Proposal for Energy Rating System of windows in EU

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Proposal for energy rating system of windows in EU

The European Commission has proposed to expand the labelling directive to include energy saving products like windows. This report presents a proposal for such an energy rating system of windows in EU. The energy rating system includes vertical façade windows and sloped roof windows. The rating system is based on the net energy gain for windows used in reference houses in three zones in EU.

Conclusion:

The study in this report shows that

- it should be possible to develop an European scheme for windows where Europe is divided into zones as the performances of windows for the heating season do not differ significantly in the zones; therefore the evaluation of windows can be decided on the basis of the energy performance proposed in this report

- as the solar radiation becomes high in the summer period, it is necessary to include summer conditions for windows in a labelling scheme where dynamic solutions for summer conditions could be used also

- the energy performance of sloped windows differs from vertical windows, where the passive solar radiation for sloped windows is much higher than for vertical windows and thereby the energy performance of sloped windows is better than for vertical windows

- the best performing façade window for replacement in the northern part is low energy window with U-values between 0.8 and 1.2 however the difference between the 3 best windows is below 10 kWh/m² in northern climate. The best performing façade window on an overall evaluation will be a window with a U-value of approximately 1.2 W/m²K and a g-value of approximately 0.48 for the whole window

- the performance of best sloped windows for replacement is the same for all Europe, with a U-value of 1.2 W/m²K and a g-value of 0.48 for the whole window

- by replacing the windows in the existing building stock an energy saving in Europe can be up to 134,749 GWh/year if existing old windows are replaced with new windows with a U-value of 1.2 W/m²K and a g-value of 0.5 for the whole window

- further detailed studies for the individual zones are recommended in order to define the exact values for the energy performance for the heating season.

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1. Introduction

In 2008, VELUX asked The Technical University of Denmark, Department of Civil Engineering (DTU Byg) to perform a study with the objective of providing a proposal for an energy rating system of windows in EU and also to estimate the energy saving potential for EU by changing old windows to new improved windows. This report is composed after this application from VELUX A/S and is also financed by VELUX A/S /1/.

1.1 Background

Windows have a large influence on the energy demand and indoor climate in buildings. Apart from the heat loss through windows they also provide a solar gain to the building that in some periods can be exploited for space heating. In other periods the solar gain can result in over heating problems leading to a need for cooling, and therefore it is also important to create a labelling for summer conditions.

In order to stimulate and encourage the use of windows with improved energy performance, there is a need for developing an energy rating system that makes it easier to select the best windows for the actual climate.

1.2 Purpose

The purpose of this project is to develop a proposal of a simple energy rating system of windows in EU based on the net energy gain for a reference building. The aim is to make it as simple and general as possible and also applicable for sloped windows (roof windows).

2. Method

The energy performance of a window is very dependent on the climate and the dwelling/house. Therefore a reference house is needed to make an evaluation of a specific window. A general reference dwelling/house is almost impossible to lay down for the entire Europe, though. The climate in EU also differs both regarding solar radiation and degree hours, which also makes 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 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 heating consumption and in the cooling season increases the cooling consumption.

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

- On the basis of the climate in Europe, 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 the a window is evaluated in the cooling and heating season separately 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.

2.1 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 on different locations in EU are shown in Figure 1 and Figure 2

