European energy labelling scheme for windows

Mette Belling Skou
VELUX A/S
Denmark
mette.belling.skou@velux.com

Jesper Kragh
DTU Byg
Denmarks Tekniske Universitet
Denmark
jek@byg.dtu.dk

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Abstract

In their proposals for revision of the energy labelling directive the European Commission has suggested to include windows.

The paper introduces a proposal for an European energy labelling scheme of windows for replacement of windows in the existing building stock taking into consideration the energy performance of windows in both the heating and cooling seasons. The labelling scheme evaluates a methodology where the energy performance in the heating period is established with focus on heat loss and utilization of passive solar energy, whereas the energy performance in the summer (cooling) season will focus on reduction of solar radiation into the building. The methodology is developed with focus on CEN and ISO standardization.

With inspiration from the American Energy Star programme for windows, Europe is divided into climate zones where the methodology for each zone is developed on basis of a reference building and climate data. A proposal for labelling will be presented for both heating and cooling seasons in order to enable the user to choose the right product for a specific performance.

Based on data from the building stock in the individual climate zones, an energy saving potential for replacement of old windows with new low energy windows will be presented.

The possibility for using energy labelling of windows as reference and requirement in the building legislation as an alternative to U-values, will be presented with among others examples from legislation in UK and Denmark.

Introduction

Windows have a large influence on the energy demand and indoor climate in buildings. Apart from a heat loss through windows, windows also provide a solar gain to the building that in some periods can be exploited for space heating and in other periods can result in overheating problems leading to a need for cooling.

To stimulate and encourage the use of windows with improved energy performance, there is a need to develop an energy rating system that will make it easier to select the best windows for the actual climate.

The purpose of the project performed by DTU Byg /4/ at the request of VELUX A/S was to develop a proposal for a simple energy rating system of windows in the EU based on the net energy gain of a reference building. The aim was to make it as simple and general as possible and also applicable for sloped windows (roof windows).

Method

The energy performance of a window is depending very much on the climate and the house. Therefore, a reference house is needed to make an evaluation of a specific window. It is, however, almost impossible to appoint a general reference house for the all of Europe. The climate in EU also differs both regarding solar radiation and degree hours and this adds to making it difficult to establish one simple equation valid for all countries in EU.

As windows both provide heat losses and solar gains, the description of windows must be based on both the thermal transmittance and the total solar energy transmittance. To evaluate the energy performance of a window the net energy gain is, therefore, very suitable as the net energy gain takes into account both the solar gains and heat losses. The method used takes into account that the solar gain in the heating season reduces the heat consumption and in the cooling season increases the cooling consumption.

The method suggested in this proposal for an energy labelling system for window assumes:

- Based on the climate, Europe is divided into three climate zones following country borders.
- Two reference houses are used to calculate the length of the heating and cooling season.
- The performance of a window is evaluated in the cooling and heating season, respectively, using the net energy gain, which is defined as the solar gain minus the heat loss.

The method also takes into account the influence of solar shading devices on the energy performance of a window.

THE CLIMATE DATA

The climatic data used in this analysis is taken from: http://apps1.eere.energy.gov/buildings/energyplus/cfm/weather_data.cfm

Hourly data for the calculations are:

- Dry bulb temperature [°C]
- Global Horizontal Radiation [W/m²]
- Direct Normal Radiation [W/m²]
- Diffuse Horizontal Radiation [W/m²]

Based on the weather data for different cities in Europe, the global solar radiation and the degree hours at different locations in EU are shown in Figure 1 and Figure 2.

THE CLIMATE ZONES

Based on analysis of the weather data of EU shown in Figure1 and 2, it is proposed to divide the EU into three zones following country borders as shown in Figure 3. The zones are found by comparing weather data (solar radiation and degree hours) in 10 suitable cities in the EU. Although there can be variations in the climate within each country it is chosen to draw the zone borders along the country borders. This simplification is justified by the fact that the energy performance ranking of different windows in most cases is maintained for every part of a specific country regardless of the variations in climate. Furthermore, following the country borders will simplify the administration of the rating system.

THE REFERENCE HOUSES

The two reference houses are used to calculate the length of the heating and cooling season. The designs of the reference houses are chosen to represent common dwellings in northern and southern Europe, respectively.

The first reference house (type 1) is a 1½-storey house and the second (type 2) is a one-storey house. The ground floor areas of the two houses are 96 m² and 140 m², respectively.

The total window area of the reference houses is assumed to be 20% of the heated floor area. The distribution of the vertical windows is assumed to be 41% facing south, 16.5% facing west, 16.5% facing east and 26% facing north, see Figure 4.

The area of roof windows is calculated assuming the same distribution as shown in Figure 4 and only for orientation to the north and south. The windows to the east and west are assumed to be vertical. For reference house type 1 the ground floor area is 96 m², resulting in 19 m² vertical façade windows, and a first floor area of 67 m², resulting in 4 m² vertical windows and 9 m² roof windows. For reference house type 2 the ground floor area is 140 m². The windows are distributed as 21 m² (15%) vertical façade windows and 7 m² (5%) roof windows.

The slope of the roof windows is assumed to be 45° in type 1 and 30° in type 2. The reference houses type 1 and 2 are shown in Figure 5 and Figure 6, respectively.

The thermal properties of the constructions of the building envelope of the two reference houses are shown in Table 1. The data are taken from /9/.

