	260	1946
1991-2002	506	325	175	135	175	1316
2002-2006	102	65	35	27	35	265
Baltics						
<1975 non-refurbished	68	30	25	14	24	161
<1975 refurbished	17	7	6	4	6	40
1975-1990	36	17	14	8	14	88
1991-2002	7	3	2	1	2	15
2002-2006	2.0	0.8	0.7	0.4	0.7	5
Poland						
<1975 non-refurbished	189	74	120	62	69	514
<1975 refurbished	47	19	30	16	17	129
1975-1990	121	47	76	40	44	328
1991-2002	57	22	36	19	21	154
2002-2006	17	7	11	6	6	46
Central						
<1975 non-refurbished	238	41	77	62	77	496
<1975 refurbished	60	10	19	16	19	124
1975-1990	132	22	43	34	43	274
1991-2002	26	4	8	7	8	53
2002-2006	8	1	3	2	3	16

Table 6 Distribution of floor area (x million m2).over the building ages, building types and country clusters for 2020.

	Dwelling	Apartment building small	Apartment building large	Non-residential small	Non-residential large	Total
North						
<1975 non-refurbished	40	15	8	9	15	87
<1975 refurbished	218	81	44	50	83	476
1975-1990	94	34	19	21	36	204
1991-2002	84	31	17	19	32	183
2002-2006	43	16	9	10	16	94
2007-2020	163	61	33	37	62	356
Central maritime						
<1975 non-refurbished	546	148	80	92	219	1086
<1975 refurbished	1806	490	264	306	724	3590
1975-1990	823	223	120	139	329	1635
1991-2002	620	169	90	105	248	1233
2002-2006	187	51	27	32	75	371
2007-2020	1370	372	200	232	549	2722
Central continental						
<1975 non-refurbished	365	99	53	62	146	725
<1975 refurbished	973	264	142	165	390	1934
1975-1990	471	128	69	80	189	936
1991-2002	355	97	52	60	142	706
2002-2006	107	29	16	18	43	212
2007-2020	793	215	116	134	318	1575
South						
<1975 non-refurbished	359	231	124	96	125	935
<1975 refurbished	479	308	166	128	166	1246
1975-1990	733	470	254	195	254	1907
1991-2002	496	318	172	132	172	1290
2002-2006	102	65	35	27	35	265
2007-2020	741	477	257	198	258	1930
Baltics						
<1975 non-refurbished	51	22	19	11	18	121
<1975 refurbished	15	6	5	3	5	35
1975-1990	35	16	13	8	13	86
1991-2002	7	3	2	1	2	15
2002-2006	2.0	0.8	0.7	0.4	0.7	5
2007-2020	38	17	14	8	14	91
Poland						
<1975 non-refurbished	136	54	86	45	49	370
<1975 refurbished	39	15	25	13	14	105
1975-1990	118	46	75	39	43	321
1991-2002	57	22	36	19	21	154
2002-2006	17	7	11	6	6	46
2007-2020	124	49	79	41	45	338
Central	181	31	59	47	59	377
<1975 non-refurbished	49	8	16	13	16	102
<1975 refurbished	129	21	42	33	42	268
1975-1990	26	4	8	7	8	53
1991-2002	8	1	3	2	3	16
2002-2006	135	23	44	35	44	282
2007-2020	181	31	59	47	59	272

2.2.3 *Definition of building insulation and window properties*

Thermal insulation of buildings depends on the age of the building and on the climate and so do the U-value of the windows and the g-value. Table 7 presents the U-values and g-values used for the reference calculations, i.e. without application of solar control glass. Most insulation values have been derived from [8], [9] and [10]. The 2020 value have been extrapolated. U-values and g-values are result from discussion in the GEPVP Working Group for this study.

Glazing properties for optimum solar control glass also differ for the various country clusters: see Table 8.

Table 7 Heat transfer coefficient for roofs, façades, floors and windows as well as the window g-value for different building ages and country clusters.