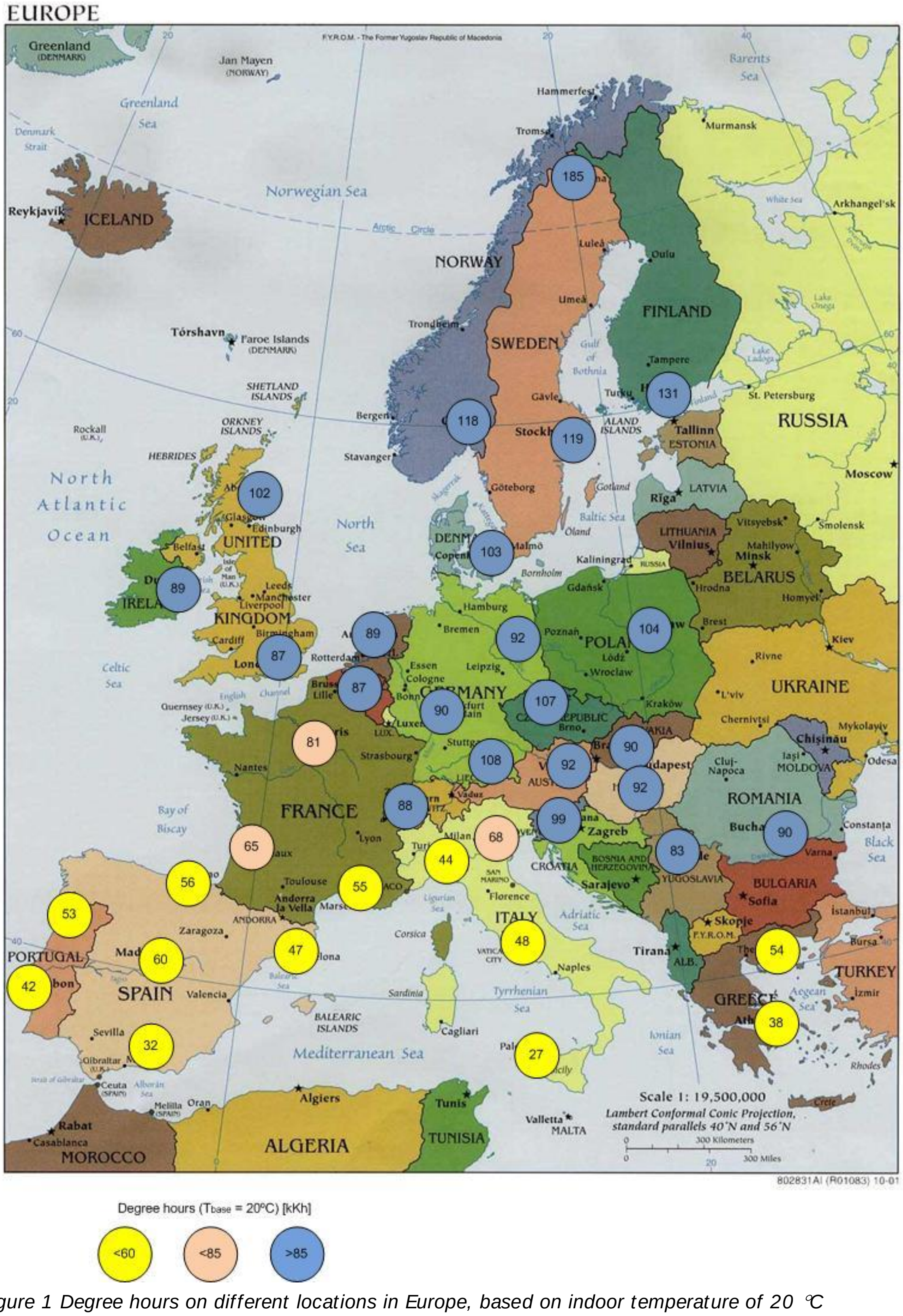

Figure 1 Degree hours on different locations in Europe, based on indoor temperature of 20 °C

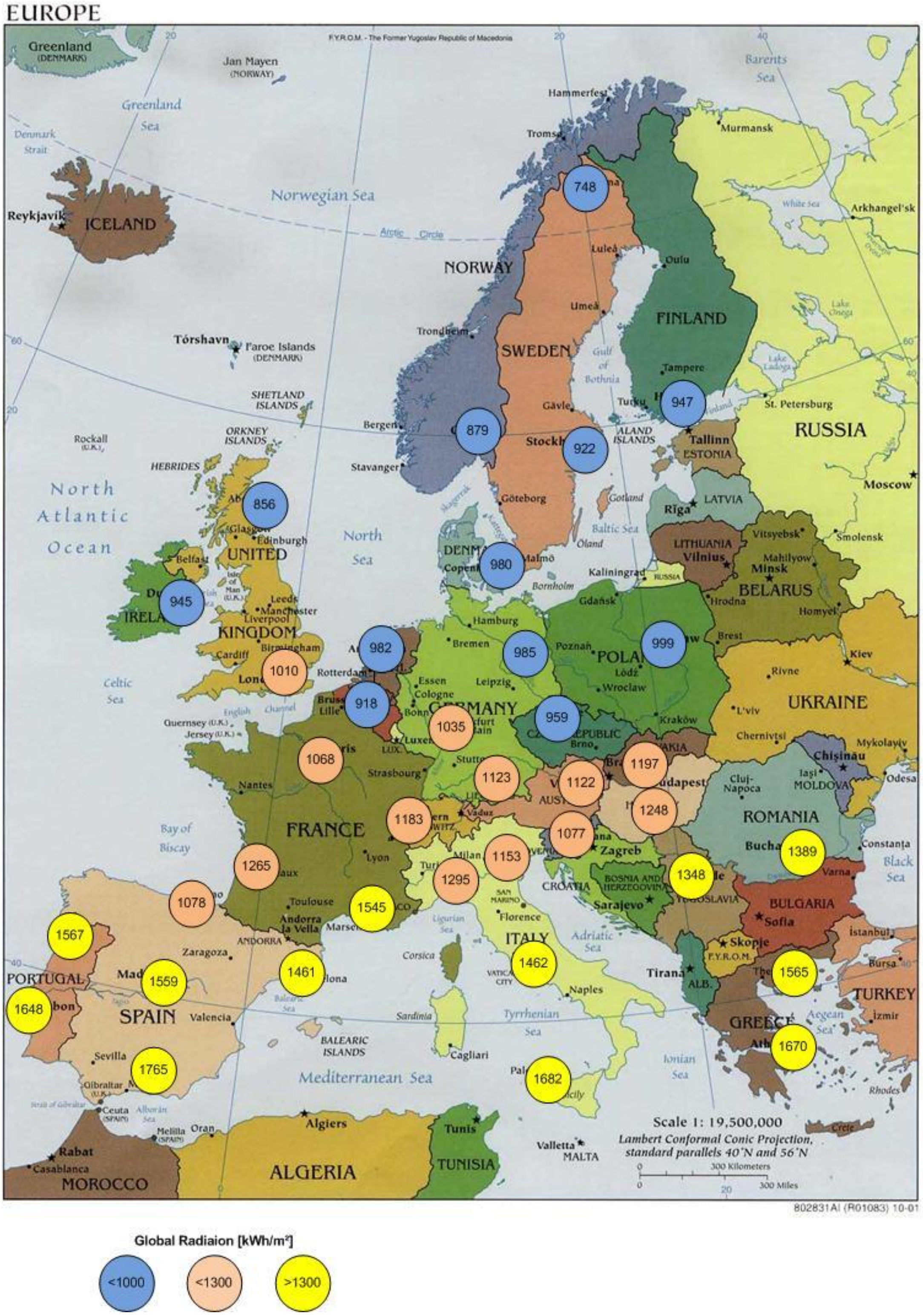

Figure 2 Annual solar radiation on different locations in Europe. (Radiation on horizontal plane)