THE HEATING AND COOLING SEASON IN SELECTED CITIES IN EU

In order to determine the net energy gain, the length of the heating and cooling seasons must be known for the actual location and for the specific reference house. The length of the heating and cooling seasons is calculated for selected cities covering the EU according to the method described in ISO 13790 /7/ and using the two reference houses type 1 and 2. According to the standard the heating season includes all days where the heat gain, calculated with a conventional utilization factor, does not balance the heat transfer and vice-versa for the cooling season. The programme WinDesign /3/ that is based on ISO 13790 was used for the calculations. The method takes into account a utilisation factor for the heat gains and heat losses in the calculations of energy requirements for heating and cooling. The calculated heating and cooling seasons are shown in Table 2.

The results in Table 2 show that the length of the heating season does not change much from zone 1 to zone 2 although there is a difference in climate. This is because the thermal properties of the reference houses in the two zones are different, i.e. the house in zone 2 is poorly insulated compared to the house in zone 1.

DEGREE HOURS

For the different locations the net degree hour, *D*, is calculated for each cooling and heating season as the sum of the difference between the indoor base temperature and the external temperature during the heating season on an hourly basis using equations (1) and (2):

$$D_{heating} = \sum_{i=heating\ start}^{heating\ stop} T_{base,\,heating} - T_{out} \quad \textit{for the heating season} \tag{1}$$

$$D_{cooling} = \sum_{i=cooling\ start}^{cooling\ stop} T_{out} - T_{base,\,cooling} \quad \textit{for the cooling season} \tag{2}$$

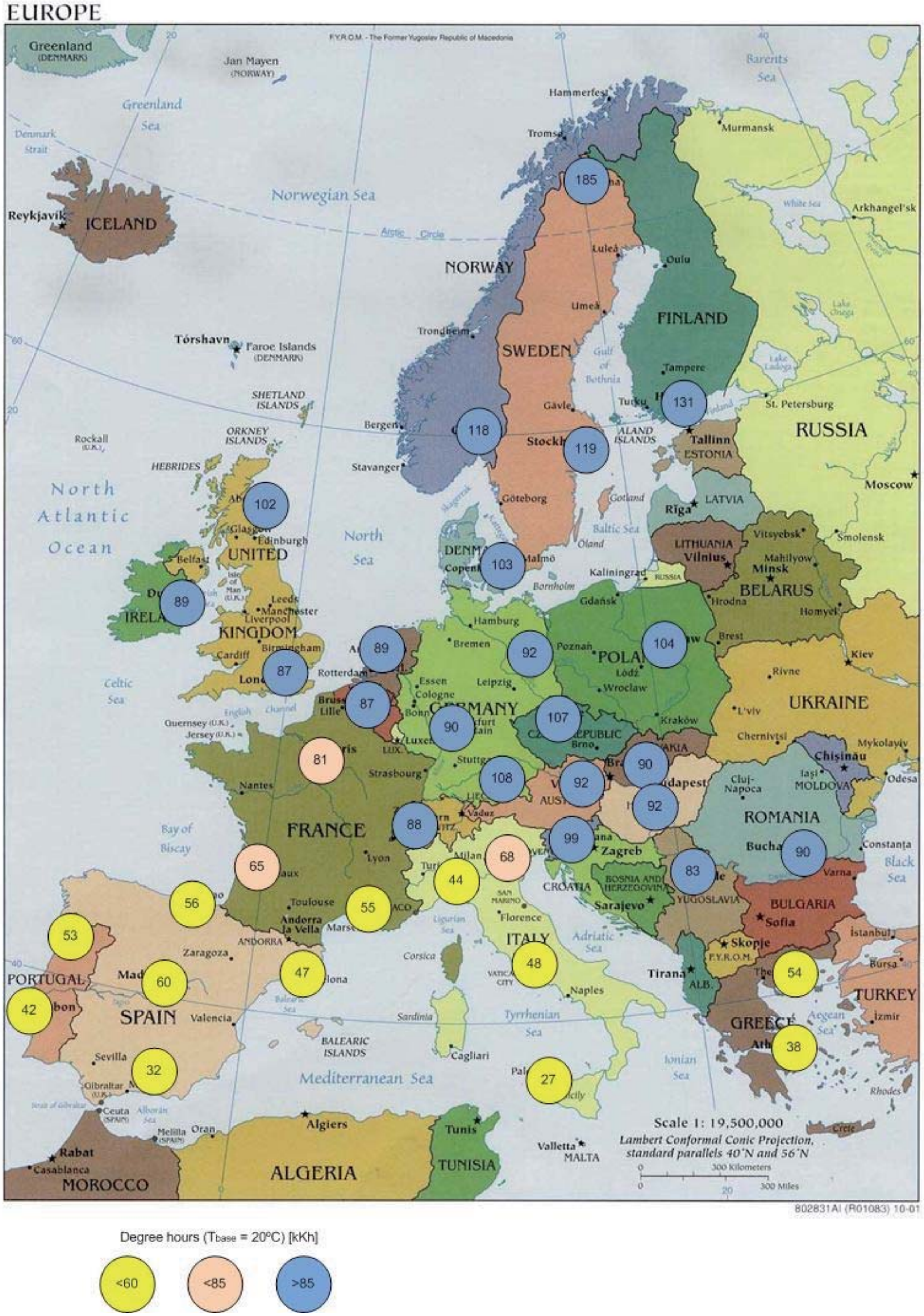

Figure 1. Degree hours at different locations in Europe. Based on an indoor temperature of 20°C.