	< 1975 non-refurbished	**< 1975 refurbished**	**1975-1990**	**1991-2002**	**2002-2006**	**2020**
North						
U_{roof} [W/(m^{2}K)]	0.50	0.20	0.20	0.15	0.15	0.13
U_{facade} [W/(m^{2}K)]	0.50	0.30	0.30	0.20	0.18	0.17
U_{floor} [W/(m^{2}K)]	0.50	0.20	0.20	0.15	0.18	0.17
U_w [W/(m^{2}K)]	3.00	1.60	2.00	1.60	1.42	1.33
g_w [-]	0.8	0.6	0.7	0.6	0.6	0.6
Central maritime						
U_{roof} [W/(m^{2}K)]	1.50	0.50	0.50	0.40	0.25	0.23
U_{facade} [W/(m^{2}K)]	1.50	1.00	1.00	0.50	0.41	0.38
U_{floor} [W/(m^{2}K)]	1.20	0.80	0.80	0.50	0.44	0.41
U_w [W/(m^{2}K)]	4.00	2.00	3.50	2.00	1.84	1.68
g_w [-]	0.8	0.7	0.8	0.7	0.7	0.6
Central continental						
U_{roof} [W/(m^{2}K)]	1.50	0.50	0.50	0.40	0.25	0.23
U_{facade} [W/(m^{2}K)]	1.50	1.00	1.00	0.50	0.41	0.38
U_{floor} [W/(m^{2}K)]	1.20	0.80	0.80	0.50	0.44	0.41
U_w [W/(m^{2}K)]	4.00	2.00	3.50	2.00	1.84	1.68
g_w [-]	0.8	0.7	0.8	0.7	0.7	0.6
South						
U_{roof} [W/(m^{2}K)]	3.40	1.00	0.80	0.50	0.50	0.43
U_{facade} [W/(m^{2}K)]	2.60	1.40	1.20	0.60	0.60	0.48
U_{floor} [W/(m^{2}K)]	3.40	1.00	0.80	0.55	0.55	0.48
U_w [W/(m^{2}K)]	4.20	3.50	4.20	3.50	3.04	2.71
g_w [-]	0.8	0.8	0.8	0.8	0.8	0.7
Baltics						
U_{roof} [W/(m^{2}K)]	0.70	0.62	0.62	0.62	0.19	0.17
U_{facade} [W/(m^{2}K)]	0.90	0.78	0.78	0.33	0.27	0.23
U_{floor} [W/(m^{2}K)]	0.70	0.64	0.64	0.34	0.26	0.25
U_w [W/(m^{2}K)]	3.00	2.60	2.60	2.10	1.90	1.66
g_w [-]	0.8	0.7	0.7	0.7	0.7	0.6
Poland						
U_{roof} [W/(m^{2}K)]	0.90	0.45	0.45	0.30	0.30	0.23
U_{facade} [W/(m^{2}K)]	1.20	0.50	0.75	0.55	0.45	0.30
U_{floor} [W/(m^{2}K)]	1.20	1.00	0.70	0.70	0.70	0.60
U_w [W/(m^{2}K)]	3.50	2.60	2.60	2.40	2.30	2.00
g_w [-]	0.8	0.7	0.7	0.7	0.7	0.7

Table continues on next page

Table 7 continued

	< 1975 non-refurbished	< 1975 refurbished	1975-1990	1991-2002	2002-2006	2020
Central						
U_{roof} [W/(m^{2}K)]	1.40	0.70	0.70	0.70	0.38	0.23
U_{facade} [W/(m^{2}K)]	1.50	1.00	1.00	1.00	0.55	0.34
U_{floor} [W/(m^{2}K)]	1.40	0.90	0.90	0.90	0.68	0.44
U_w [W/(m^{2}K)]	4.00	3.40	3.40	3.40	2.90	1.65
g_w [-]	0.8	0.8	0.8	0.8	0.8	0.6

Table 8 U-value and g-value for optimum solar control glass for different country clusters.