2.2 The climate zones

Based on analysis of the weather data of EU shown in Figure 1 and Figure 2 it is proposed to divide the EU in 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 EU. Although there can be variations in the climate within each country it is chosen to draw the zone borders along the national country borders. This simplification is justified by the fact that, in most cases, the energy performance ranking of different windows 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.

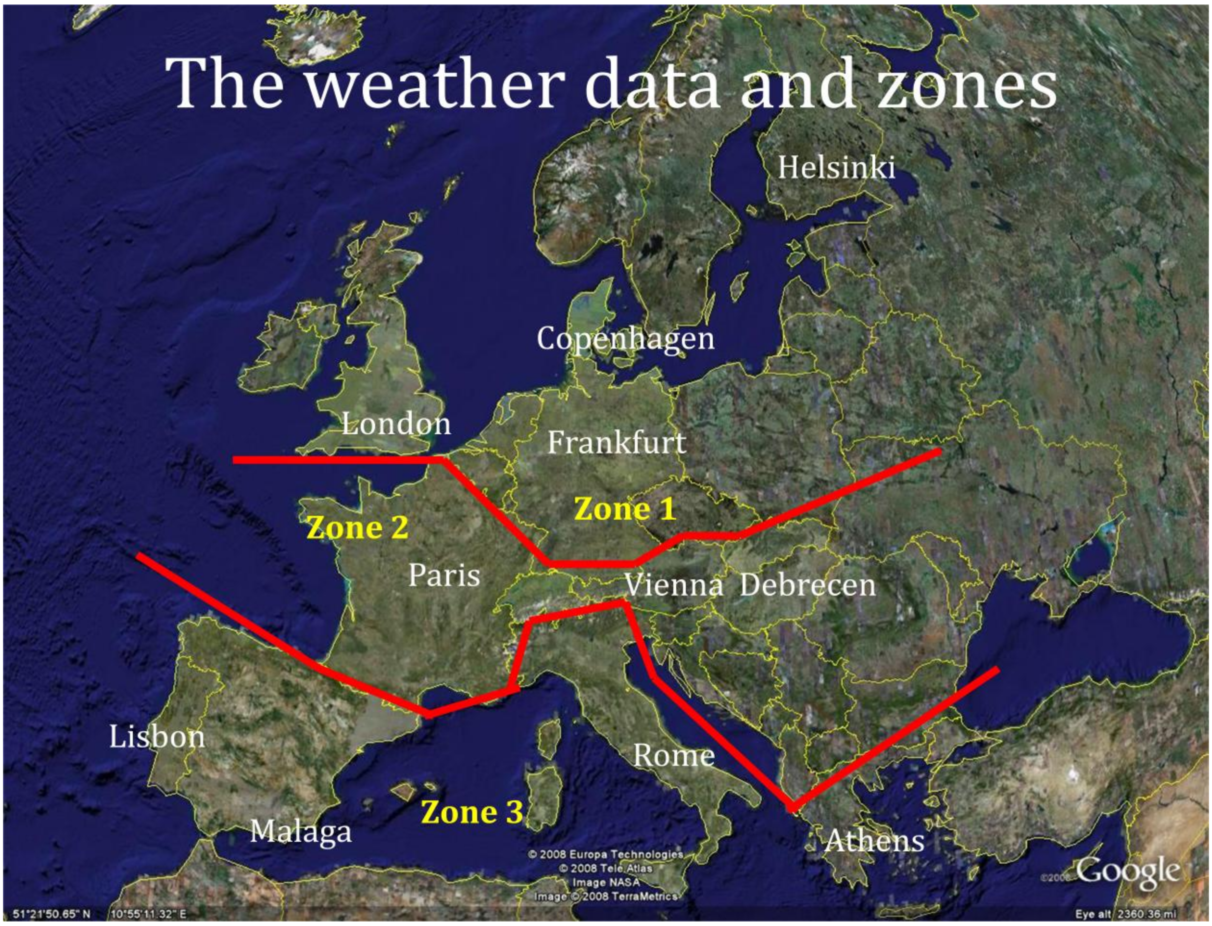

Figure 3 The suggested climate zone in EU with suitable selected cities.

Zone 1: Ireland, United Kingdom, Denmark, Sweden, Finland, The Netherlands, Belgium, Luxemburg, Germany, Poland, Estonia, Latvia and Lithuania.

Zone 2: France, Austria, Switzerland, Hungary, Slovenian, Czech Republic, Bulgaria, Romania and Slovakia.

Zone 3: Portugal, Spain, Italy, Malta, Greece and Cyprus.