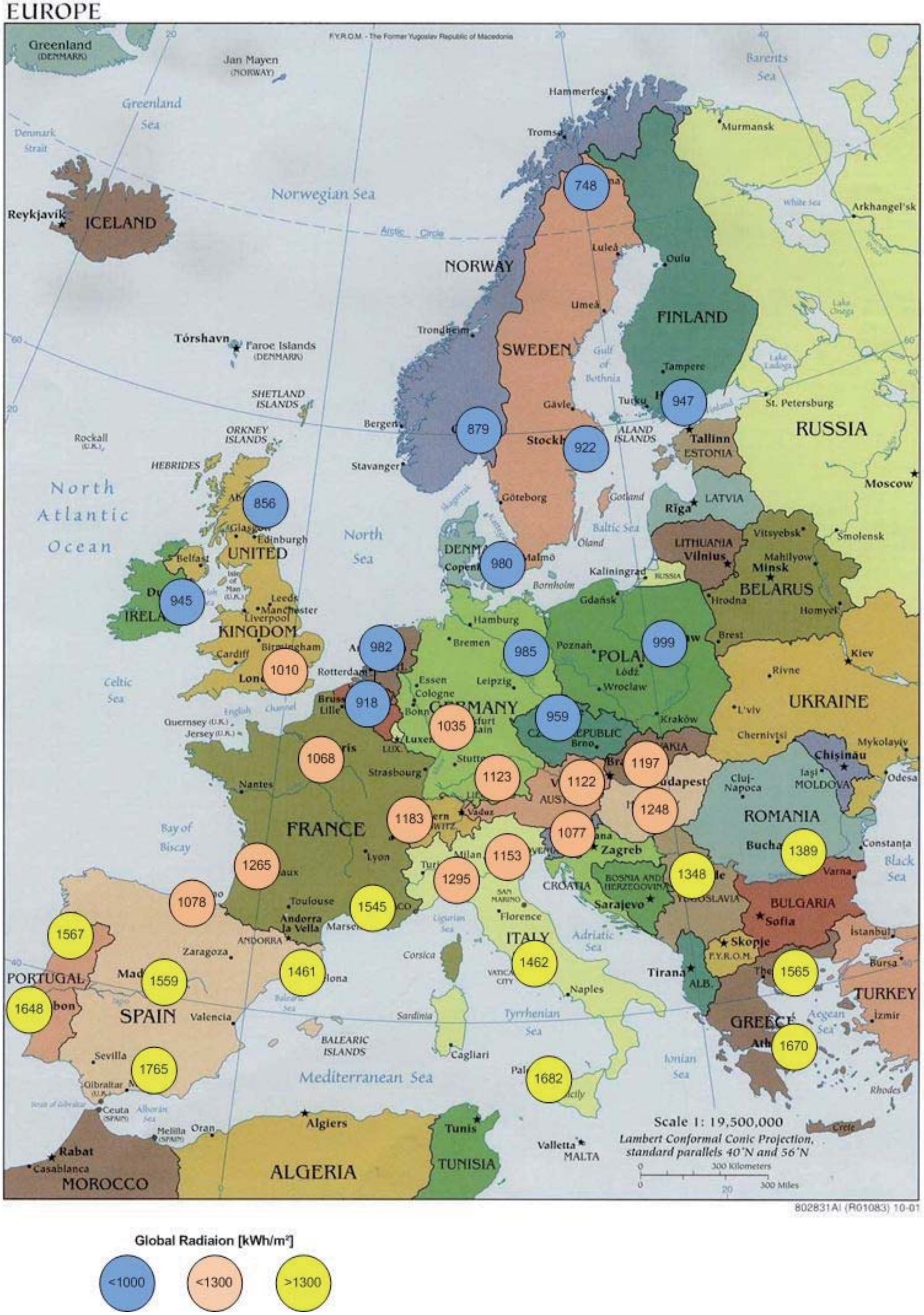

Figure 2. Annual solar radiation at different locations in Europe. Radiation on horizontal plane.