Country cluster	U_w [W/(m^{2}K)]	g_w [-]
North	1.1	0.40
Central maritime	1.1	0.40
Central continental	1.1	0.40
South	1.7	0.35
Baltics	1.1	0.40
Poland	1.1	0.40
Central	1.1	0.40

2.2.4 *Definition of internal climate control and building occupancy*

Heating and cooling load of buildings depend on control systems for the internal climate and their settings. Internal climate for the calculations is controlled by set point temperatures for heating and cooling and ventilation rates as follows:

- set point for heating: 19°C;
- set point for cooling: 24°C;
- ventilation regime:
  - for dwellings and small apartment buildings: natural ventilation;
  - for large apartment buildings and small non-residential buildings: forced ventilation;
  - for large non-residential buildings: balanced ventilation;
- ventilation rate:
  - for natural and forced ventilation for residential buildings: 0.6 x used building area in litres/s;
  - for natural and forced ventilation for non-residential buildings: 0.65 x used building area in litres/s;
  - for balanced ventilation: 0.65 x (1 – efficiency of heat recovery) x used building area in litres/s, where efficiency of heat recovery = 0.70

The internal heat gain depends on the building occupancy as follows:

- for residential buildings: 6 W/m^2;
- for non-residential buildings: 10.8 W/m^2.

In the sensitivity study reported in Section 3.6, ventilation rate and internal heat gain are halved and doubled.

2.2.5 *Definition of conversion of energy for heating and cooling into CO_2 production*

The calculation core of the tool delivers energy for heating and cooling of the many combinations. Final processing gives energy savings. Two conversions are needed to derive CO_2 savings from the energy savings, i.e. efficiency of heating and cooling systems and CO_2 production related to heating and cooling:

$$\Delta M_{CO2} = \Delta Q_{nd} \cdot (CO_2 \textit{ production per unit of energy}) / \eta_{sys} \quad (9)$$

where:

η_{sys} is the efficiency of the heating or cooling system;

ΔQ_{nd} is the energy savings for heating or cooling.

System efficiency for the calculations has been defined as follows:

- for heating systems: 0.80, as the majority of heating systems use primary energy sources;
- for cooling systems (coefficient of performance, COP): 2.5.

CO_2 production related to heating and cooling differs per country mainly due to the mix of primary energy sources used for heat and electricity production. For the calculations, it is assumed that cooling is provided by electricity whereas heating uses primary energy sources as well as electricity, the share depending on the country cluster.

Table 9 presents the conversion from energy for heating and cooling into CO_2 production. The conversion data for heating come from [8], [9] and [10]. For cooling, the base data used involve the so-called Ecoinvent Life Cycle Inventory Data ([11]). These data are, within the world of LCA experts, known as highly complete and also reliable. The data are verified after data entry by an internal reviewer. The (low voltage) electricity mix of a specific country includes the imports and internal use. In the low voltage data, transmission and transforming losses (around 10%) have been accounted for. The CO_2 equivalents not only contain the emission of CO_2 but also of other gasses with a global warming potential such as methane, HFCs, CFCs and halons. Moreover, emissions before the actual generation of electricity are included, e.g. methane losses during natural gas exploration or coal mining as well as emissions due to transportation of the raw materials.

Table 9 Conversion from energy for heating and cooling into CO_2 production for different country clusters and countries.

Country cluster/ country	**CO_2 production per unit of energy for heating** [kt/TJ]	**CO_2 production per unit of energy for cooling** [kt/TJ]
North	0.087	
- Finland		0.085
- Sweden		0.012
Central maritime	0.083	
- Belgium		0.097
- Denmark		0.157
- Ireland		0.243
- Luxemburg		0.177
- Netherlands		0.204
- United Kingdom		0.165
- France		0.027
Central continental	0.083	
- Austria		0.082
- Germany		0.186