2.3 The reference houses

The two reference houses are used to calculate the length of the heating and cooling season. The design of the reference houses are chosen so they 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 single storey house. The ground floor area of the two houses is 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 % south, 16.5% west, 16.5% east and 26% north, see Figure 4.

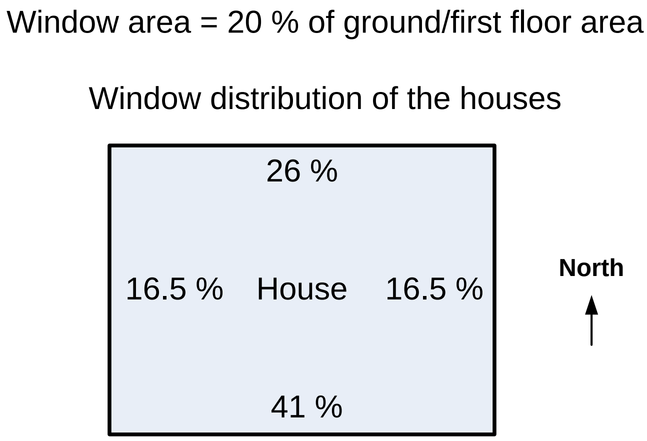

Figure 4 Distribution of the window area in the reference houses regarding the orientations. The total window area is calculated as 20 % of the floor area.

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 m^2, resulting in 19 m^2 vertical façade windows, and a first floor area of 67 m^2, resulting in 4 m^2 vertical windows and 9 m^2 roof windows. For reference house type 2 the ground floor area is 140 m^2. The windows are distributed as 21 m^2 (15%) vertical façade windows and 7 m^2 (5%) roof windows.

The slope angle of the roof windows is assumed to be 45º in type 1 and 30º in type 2. The reference house types 1 and 2 are shown in Figure 5 and Figure 6 respectively.