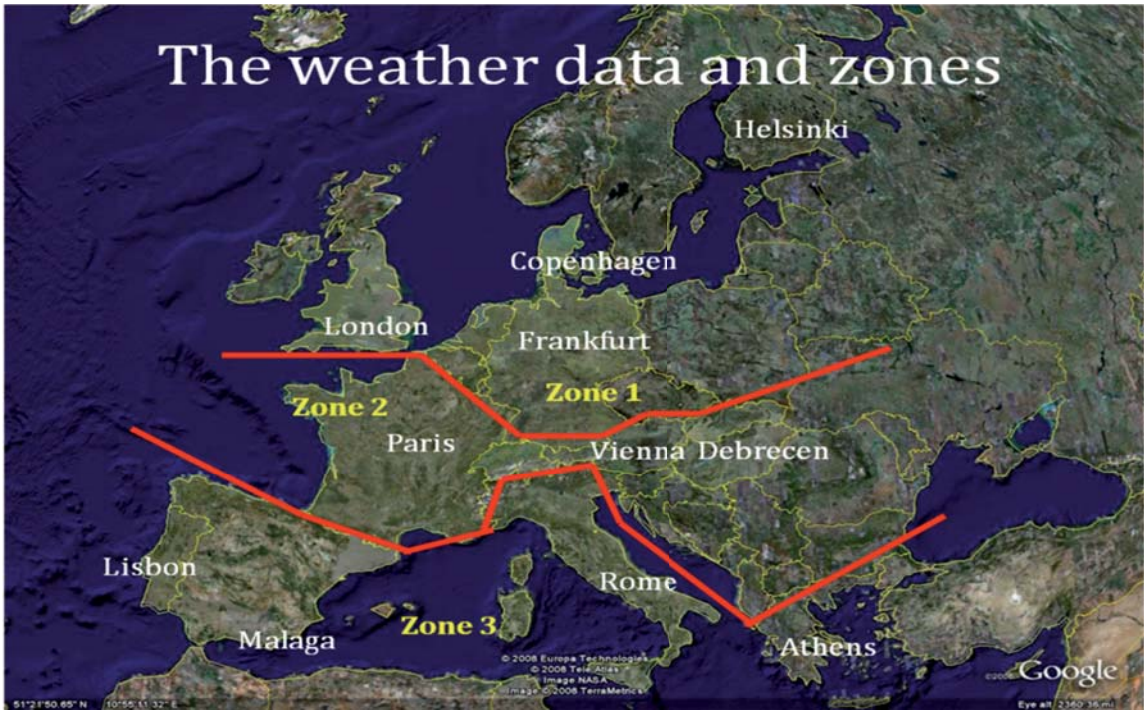

Figure 3. The suggested climate zone in EU with suitable selected cities.

Zone 1: Ireland, United Kingdom, Denmark, Sweden, Finland, Netherlands, Belgium, Luxemburg, Germany, Poland, Estonia, Latvia and Lithuania.
Zone 2: France, Austria, Switzerland, Hungary, Slovenia, Czech Republic, Bulgaria, Romania and Slovakia.
Zone 3: Portugal, Spain, Italy, Malta, Greece and Cyprus.

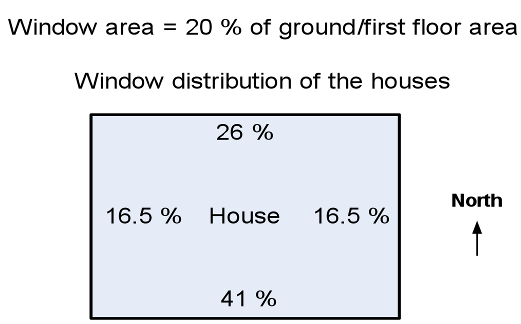

Figure 4. Distribution of the window area in the reference houses regarding orientations. The total window area is calculated as 20% of the floor area.

where,

T_{out} is the dry bulb temperature outside	[°C]
$T_{base, heating}$ is the base temperature for heating	[°C]
$T_{base, cooling}$ is the base temperature for cooling	[°C]

The calculations are based on the weather data for the specific location.

SOLAR RADIATION

Using a pc software as e.g. BuildingCalc /2/ the solar radiation is calculated on hourly basis on vertical (90°) and sloped (45° and 30°) surfaces orientated south, west, east and north.

The total solar irradiance on the windows is calculated assuming a distribution of the windows in the reference houses as: 41% south, 16.5% west, 16.5% east and 26% north.

$$I_{90^\circ} = 0.26 \cdot I_{north,90^\circ} + 0.165 \cdot I_{west,90^\circ} + 0.165 \cdot I_{east,90^\circ} + 0.41 \cdot I_{south,90^\circ} \tag{3}$$

$$I_{45^\circ} = 0.26 \cdot I_{north,45^\circ} + 0.165 \cdot I_{west,45^\circ} + 0.165 \cdot I_{east,45^\circ} + 0.41 \cdot I_{south,45^\circ} \tag{4}$$

$$I_{30^\circ} = 0.26 \cdot I_{north,30^\circ} + 0.165 \cdot I_{west,30^\circ} + 0.165 \cdot I_{east,30^\circ} + 0.41 \cdot I_{south,30^\circ} \tag{5}$$

For vertical windows the solar radiation usable for heating, $I_{heating}$, is calculated for the heating season using eq. (6):

$$I_{heating} = \sum_{i=heating\ start}^{heating\ stop} I_{90^\circ}\ , \textit{for the heating season} \tag{6}$$

The solar radiation, which needs to be cooled, $I_{cooling}$, is calculated for the cooling season using eq. (7). As not all the solar gains during the cooling season result in cooling demands only

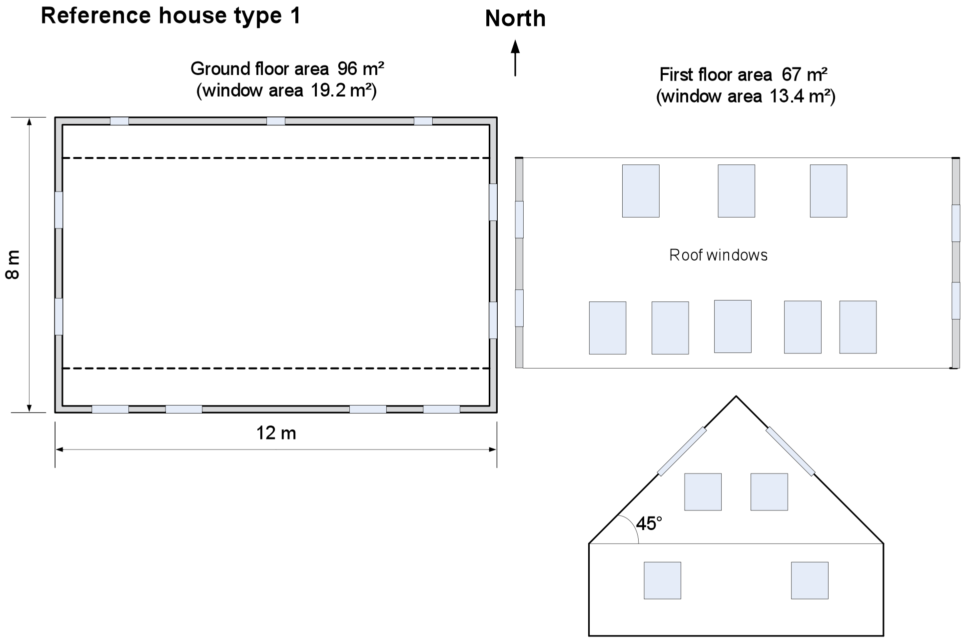

Figure 5. Outline of the reference house type 1 with 45º sloped roof construction.