Table continues on next page

Table 9 continued

South	0.076	
- Cyprus		0.326 [1)]
- Greece		0.326
- Italy		0.174
- Malta		0.250 [2)]
- Portugal		0.182
- Spain		0.152
Baltics	0.080 [4)]	
- Estonia		0.237 [3)]
- Latvia		0.237 [3)]
- Lithuania		0.237 [3)]
Poland	0.080 [4)]	
- Poland		0.330
Central	0.080 [4)]	
- Czech Republic		0.288
- Hungary		0.196
- Slovakia		0.133
- Slovenia		0.124

1) Value is assumed to be the same as for Greece

2) Value is assumed to be the average of the figures for Greece and Italy

3) Value is assumed to be the average of the figures for the Czech Republic, Poland, Slovakia and Hungary

4) Value is assumed based on the figures for the old EU15 Member States

3 Four scenarios for savings of energy and CO_2 by solar control glazing

3.1 Introduction: explanation of the presented savings

Sets of two calculations form the basis for determination of the energy savings:

- in one calculation, heating and cooling energy is calculated for the building with reference glazing, which is already present for existing buildings or is expected to be applied for future buildings (period 2007-2020), as defined by the figures in Table 7;
- in the other calculation, heating and cooling energy is calculated for the same building with solar control glazing, as defined by the figures in Table 8.

Subtraction of the energy performance resulting from the two calculations reveals the energy savings for heating and cooling. Application of solar control glazing always saves cooling energy as less solar energy enters the building. For heating, the energy savings can be positive or negative depending on the effect of the lower heat loss through the glazing on one side and (again) less solar energy entering the building on the other side.

The next Sections describe different scenarios for application of solar control glazing in new buildings as well as the impact of replacing glass in existing buildings by solar control glazing:

- Scenario 1: application of solar control glazing in all future air-conditioned buildings under the assumption that the percentage of air conditioning in new buildings (built between 2007 and 2020) is twice as high as in present buildings;
- Scenario 2: as Scenario 1 but with the suggestion that the application of solar control glazing may cause air conditioners to be left out for all new buildings except for South Europe;
- Scenario 3: application of solar control glazing in all future air-conditioned buildings and replacing glass in all existing air-conditioned buildings by solar control glazing;
- Scenario 4: as Scenario 3 with vast increase of air conditioning in both existing and future buildings to present USA levels of 65% for residential and 80% (100% for South Europe) for non-residential buildings.

For all scenarios, energy savings for heating and cooling have been presented separately. Savings for Cyprus and Malta have been extrapolated using the summed savings for Greece, Italy, Portugal and Spain together with the number of inhabitants of the six countries in the South region. For the ‘old’ EU Member States with Cyprus and Malta added, energy savings have been distributed additionally according to the number of inhabitants of the various countries. Energy savings have been converted into CO_2 savings using the conversion factors in Table 9.

3.2 Scenario 1: Solar control glazing in all future air-conditioned buildings

In this scenario, all future (2007 – 2020) buildings with air conditioning will also be provided with solar control glazing to reduce energy use and CO_2 production. It is assumed that the percentage of air conditioning in the new buildings built between 2007 and 2020 is twice as high as in present buildings as indicated in an EU SAVE study on air conditioners ([12]); see Table 10.

Table 10 Share of air-conditioned buildings in 2020.

Country cluster	**Share of air-conditioned buildings** [%]	
	Residential	Non-residential
North	10	55
Central maritime	10	55
Central continental	7	39
South	15	83
Baltics	11	59
Poland	11	59
Central	11	59

Table 11 presents the annual energy savings for heating and cooling and matching CO_2 reduction to be achieved in 2020 for Scenario 1.

Table 11 Annual energy savings for heating and cooling and matching CO_2 reduction in 2020 for Scenario 1.