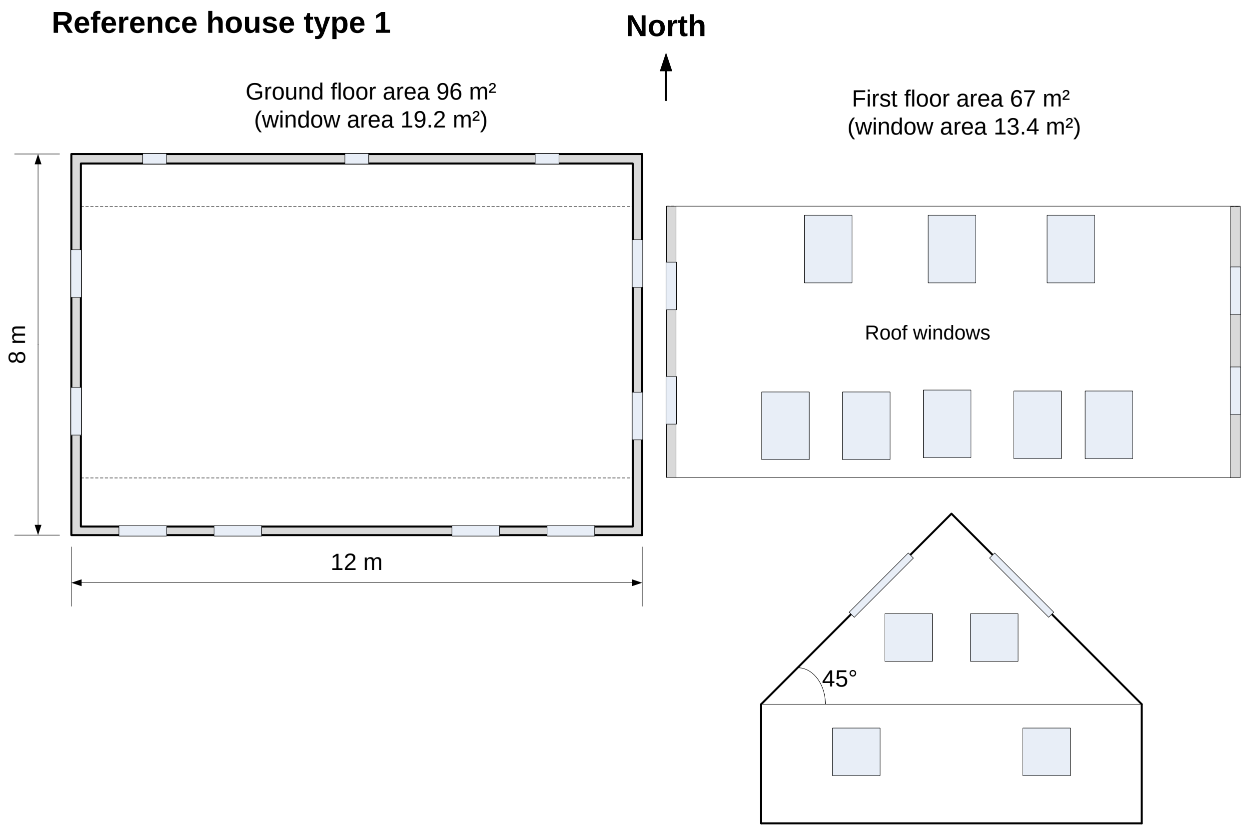

Figure 5 Outline of the reference house type 1 with 45º sloped roof construction

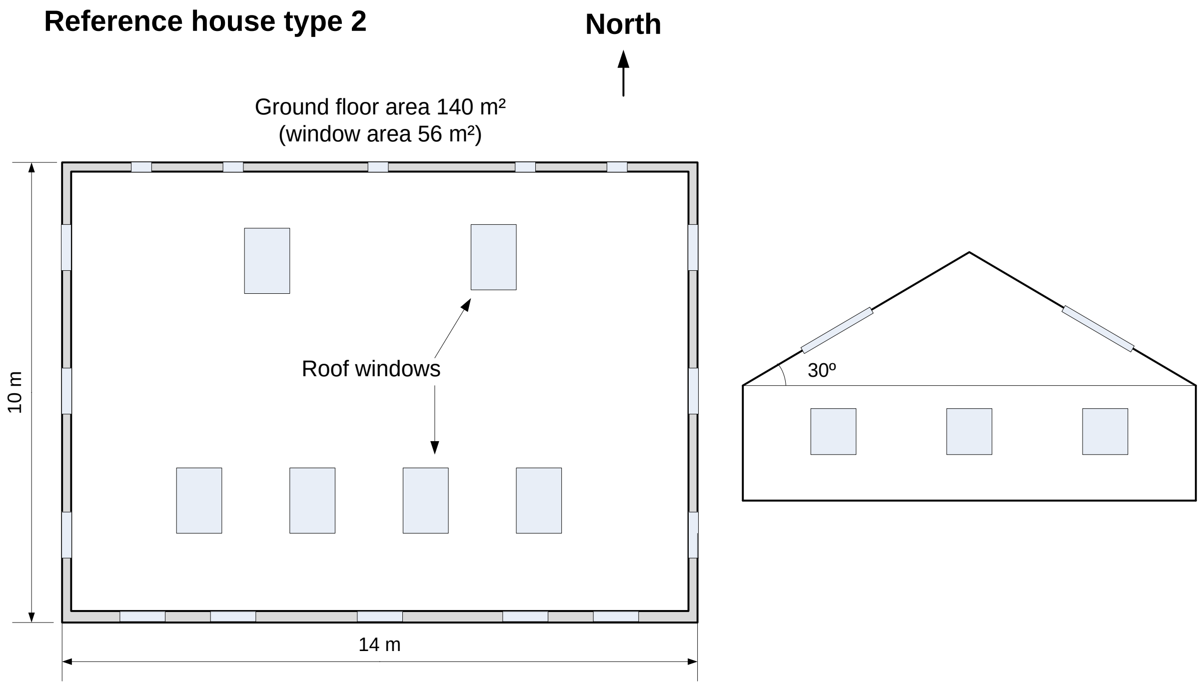

Figure 6 Outline of the reference house type 2 with 30º sloped roof construction

The thermal properties of the constructions of the building envelope of the two reference houses are shown in Table 1, Table 2 and Table 3. The data are taken from /2/.

Table 1 U-value for the building envelope of the reference houses

Construction	U-value [W/m²K] Zone 1 / 2/ 3
Roof	0.2/0.5/0.8
Wall	0.3/1.0/1.2
Floor	0.2/0.8/0.8

Table 2 Air change rate of the reference houses during winter and summer

Ventilation	Winter/Summer [h^{-1}]
Zone 1	0.5/1.5
Zone 2	0.5/2.0
Zone 3	0.5/2.5

Table 3 Data of the window in the reference houses

Window	U_w-value	g_w - value
Zone 1/2	2.0/3.5	0.50/0.58
Zone 2/3	3.5/4.2	0.58/0.58

Table 4 Heat capacity of the reference houses

Window	Category	C [J/Km2]
House type 1 Zone 1, 2 and 3	Medium	165.000
House type 2 Zone 1, 2 and 3	Heavy	260.000

2.4 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 season must be known for the actual location and for the specific reference house. The length of the heating and cooling season is calculated in selected cities covering the EU according to method described in ISO 13790 /5/ and using the two reference houses types 1 and 2. According to the standard, the heating season includes all days for which the heat gains, calculated with a conventional utilization factor, do not balance the heat transfer and vice-versa for the cooling season. The program WinDesign /4/ that is based on ISO 13790 was used for the calculations. The method takes into account an utilisation factor for the heat gains and for the heat losses in the calculations of energy needs for heating and cooling. The calculated heating and cooling seasons are shown in Table 5.

Table 5 Calculated heating and cooling seasons for selected EU cities.