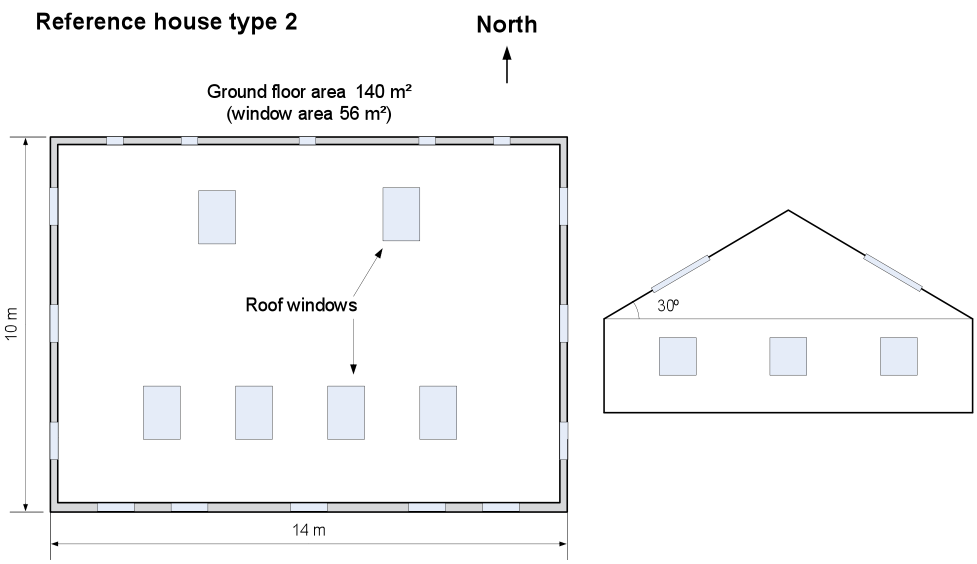

Figure 6. Outline of the reference house type 2 with 30º sloped roof construction.

Table 1. Data for the building envelope of the reference houses.

		Zone 1	Zone 2	Zone 3
Construction	Roof	0.2	0.5	0.8
	Wall	0.3	1.0	1.2
	Floor	0.2	0.8	0.8
Ventilation $[h^{-1}]$	Winter	0.5	0.5	0.5
	Summer	1.5	2.0	2.5
Window	U_w $[W/m^2K]$	2.0	3.5	4.2
	g_w	0.50	0.58	0.58
House Type 1 Heat Capacity	Category	medium	medium	medium
	C $[J/Km^2]$	165 000	165 000	165 000
House Type 2 Heat Capacity	Category	heavy	heavy	heavy
	C $[J/Km^2]$	260 000	260 000	260 000

Table 2. Calculated heating and cooling seasons for selected EU cities

Zone	Location	Reference house			
		Type 1		Type 2	
		Heating	Cooling	Heating	Cooling
1	Helsinki	9 Aug – 18 May	13 Jun – 15 Aug	5 Sept – 27 May	5 Jul – 26 Jul
	Copenhagen	17 Sept – 14 May	12 Jun – 21 Aug	12 Sept – 23 May	12 Jul – 30 Jul
	Frankfurt	2 Oct – 24 Apr	2 Jun – 2 Sept	27 Sept – 30 Apr	23 Jun – 24 Aug
	London	24 Sept – 10 May	21 Jun – 22 Aug	16 Sept – 25 May	10 Jul – 29 Jul
2	Paris	19 Sept – 27 May	3 Jul – 22 Aug	14 Sept – 7 Jun	15 Jul – 16 Aug
	Vienna	19 Sept – 19 May	26 Jun – 23 Aug	15 Sept – 1 Jun	6 Jul – 18 Aug
	Debrechen	23 Sept – 8 May	5 Jun – 27 Aug	18 Sept – 15 May	13 Jun – 22 Aug
3	Lisbon	1 Nov – 25 Apr	1 Jun – 28 Sept	29 Oct – 2 May	17 Jun – 20 Sept
	Rome	25 Oct – 27 Apr	30 May – 24 Sept	23 Oct – 1 May	9 Jun – 18 Sept
	Athens	10 Nov – 14 Apr	13 May – 9 Oct	7 Nov – 17 Apr	21 May – 3 Oct

the solar irradiance above 300 W/m^2 is included. This corresponds to ISO 13790, Annex G, which states "solar shading shall be taken as being switched on if the intensity of the solar radiation on the surface at the given hour exceeds 300 W/m^2." However, this criteria is further extended so only solar radiation in hours where the outside temperature is above 23ºC is included. See eq. (7).

$$I_{cooling} = \sum_{i=cooling\ start}^{cooling\ stop} I_{90^\circ}\ for\ I_{90^\circ} > 300W\ and\ T_{out} > 23\ ^\circ C \tag{7}$$

The solar radiation on sloped windows is calculated similarly as eq. (6) and (7).