2020	**Energy savings** [TJ]			**CO_2 reduction** [kt]		
	Total	Heating	Cooling	Total	Heating	Cooling
North	**1362**	**-414**	**1775**	**-17**	**-45**	**27**
- Finland	500	-152	652	6	-16	22
- Sweden	862	-262	1124	-23	-28	5
Central maritime	**9301**	**593**	**8708**	**456**	**62**	**394**
- Belgium	610	39	571	26	4	22
- Denmark	320	20	300	21	2	19
- Ireland	239	15	223	23	2	22
- Luxemburg	28	2	26	2	0	2
- Netherlands	969	62	907	80	6	74
- United Kingdom	3560	227	3333	243	24	219
- France	3576	228	3348	60	24	36
Central continental	**4157**	**68**	**4089**	**296**	**7**	**289**
- Austria	376	6	370	13	1	12
- Germany	3781	62	3719	284	6	277
South	**46326**	**-4281**	**50608**	**3281**	**-407**	**3688**
- Cyprus	306	-28	335	41	-3	44
- Greece	4091	-378	4469	548	-36	584
- Italy	22253	-2057	24309	1498	-195	1693
- Malta	153	-14	167	15	-1	17
- Portugal	4060	-375	4435	287	-36	323
- Spain	15464	-1429	16893	893	-136	1028
New EU Members States	**4367**	**753**	**3614**	**486**	**75**	**411**
- Baltics	500	130	370	48	13	35
- Poland	2797	671	2126	348	67	280
- Central	1070	-48	1117	90	-5	95
EU15	**61146**	**-4035**	**65180**	**4016**	**-382**	**4399**
EU25	**65513**	**-3282**	**68794**	**4502**	**-307**	**4809**

3.3 Scenario 2: Solar control glazing in all future buildings avoiding air conditioning in all new buildings except for South Europe

This scenario quantifies the suggestion that application of solar control glazing may cause air conditioners to be left out for buildings built between 2007 and 2020 in all countries except for South Europe. In that case, the whole cooling load of the reference situation is saved for all but the South country cluster. For the South region itself, the savings will be the same as for Scenario 1 provided that the number of new air-conditioned buildings is according to the data in Table 10. Table 12 presents the savings for Scenario 2.

Table 12 Annual energy savings for heating and cooling and matching CO_2 reduction in 2020 for Scenario 2.

2020	**Energy savings** [TJ]			**CO_2 reduction** [kt]		
	Total	Heating	Cooling	Total	Heating	Cooling
North	**4224**	**-414**	**4638**	**27**	**-45**	**72**
- Finland	1551	-152	1703	41	-16	58
- Sweden	2673	-262	2935	-15	-28	14
Central maritime	**28961**	**593**	**28368**	**1346**	**62**	**1284**
- Belgium	1898	39	1859	76	4	72
- Denmark	997	20	977	63	2	61
- Ireland	743	15	728	72	2	71
- Luxemburg	87	2	85	6	0	6
- Netherlands	3016	62	2955	247	6	241
- United Kingdom	11086	227	10859	739	24	715
- France	11134	228	10906	142	24	119
Central continental	**11806**	**68**	**11738**	**837**	**7**	**830**
- Austria	1067	6	1061	35	1	35
- Germany	10738	62	10677	802	6	796
South	**46326**	**-4281**	**50608**	**3281**	**-407**	**3688**
- Cyprus	306	-28	335	41	-3	44
- Greece	4091	-378	4469	548	-36	584
- Italy	22253	-2057	24309	1498	-195	1693
- Malta	153	-14	167	15	-1	17
- Portugal	4060	-375	4435	287	-36	323
- Spain	15464	-1429	16893	893	-136	1028
New EU Members States	**9951**	**753**	**9198**	**1103**	**75**	**1027**
- Baltics	1164	130	1034	111	13	98
- Poland	5685	671	5014	729	67	661
- Central	3101	-48	3149	263	-5	268
EU15	**91317**	**-4035**	**95352**	**5491**	**-382**	**5874**
EU25	**101268**	**-3282**	**104550**	**6594**	**-307**	**6901**

3.4 Scenario 3: Solar control glazing in all existing and future air-conditioned buildings

Currently, an average of 5% of the residential buildings in Europe has been equipped with air conditioning, and 27% of the non-residential buildings ([12]). This scenario considers these existing buildings together with the future buildings as in Scenario 1. For the new buildings, the share of air conditioning is as in Table 10. Table 13 presents the savings for Scenario 3.