Reference house	Location	Heating	Cooling
Type 1	Helsinki	9.8 – 18.5	13.6 – 15.8
Type 1	Copenhagen	17.9 – 14.5	12.6 – 21.8
Type 1	Frankfurt	2.10 – 24.4	2.6 – 2.9
Type 1	London	24.9 – 10.5	21.6 – 22.8
Type 2	Helsinki	5.9 – 27.5	5.7 – 26.7
Type 2	Copenhagen	12.9 – 23.5	12.7 – 30.7
Type 2	Frankfurt	27.9 – 30.4	23.6 – 24.8
Type 2	London	16.9 – 25.5	10.7 – 29.7
Type 1	Paris	19.9 – 27.5	3.7 – 22.8
Type 1	Vienna	19.9 – 19.5	26.6 – 23.8
Type 1	Debrecen	23.9 – 8.5	5.6 – 27.8
Type 2	Paris	14.9 – 7.6	15.7 – 16.8
Type 2	Vienna	15.9 – 1.6	6.7 – 18.8
Type 2	Debrecen	18.9 – 15.5	13.6 – 22.8
Type 1	Lisbon	1.11 – 25.4	1.6 – 28.9
Type 1	Rome	25.10 – 27.4	30.5 – 24.9
Type 1	Athens	10.11 – 14.4	13.5 – 9.10
Type 2	Lisbon	29.10 – 2.5	17.6 – 20.9
Type 2	Rome	23.10 – 1.5	9.6 – 18.9
Type 2	Athens	7.11 – 17.4	21.5 – 3.10

The results in Table 5 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.

2.5 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):

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

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

Where

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

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

2.6 Solar radiation

Using a pc software as e.g. BuildingCalc /3/, the solar radiation is calculated on hourly basis on vertical (90º) and sloped (45° and 30º) 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.

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

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

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

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

$$I_{heating} = \sum_{i=\text{heating start}}^{\text{heating stop}} I_{90°} \quad , \text{for the heating seseason} \tag{6}$$

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 demand, only 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." This criteria is though further extended so only solar radiation in hours where the outside temperature is above 23 ºC is included. See eq. (7).

$$I_{cooling} = \sum_{\text{i=cooling start}}^{\text{cooling stop}} I_{90°} \text{ for } I_{90°} > 300W \ and \ T_{out} > 23\ ºC \qquad (7)$$

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

3. 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.

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

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

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 build-in (overhang, side fins)	[-]
U_w	is the total heat transfer coefficient 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 build-in, F_s, could be estimated in general to be 0.7 for horizontal windows (European standard EN 832, 1998). For roof windows $F_s = 0.9$ can be used.

4. 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 6.

Table 6 Calculated solar radiation on vertical and sloped windows and degree hours for the heating and cooling season for the two reference houses used on different locations in Europe.

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

In order to compare different window solutions, 10 different windows are calculated with the above values. The result is shown in appendix 2.

4.1 Zones

From the results in Table 6 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 smaller than in Helsinki.

In spite of this, the values are in 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 10 different windows shows that the classifications of the individual windows do not differ much within the zones. See appendix 2. Therefore, putting the countries together in the mentioned zones makes good sense.

4.2 Slope angle

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

4.3 Final proposal

In Table 7 the values of solar radiation and degree hours used in the proposed energy rating system are shown. The values in Table 7 are average values for the two building forms based on the detailed values in Table 6.

Table 7 Solar radiation on vertical and sloped windows and degree hours for the heating and cooling season for the two reference houses used in the three climate zones in Europe. Average values.

	Heating season				Cooling season			
	Solar radiation (kWh/m^2)			Degree hours (kKh)	Solar radiation (kWh/m^2)			Degree hours (kKh)
Location	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

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

The Danish Energy Label for vertical windows has a solar radiation of 196 kWh/m^2 and a degree hour of 90 kKh.

The BFRC /7/ 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 8 the specific equations of the net energy gain in the heating and cooling season are presented. The table also includes equations for sloped windows of 30º and 45º.

Table 8 Equations for determination of the net energy gain in the heating and cooling season in the three zones for window sloped angles of 90º, 45º and 30º.

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

Using the above equation, the input data should be

- the U-value calculated according to EN 10077(1-2) or EN 12567 (1-2)
- the U-value of the reference dimension 1230 mm x 1480 mm.
- the U-value for sloped windows must be given for the slope angle
- the g-value for the window, where the g-value for the pane is calculated from EN 610

5. 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 (eq. 8 and 9) and the climate data given in Table 7.

The number of old windows in EU, U-values and g-values are assumed as presented in Table 9.

Table 9 Number of windows in EU, assumed U-value and g-value of the old windows /2/ and estimated U-value and g-value of new windows. The window area is estimate 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				

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. See appendix A for the savings in the different zones of EU.

6. SUGGESTION FOR A RATING SYSTEM OF WINDOWS

The aim of the rating system is to develop a scheme that helps consumers to choose the best performing windows for replacement in the different regions, taking into account both the energy performance during the heating period and the energy performance for 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 8.

A labelling scheme can be developed as illustrated below. The classification for the heating season is equal to the BFRC label /7/ used for vertical windows in UK.

Label for heating period		Label for cooling period		
kWh/m^2		Without shading	With shading	kWh/m^2
> 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

A window needs to be labelled both for the heating period as well as the cooling period. This will allow the consumer to do 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/m^2K and a g-value for the whole window of 0.48 will

- for the heating season be classified as $212 \cdot 0.48 - 89 \cdot 1.2 = -5$ kWh/m^2 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/m^2 equal to an A label,
- for the cooling period be classified as $120 \cdot 0.48 - 2 \cdot 1.2 = 55$ kWh/m^2 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 a $120 \cdot 0.1 - 2 \cdot 1.2 = 9.6$ kWh/m², equal to A label.