The window energy performance

The energy performance of the window is calculated as the difference between the transmitted solar energy and the thermal heat loss during the cooling and heating seasons.

$$E_{ref,\,cooling} = I_{cooling} \cdot F_s \cdot g_w - D_{cooling} \cdot U_w \tag{8}$$

$$E_{ref,\,heating} = I_{heating} \cdot F_s \cdot g_w - D_{heating} \cdot U_w \tag{9}$$

where,

$E_{ref,\ cooling}$ is the energy performance of the window in the cooling season [kWh/m²]

$E_{ref,\ heating}$ is the energy performance of the window in the heating season [kWh/m²]

$I_{heating}$ is the solar radiation on the window in the heating season [kWh/m²]

$I_{cooling}$ is the unusable solar radiation in the cooling season [kWh/m²]

$D_{cooling}$ is the degree hour in the cooling season [kKh]

$D_{heating}$ is the degree hour in the heating season [kKh]

g_w is the solar energy transmittance of the window (including solar shading) [–]

F_s is the shadow factor due to the horizon and built-in (overhang, side fins) [–]

U_w is the thermal transmittance of the window [W/m²K]

NOTE: There may be a difference in g_w between heating and cooling mode if the window is adaptive to the season (e.g. movable solar shading devices).

The shadow factor for the horizon and built-in, F_s, could be estimated in general to be 0.7 for horizontal windows (European standard EN 832, 1998) /6/. For roof windows F_s = 0.9 can be used.

Results

The heating and cooling seasons were calculated for both reference houses in the three climate zones. The three zones are represented by three to four cities each in order to evaluate the climate differences within the zones. The results are shown in Table 3.

In order to compare different window solutions, ten different single frame windows are calculated with the above values in order to study their energy performance in different climates and in order to evaluate the classification.

The technical values of the windows are estimated for different insulating glass units available on the market. Windows with U-values of 0.8 W/m^{2}K are estimated to be triple glazed windows with special gas filling (Krypton) that are not available as standard solutions for all windows produced in Europe; however, they are included in the evaluation to show the per-

Table 3. Calculated solar radiation on vertical and sloped windows and degree hours for the heating and cooling season for the two reference houses used at different locations in Europe.

			Heating season				Cooling season			
			Solar radiation (kWh/m²)			Degree hours (kKh)	Solar radiation (kWh/m²)			Degree hours (kKh)
Location		Ref. House	I_90º	I_45º	I_30º	D	I_90º	I_45º	I_30º	D
Zone 1	**Helsinki**	Type 1	252	420	434	119	16	35	43	0
	Copenhagen		203	335	343	88	12	27	34	0
	Frankfurt		164	273	281	73	37	105	126	0
	London		200	333	342	71	22	63	74	0
Zone 1	**Helsinki**	Type 2	230	382	394	118	14	30	38	0
	Copenhagen		227	381	393	90	12	27	34	0
	Frankfurt		183	308	317	76	37	104	125	0
	London		234	398	413	75	11	32	38	0
Zone 2	**Paris**	Type 1	239	422	443	72	26	78	95	0
	Vienna		241	424	445	83	41	130	156	0
	Debrechen		235	409	426	83	58	184	219	1
Zone 2	**Paris**	Type 2	265	476	502	75	17	54	65	0
	Vienna		269	483	510	85	29	88	106	0
	Debrechen		256	449	471	84	48	158	188	1
Zone 3	**Lisbon**	Type 1	283	459	466	33	107	390	458	2
	Rome		248	417	430	42	111	388	457	1
	Athens		216	366	378	32	161	564	653	4
Zone 3	**Lisbon**	Type 2	302	500	510	34	87	323	379	2
	Rome		253	428	442	43	98	340	401	1
	Athens		226	383	396	33	157	547	634	4

Table 4. Technical values of the evaluated windows.

Type	U_w [W/m²K] vertical window (90°)	U_w [W/m²K] roof window (45°)	U_w [W/m²K] roof window (30°)	g for the IGU	g for the window
1	0.8	0.95	1.0	0.30	0.24
2	0.8	0.95	1.0	0.40	0.32
3	1.0	1.15	1.2	0.40	0.32
4	1.0	1.15	1.2	0.50	0.40
5	1.2	1.4	1.5	0.50	0.40
6	1.2	1.4	1.5	0.60	0.48
7	1.4	1.6	1.7	0.50	0.40
8	1.4	1.6	1.7	0.60	0.48
9	1.6	1.8	1.9	0.50	0.40
10	1.6	1.8	1.9	0.60	0.48

Table 5. Solar radiation on vertical and sloped windows and degree hours for the heating and cooling seasons for the two reference houses used in the three climate zones in Europe. Average values.

Location	Heating season				Cooling season			
	Solar radiation (kWh/m²)			Degree hours (kKh)	Solar radiation (kWh/m²)			Degree hours (kKh)
	I_90º	I_45º	I_30º	D	I_90º	I_45º	I_30º	D
Zone 1	212	354	365	89	20	53	64	0
Zone 2	251	444	466	80	36	116	138	1
Zone 3	254	426	437	36	120	425	497	2

Table 6. Equations for determination of the net energy gain in the heating and cooling seasons in the three zones for window slopes of 90º, 45º and 30º.