Table 13 Annual energy savings for heating and cooling and matching CO_2 reduction in 2020 for Scenario 3.

2020	**Energy savings** [TJ]			**CO_2 reduction** [kt]		
	Total	Heating	Cooling	Total	Heating	Cooling
North	**5050**	**277**	**4773**	**104**	**30**	**74**
- Finland	1854	102	1752	70	11	59
- Sweden	3196	176	3021	33	19	14
Central maritime	**37938**	**9561**	**28377**	**2282**	**997**	**1284**
- Belgium	2487	627	1860	137	65	72
- Denmark	1306	329	977	96	34	61
- Ireland	973	245	728	96	26	71
- Luxemburg	114	29	85	9	3	6
- Netherlands	3951	996	2955	345	104	241
- United Kingdom	14522	3660	10862	1097	382	715
- France	14586	3676	10910	502	383	119
Central continental	**18936**	**5600**	**13335**	**1527**	**584**	**943**
- Austria	1712	506	1206	92	53	39
- Germany	17224	5094	12130	1435	531	904
South	**138514**	**-9049**	**147563**	**9894**	**-859**	**10753**
- Cyprus	916	-60	975	122	-6	127
- Greece	12232	-799	13032	1626	-76	1701
- Italy	66534	-4347	70881	4523	-413	4936
- Malta	458	-30	488	46	-3	49
- Portugal	12139	-793	12932	866	-75	941
- Spain	46236	-3020	49256	2712	-287	2999
New EU Members States	**19975**	**9851**	**10124**	**2107**	**985**	**1122**
- Baltics	2413	1195	1217	235	120	115
- Poland	9997	4690	5307	1169	469	700
- Central	7566	3966	3601	703	397	306
EU15	**200438**	**6390**	**194049**	**13807**	**752**	**13055**
EU25	**220414**	**16241**	**204173**	**15913**	**1737**	**14176**

3.5 Scenario 4: Vast increase of air conditioning in buildings

For the United States, 65% of the residential buildings have been equipped with air conditioning, and 80% of the non-residential buildings ([12]). This scenario considers the increase of air conditioning in both existing and future buildings towards these present USA levels. For South Europe, 100% air conditioning is assumed for non-residential buildings. Current developments in air-conditioned buildings in Europe make that this scenario is rather realistic. Table 14 presents the annual energy savings for heating and cooling and matching CO_2 reduction for Scenario 4, again to be achieved in 2020.

Table 14 Annual energy savings for heating and cooling and matching CO_2 reduction in 2020 for Scenario 4.

2020	**Energy savings** [TJ]			**CO_2 reduction** [kt]		
	Total	Heating	Cooling	Total	Heating	Cooling
North	**29957**	**2348**	**27609**	**681**	**254**	**426**
- Finland	10999	862	10136	437	93	344
- Sweden	18959	1486	17473	243	161	82
Central maritime	**232331**	**69800**	**162531**	**14636**	**7280**	**7357**
- Belgium	15229	4575	10654	888	477	411
- Denmark	7998	2403	5595	602	251	351
- Ireland	5960	1791	4169	592	187	406
- Luxemburg	695	209	487	56	22	34
- Netherlands	24197	7270	16927	2137	758	1379
- United Kingdom	88930	26717	62212	6882	2786	4096
- France	89322	26835	62486	3479	2799	680
Central continental	**161478**	**52367**	**109111**	**13180**	**5462**	**7718**
- Austria	14600	4735	9865	816	494	322
- Germany	146878	47633	99245	12363	4968	7396
South	**575040**	**-50888**	**625928**	**40781**	**-4832**	**45613**
- Cyprus	3801	-336	4137	508	-32	540
- Greece	50783	-4494	55277	6790	-427	7217
- Italy	276217	-24444	300660	18617	-2321	20938
- Malta	1901	-168	2069	191	-16	207
- Portugal	50393	-4460	54853	3568	-423	3991
- Spain	191946	-16986	208932	11107	-1613	12720
New EU Members States	**121683**	**66187**	**55496**	**12753**	**6619**	**6135**
- Baltics	15416	8094	7322	1503	809	694
- Poland	59259	30583	28676	6841	3058	3783
- Central	47008	27510	19498	4409	2751	1658
EU15	**998807**	**73628**	**925179**	**69278**	**8163**	**61114**
EU25	**1120490**	**139815**	**980675**	**82031**	**14782**	**67249**