Daylight

The amount of daylight in buildings is very important for people's well being, and daylight is normally preferred rather than electric lighting. Furthermore, optimised exploitation of daylight can lead to large energy savings. Therefore it is recommended to include daylight properties, given by the light transmittance, τ, in the rating system, and with the daylight potential, as described in ISO/CD 18292 /6/.

The daylight potential (DP) is expressed as:

$$DP = t_{vis} \cdot (F_{g\text{-}s} + 0.2\ F_{g\text{-}g}) \cdot A_g/A_w \qquad (11)$$

Where,

t_{vis} is the visible transmittance of the glazing
$F_{g\text{-}s}$ is the view factor from the glazing to the sky
$F_{g\text{-}g}$ 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]

7. Conclusion

The study in this report shows that

- it should be possible to develop an European scheme for windows where Europe is divided into zones as the performances of windows for the heating season do not differ significantly in the zones; therefore the evaluation of windows can be decided on the basis of the energy performance proposed in this report

- as the solar radiation becomes high in the summer period, it is necessary to include summer conditions for windows in a labelling scheme where dynamic solutions for summer conditions could be used also

- the energy performance of sloped windows differs from vertical windows, where the passive solar radiation for sloped windows is much higher than for vertical windows and thereby the energy performance of sloped windows is better than for vertical windows

- the best performing façade window for replacement in the northern part is low energy window with U-values between 0.8 and 1.2 however the difference between the 3 best windows is below 10 kWh/m² in northern climate. The best performing façade window on an overall evaluation will be a window with a U-value of approximately 1.2 W/m²K and a g-value of approximately 0.48 for the whole window

- the performance of best sloped windows for replacement is the same for all Europe, with a U-value of 1.2 W/m²K and a g-value of 0.48 for the whole window

- by replacing the windows in the existing building stock an energy saving in Europe can be up to 134,749 GWh/year if existing old windows are replaced with new windows with a U-value of 1.2 W/m²K and a g-value of 0.5 for the whole window

- further detailed studies for the individual zones are recommended in order to define the exact values for the energy performance for the heating season.

8. Reference

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9. Appendix 1 – Energy saving potential in EU

Energy saving potential in EU		Number of buildings (mill m2) dwellings	Window area (mill m2) 0.15	Old Windows Net Energy Gain Heating [kWh/m²]	Old Windows Net Energy Gain Cooling [kWh/m²]	New Windows Net Energy Gain Heating [kWh/m²]	New Windows Net Energy Gain Cooling [kWh/m²]	Savings per m² Heating [kWh/m²]	Savings per m² Cooling [kWh/m²]	Energy saving potential Heating [GWh]	Energy saving potential Cooling [GWh]	Energy saving potential Total [GWh]
North	Before 1975	67	10	-145	12	-1	10	144	2	1,448	15	1,464
Zone 1	Before 1975, but renovated	266	40									
	1975-1990	102	15	-71	10	-1	10	70	0	1,076	1	1,078
	1991-2002	86	13	-51	9	-1	10	50	-1	645	-17	627
	2002-2006	43	6									
Baltic	Before 1975	68	10	-145	12	-1	10	144	2	1,470	16	1,486
Zone 1	Before 1975, but renovated	17	3									
	1975-1990	36	5	-125	10	-1	10	124	0	668	1	669
	1991-2002	7	1	-80	10	-1	10	79	0	83	0	83
	2002-2006	2	0									
Central Coast	Before 1975	911	137	-177	19	29	18	206	1	28,175	129	28,303
Zone 2	Before 1975, but renovated	2125	319									
	1975-1990	840	126	-137	19	29	18	166	1	20,914	150	21,064
	1991-2002	633	95	-34	17	29	18	63	-1	6,023	-64	5,959
	2002-2006	187	28									
Central continent	Before 1975	521	78	-177	19	29	18	206	1	16,113	74	16,187
Zone 2	Before 1975, but renovated	1216	182									
	1975-1990	480	72	-137	19	29	18	166	1	11,951	86	12,036
	1991-2002	362	54	-34	17	29	18	63	-1	3,444	-37	3,408
	2002-2006	107	16									
Poland	Before 1975	189	28	-137	19	29	18	166	1	4,706	34	4,739
Zone 2	Before 1975, but renovated	47	7									
	1975-1990	121	18	-83	17	29	18	112	-1	2,027	-18	2,009
	1991-2002	57	9	-67	17	29	18	96	-1	817	-7	810
	2002-2006	17	3									
Central east	Before 1975	238	36	-177	19	29	18	206	1	7,361	34	7,394
Zone 2	Before 1975, but renovated	60	9									
	1975-1990	132	20	-129	19	29	18	158	1	3,127	25	3,152
	1991-2002	26	4	-129	19	29	18	158	1	616	5	621
	2002-2006	8	1									
South	Before 1975	599	90	-5	61	84	58	89	3	7,987	247	8,234
Zone 3	Before 1975, but renovated	599	90									
	1975-1990	748	112	-5	61	84	58	89	3	9,974	308	10,282
	1991-2002	506	76	20	62	84	58	64	4	4,831	315	5,146
	2002-2006	102	15									
									Total [GWh]	**133,455**	**1,294**	**134,749**

10. Appendix 2 – Evaluation of 10 different windows

An evaluation of 10 different windows and their classification has been calculated in order to study their energy performance in different climates and in order to evaluate the classification.

The technical values are estimated for different panes which are available on the market.