Net energy gain [kWh/m²]	Slope	Heating season	Cooling season
Zone 1	90°	$E_{ref,heating} = 212 \cdot g_w - 89 \cdot U_w$	$E_{ref,cooling} = 20 \cdot g_w - 0 \cdot U_w$
	45°	$E_{ref,heating} = 354 \cdot g_w - 89 \cdot U_w$	$E_{ref,cooling} = 53 \cdot g_w - 0 \cdot U_w$
	30°	$E_{ref,heating} = 365 \cdot g_w - 89 \cdot U_w$	$E_{ref,cooling} = 64 \cdot g_w - 0 \cdot U_w$
Zone 2	90°	$E_{ref,heating} = 251 \cdot g_w - 80 \cdot U_w$	$E_{ref,cooling} = 36 \cdot g_w - 1 \cdot U_w$
	45°	$E_{ref,heating} = 444 \cdot g_w - 80 \cdot U_w$	$E_{ref,cooling} = 116 \cdot g_w - 1 \cdot U_w$
	30°	$E_{ref,heating} = 466 \cdot g_w - 80 \cdot U_w$	$E_{ref,cooling} = 138 \cdot g_w - 1 \cdot U_w$
Zone 3	90°	$E_{ref,heating} = 254 \cdot g_w - 36 \cdot U_w$	$E_{ref,cooling} = 120 \cdot g_w - 2 \cdot U_w$
	45°	$E_{ref,heating} = 426 \cdot g_w - 36 \cdot U_w$	$E_{ref,cooling} = 425 \cdot g_w - 2 \cdot U_w$
	30°	$E_{ref,heating} = 437 \cdot g_w - 36 \cdot U_w$	$E_{ref,cooling} = 497 \cdot g_w - 2 \cdot U_w$

formance. Windows with U-values of 1.0 W/m²K are estimated to be triple glazed windows with standard gas filling (Argon) and low-e coating. Windows with U-values of 1.2 W/m²K and above are estimated to be double glazed windows with standard gas filling (Argon), with low-e coating and with different energy performances of sash and frame.

The glazed area of the windows is estimated to be 80% of the total window area.

ZONES

From the results in Table 3 it can be seen that there are variations in the solar radiation and the degree hours for both heating and cooling season within each zone and for one reference house as a result of the different climates. For instance, the solar radiation and degree hours in Frankfurt are less/fewer than in Helsinki.

In spite of this the values are of the same magnitude and when used in the expression of the net energy gain for specific windows the ranking will be the same, meaning that a good window in Frankfurt will also be a good window in Helsinki. A simple study of ten different windows shows that the classifications of the individual windows do not differ much within the zones. Therefore, gathering the countries in the mentioned zones makes good sense.

SLOPE ANGLE

The results show that solar radiation on the vertical windows is significantly less than on the sloped windows. Therefore, the vertical windows must also be dealt with separately from the sloped roof windows when evaluated on the net energy gain. On the other hand, looking at the sloped windows the radiation only varies slightly between 30º and 45º.

FINAL PROPOSAL

In Table 5 the values for solar radiation and degree hours used in the proposed energy rating system are shown. The values in Table 5 are average values for the two building forms based on the detailed values in Table 3.

For reference the above can be compared with existing national energy labelling schemes for windows.

The Danish Energy Label for vertical windows /5/ has a solar radiation of 196 kWh/m² and a degree hour of 90 kKh.

The BFRC /1/ label for vertical windows in UK has a solar radiation of 218.6 kWh/m² and a degree hour of 68.5 kKh, including the air permeability of the window.

THE NET ENERGY GAIN EQUATIONS

In Table 6 the specific equations of the net energy gain in the heating and cooling seasons are presented. The table also includes equations for sloped windows of 30º and 45º.

Using the above equations, the input data should be

- U-value determined according to EN 10077 or EN ISO 12567
- U-value of the reference dimension 1230 mm x 1480 mm
- U-value for sloped windows must be given for the angle of the slope
- g-value for the window, where the g-value for the insulating glass unit is found in EN 410

Energy saving potential

The energy saving potential for EU by changing old windows to new improved windows, which are found as the best average windows, is determined based on the proposed expression (equations 8 and 9) and the climate data given in Table 5. The number of old windows in EU, U-values and g-values are assumed as presented in Table 7.

Calculating the difference in the net energy gain (both the cooling and heating seasons) shows an energy saving potential of 134,749 GWh per year.

Suggestion for a rating system for windows

The aim of the rating system is to develop a scheme that helps consumers to choose the best performance windows for replacement in the different regions, taking into account both the energy performance during the heating period and the energy performance during the summer period.

In order to have simplified labelling, the same labelling must be used both for vertical and sloped windows, as well as the same labelling scheme must be used in all zones in Europe; however, the calculation of the window depends on the zone and the formula described in Table 6.

Table 7. Number of windows in EU, assumed U-value and g-value of the old windows /9/ and estimated U-value and g-value of new windows. The window area is estimated as being 15% of the building area.