3.6 Sensitivity of the savings for different assumptions

The energy performance figures presented in the Sections 3.2 – 3.5 have been calculated for the internal gain and ventilation rate according to European standards for buildings. For construction rate of new buildings and climate change, values have been chosen in the mid range of expected values.

In order to assess the accuracy of these figures, sensitivity of the energy savings has been studied for internal heat gain, ventilation rate, construction rate of new buildings and climate change. Minimum and maximum values for the additional calculations have been selected as follows:

– for the internal heat gain: half and double the default values mentioned in Section 2.2.4;
– for the ventilation rate: half and double the default values mentioned in Section 2.2.4;
– for the construction rate of new buildings: 1% and 3% per year whereas the annual demolition rate remains 1% as mentioned in Section 2.2.2;
– for climate change: external temperatures increase at the top and bottom range projections of the IPPC report ([7]) as mentioned in Section 2.2.1, corresponding to 0.6°C and 3.5°C temperature increase by the year 2100.

Investigation of the sensitivity is rather extreme for the internal heat gain and the ventilation rate, i.e. not for individual buildings but surely for the whole building stock. However, the intension is to clearly show the sensitivity of the savings for these non-standard conditions. There is no data available to present statistically justified values.

Table 15 presents the change in total energy savings due to the variations as described above for the four scenarios.

Table 15 Change in total energy savings for the four scenarios due to variation of internal heat gain, ventilation rate, construction rate of new buildings and climate change.

	Change in total energy savings [%]			
	Scenario 1		Scenario 2	
	Minimum	Maximum	Minimum	Maximum
Internal heat gain: 50 - 200%	-33%	+29%	-47%	+116%
Ventilation rate: 50 - 200%	-59%	+41%	-69%	+83%
Construction rate new buildings: 1 - 3% per year	-48%	+48%	-48%	+48%
Climate change: top – bottom range IPPC	-1%	+8%	-2%	+11%
	Scenario 3		Scenario 4	
	Minimum	Maximum	Minimum	Maximum
Internal heat gain: 50 - 200%	-21%	+11%	-21%	+15%
Ventilation rate: 50 - 200%	-46%	+24%	-49%	+28%
Construction rate new buildings: 1 - 3% per year	-19%	+23%	-11%	+13%
Climate change: top – bottom range IPPC	-1%	+5%	-1%	+6%

Table 15 shows that energy (and CO_2) savings largely depend on choices for internal heat gain, ventilation rate and rate of construction of new buildings. Influence of climate change is much lower.

4 Conclusions

This study quantifies the impact of application of solar control glazing in existing and new buildings with air conditioning on energy savings and CO_2 reduction to be achieved in 2020. The calculation method used corresponds to the EPBD standard developed for determination of heating and cooling loads of buildings. Information on building stock, material properties and meteorological data comes from European studies and statistics.

Sets of two calculations form the basis for determination of the energy savings:

– in one calculation, heating and cooling energy is calculated for the building with reference glazing, which is already present for existing buildings or is expected to be applied for future buildings (period 2007-2020);
– in the other calculation, heating and cooling energy is calculated for the same building with solar control glazing.

Subtraction of the energy performance resulting from the two calculations reveals the energy savings for heating and cooling. Subsequently, CO_2 reduction is derived from the energy savings.

Figures have been calculated for the 25 EU Member States for four scenarios:

– Scenario 1: application of solar control glazing in all future air-conditioned buildings under the assumption that the percentage of air conditioning in the new buildings (built between 2007 and 2020) is twice as high as in present buildings;
– Scenario 2: as Scenario 1 but with the suggestion that the application of solar control glazing may cause air conditioners to be left out for all new buildings except for South Europe;
– Scenario 3: application of solar control glazing in all existing and future air-conditioned buildings, i.e. combining Scenario 1 with the existing buildings with air conditioners;
– Scenario 4: as Scenario 3 with vast increase of air conditioning in both existing and future buildings to present USA levels of 65% for residential and 80% (100% for South Europe) for non-residential buildings.

Table 16 summarizes the summed values for the EU25 Member States of energy savings for heating and cooling and CO_2 reduction. The contribution to the Commission's target on CO_2 reduction for buildings in 2020, i.e. about 300 Mt/year, has also been indicated.

Table 16 Energy savings for heating and cooling and CO_2 reduction summarized for the EU25 Member States; CO_2 reduction has also been presented as percentage of the EU target for CO_2 reduction for buildings in 2020.

Scenario	Energy savings for heating in 2020 [TJ]	Energy savings for cooling in 2020 [TJ]	CO_2 reduction in 2020 [kt]	Contribution to EU target for CO_2 reduction for buildings in 2020
1	-3282	68794	4502	1.5%
2	-3282	104550	6594	2.2%
3	16241	204173	15913	5.3%
4	139815	980675	82031	27%

Relating the figures in Table 16 to the Commission's objective for all sectors, i.e. 780 Mt/year CO_2 reduction, shows that application of solar control glazing can contribute up to 10% of the target for 2020.

The big countries in the South region contribute the most to the potential for CO_2 reduction as can be seen from Table 17 presenting the CO_2 reduction figures of the Tables 11 – 14 as percentage of the total EU25 figure. The South region is followed by the mid-European countries with the Central and Central continental country clusters. There is also interesting potential for Poland and the United Kingdom.

Table 17 CO_2 reduction in 2020 as percentage of the total EU25 figure for the EU25 Member States for all four scenarios.

2020	**CO_2 reduction as percentage of the total EU25 figure [%]**			
	Scenario 1	Scenario 2	Scenario 3	Scenario 4
North	**-0.4**	**0.4**	**0.7**	**0.8**
- Finland	0.1	0.6	0.4	0.5
- Sweden	-0.5	-0.2	0.2	0.3
Central maritime	**10.1**	**20.4**	**14.3**	**17.8**
- Belgium	0.6	1.1	0.9	1.1
- Denmark	0.5	1.0	0.6	0.7
- Ireland	0.5	1.1	0.6	0.7
- Luxemburg	0.0	0.1	0.1	0.1
- Netherlands	1.8	3.7	2.2	2.6
- United Kingdom	5.4	11.2	6.9	8.4
- France	1.3	2.2	3.2	4.2
Central continental	**6.6**	**12.7**	**9.6**	**16.1**
- Austria	0.3	0.5	0.6	1.0
- Germany	6.3	12.2	9.0	15.1
South	**72.9**	**49.8**	**62.2**	**49.7**
- Cyprus	0.9	0.6	0.8	0.6
- Greece	12.2	8.3	10.2	8.3
- Italy	33.3	22.7	28.4	22.7
- Malta	0.3	0.2	0.3	0.2
- Portugal	6.4	4.4	5.4	4.3
- Spain	19.8	13.5	17.0	13.5
New EU Members States	**10.8**	**16.7**	**13.2**	**15.5**
- Baltics	1.1	1.7	1.5	1.8
- Poland	7.7	11.0	7.3	8.3
- Central	2.0	4.0	4.4	5.4
EU25	**100.0**	**100.0**	**100.0**	**100.0**

Potentials in Tables 16 and 17 present an appealing contribution to the EU target. This is confirmed by the further properties of the solar control glazing:

- the product is available and does not need development;
- the solar control glass puts up the cost of the window only slightly when compared to more common double glazing;
- no adaptation of the infrastructure for installation is needed;
- maintenance of the product is minimal and not different than for common glass.

This makes solar control glazing very worthwhile considering both for new houses and buildings and for replacement in case of refurbishment.

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