Energy saving potential in EU		Number of buildings (mill m²) dwellings	Window area (mill m²) (15 %)	Old windows U-value [W/m²K]	Old windows g-value	New windows U-value [W/m²K]	New windows g-value [-]
North	Before 1975	67	10	3.0	0.58	1.2	0.5
Zone 1	Before 1975, but renovated	266	40				
	1975-1990	102	15	2.0	0.50	1.2	0.5
	1991-2002	86	13	1.6	0.43	1.2	0.5
	2002-2006	43	6				
Baltic	Before 1975	68	10	3.0	0.58	1.2	0.5
Zone 1	Before 1975, but renovated	17	3				
	1975-1990	36	5	2.6	0.50	1.2	0.5
	1991-2002	7	1	2.1	0.50	1.2	0.5
	2002-2006	2	0				
Central Coast	Before 1975	911	137	4.0	0.58	1.2	0.5
Zone 2	Before 1975, but renovated	2125	319				
	1975-1990	840	126	3.5	0.58	1.2	0.5
	1991-2002	633	95	2.0	0.50	1.2	0.5
	2002-2006	187	28				
Central continent	Before 1975	521	78	4.0	0.58	1.2	0.5
Zone 2	Before 1975, but renovated	1216	182				
	1975-1990	480	72	3.5	0.58	1.2	0.5
	1991-2002	362	54	2.0	0.50	1.2	0.5
	2002-2006	107	16				
Poland	Before 1975	189	28	3.5	0.58	1.2	0.5
Zone 2	Before 1975, but renovated	47	7				
	1975-1990	121	18	2.6	0.50	1.2	0.5
	1991-2002	57	9	2.4	0.50	1.2	0.5
	2002-2006	17	3				
Central east	Before 1975	238	36	4.0	0.58	1.2	0.5
Zone 2	Before 1975, but renovated	60	9				
	1975-1990	132	20	3.4	0.58	1.2	0.5
	1991-2002	26	4	3.4	0.58	1.2	0.5
	2002-2006	8	1				
South	Before 1975	599	90	4.2	0.58	1.2	0.5
Zone 3	Before 1975, but renovated	599	90				
	1975-1990	748	112	4.2	0.58	1.2	0.5
	1991-2002	506	76	3.5	0.58	1.2	0.5
	2002-2006	102	15				

A labelling scheme can be developed as illustrated in Table 8. The classification of the heating season is equal to the BFRC label /1/ used for vertical windows in UK.

A window needs to be labelled both for the heating period and the cooling period. This will allow the consumer to make the correct evaluation for the best window, depending on the need.

For northern climate it is most important to focus on the heating period and to choose a high rated window for that performance, while for the southern climate it can be more important to focus on the cooling period and to choose a window with a high rating for that purpose.

As an example, a window in zone 1 with a U-value of 1.2 W/m²K and a g-value for the total window of 0.48 will

- for the heating season be classified as $212 \cdot 0.48 - 89 \cdot 1.2 = -5$ kWh/m² equal to a B label,
- for the cooling period be classified as $20 \cdot 0.48 = 9.6$ equal to an A label

The same window in zone 3 will

- for the heating season be classified as $254 \cdot 0.48 - 36 \cdot 1.2 = 79$ kWh/m² equal to an A label,
- for the cooling period be classified as $120 \cdot 0.48 - 2 \cdot 1.2 = 55$ kWh/m² equal to a D label

The above indicates that for the zone 1 better performances can be reached for the heating season, while for zone 3 better performances can be reached for the cooling season.

If the window in zone 3 is equipped with shadings, the g-value is reduced and it should be possible to use the g-value with shadings. If external shading is installed on the window in zone 3, the g-value can for instance be reduced to 0.1, which then can move the window from a D classification to $120 \cdot 0.1 - 2 \cdot 1.2 = 9.6$ kWh/m², equal to an A label.

DAYLIGHT

The amount of daylight in buildings is very important for people's wellbeing and daylight is normally preferred rather than electric lighting. Furthermore, optimised exploitation of daylight can lead to large energy savings. Therefore, it is rec-

Table 8. Suggested rating system for windows.

Label for heating period kWh/m²		Label for cooling period Without shading	With shading	kWh/m²
> 0	A	A	A	< 10
0 to -10	B	B	B	10 to <30
> -10 to -20	C	C	C	30 to <50
> -20 to -30	D	D	D	50 to <70
> -30 to -50	E	E	E	70 to <100
> -50 to -70	F	F	F	100 to <130
> -70	G	G	G	more than 130

ommended to include daylight properties given by the light transmittance, t_{vis}, in the rating system and with the daylight potential as described in ISO/WD 18292 /8/.

The daylight potential (DP) is expressed as:

$$DP = t_{vis} \cdot (F_{g-s} + 0.2\ F_{g-g}) \cdot A_g/A_w \quad (10)$$

where,

t_{vis} is the transmittance of visible light of the glazing
F_{g-s} is the view factor from the glazing to the sky
F_{g-g} is the view factor from the glazing to the ground
0.2 is the albedo of the ground
A_g is the visible glazing area of the window [m²]
A_w is the area of the window [m²]

Conclusion

The study shows that

- It is possible to develop an European scheme for energy labelling of windows where Europe is divided into zones. As solar radiation becomes high in the summer period, it is necessary to include summer conditions for windows in the labelling scheme where dynamic solutions for summer conditions could also be evaluated.
- The energy performance of sloped windows differs significantly from vertical windows, as the passive solar radiation for sloped windows is much higher than for vertical windows and, therefore, the energy performance of sloped windows is better than for vertical windows during the heating season.
- The assessment of ten different single frame windows shows that not only the window heat loss (U-value), but also the solar gain (g-value) should be considered. For example, the best performing window is not the one with the lowest U-value, but the window with an optimized combination of U-value and g-value. Of the ten roof windows evaluated, the best performing window has a U-value of 1.2 W/m²K and a g-value of 0.48. This is the situation for all of Europe. The assessment of the ten windows also shows that there is no great gap in the classification of windows in each zone, and it indicates that Europe can perfectly well be divided into zones.
- By replacing the windows in the existing building stock, the energy saving in Europe can be up to approximately 135,000 GWh/year if the existing old windows are replaced by new windows with a U-value of 1.2 W/m²K and a g-value of 0.50 for the total window.
- Further detailed evaluations are recommended in order to define the exact values of the energy performance.

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