Windows with U-values of 0.8 W/m²K are estimated to be triple glazed windows with special gas fillings (Krypton) that are not available as standard solutions for all windows produced in Europe, however they are included in the evaluation to show the performance.

Windows with U-values of 1.0 W/m²K are estimated to be triple glazed windows with standard gas fillings (Argon) and low e coatings.

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 coatings 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.

Table 10 Technical values for the windows evaluated

Type	U_w [W/m²K] vertical window (90°)	U_w [W/m²K] roof window (45°)	U_w [W/m²K] roof window (30°)	g-value for the pane	g-value 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 11-13 shows the energy performance of the different windows in the heating season for the different locations in Europe. The calculation is based on the figures from table 6.

Table 11 Vertical windows

Window type	1	2	3	4	5	6	7	8	9	10
U-value - 90 degrees	0.8	0.8	1	1	1.2	1.2	1.4	1.4	1.6	1.6
g-value for the window	0.24	0.32	0.32	0.40	0.40	0.48	0.40	0.48	0.40	0.48
Location/Energy balance [kWh/m²]										
Helsinki	-35	-15	-38	-18	-42	-22	-66	-46	-90	-69
Copenhagen	-21	-5	-23	-6	-24	-8	-41	-25	-59	-43
Frankfurt	-19	-6	-20	-7	-22	-9	-36	-23	-51	-38
London	-8	8	-7	9	-5	11	-19	-3	-33	-17
Helsinki	-39	-21	-44	-26	-49	-31	-73	-54	-96	-78
Copenhagen	-18	0	-18	1	-18	1	-36	-17	-54	-36
Frankfurt	-17	-2	-17	-3	-18	-3	-33	-18	-48	-33
London	-4	15	0	19	4	23	-11	8	-26	-7
Paris	0	19	4	23	9	28	-6	14	-20	-1
Vienna	-9	10	-6	13	-4	16	-20	-1	-37	-18
Debrecen	-10	9	-7	11	-5	14	-22	-3	-38	-19
Paris	4	25	10	31	16	38	1	23	-13	8
Vienna	-4	18	1	22	5	27	-12	10	-29	-8
Debrecen	-6	15	-2	18	1	22	-16	5	-32	-12
Lisbon	42	64	58	80	74	96	67	90	60	83
Rome	26	46	37	57	49	69	41	60	32	52
Athens	26	43	37	54	48	65	41	58	35	52
Lisbon	45	70	63	87	80	104	73	98	67	91
Rome	27	47	39	59	50	71	42	62	33	54
Athens	28	46	39	57	51	69	44	62	37	55

Green	Best performing product
Cyan	2. best performing product
Yellow	3. best performing product
Light orange	4. best performing product
Red	Worth performing product

Table 12 Sloped windows in 45 degrees roof pitch

Window type	1	2	3	4	5	6	7	8	9	10
U-value - 45 degrees	0.95	0.95	1.15	1.15	1.4	1.4	1.6	1.6	1.8	1.8
g-value for the window	0.24	0.32	0.32	0.40	0.40	0.48	0.40	0.48	0.40	0.48
Location/Energy balance [kWh/m²]										
Helsinki	-12	21	-2	31	1	35	-22	11	-46	-13
Copenhagen	-3	24	6	33	11	38	-6	21	-24	3
Frankfurt	-4	18	4	25	7	29	-7	14	-22	0
London	13	39	25	52	34	61	20	47	6	33
Helsinki	-20	11	-13	18	-12	19	-35	-5	-59	-28
Copenhagen	6	36	18	49	26	56	8	38	-10	20
Frankfurt	2	27	11	36	17	42	2	27	-13	11
London	25	57	42	73	55	87	40	72	25	57
Paris	33	67	52	86	68	102	53	87	39	73
Vienna	23	56	40	74	53	87	36	70	20	53
Debrecen	20	52	36	68	48	80	31	64	15	47
Paris	43	81	66	105	86	124	71	109	56	94
Vienna	35	74	57	95	74	113	57	95	40	78
Debrecen	28	64	47	83	62	98	45	81	28	64
Lisbon	79	116	109	146	138	174	131	168	125	161
Rome	60	94	85	119	108	142	100	133	92	125
Athens	57	86	80	109	101	130	95	124	88	117
Lisbon	88	128	121	161	152	192	146	186	139	179
Rome	62	97	88	122	112	146	103	138	95	129
Athens	61	91	85	115	107	138	100	131	94	124

(green)	Best performing product
(cyan)	2. best performing product
(yellow)	3. best performing product
(light orange)	4. best performing product
(red)	Worth performing product

Table 13 Sloped windows in 30 degree roof pitch

Window type	1	2	3	4	5	6	7	8	9	10
U-value - 30 degrees	1	1	1.2	1.2	1.5	1.5	1.7	1.7	1.9	1.9
g-value for the window	0.24	0.32	0.32	0.40	0.40	0.48	0.40	0.48	0.40	0.48
Location/Energy balance [kWh/m²]										
Helsinki	-15	20	-4	31	-5	30	-29	6	-53	-18
Copenhagen	-5	22	5	32	6	33	-11	16	-29	-2
Frankfurt	-6	17	2	25	3	25	-12	11	-26	-4
London	11	39	25	52	31	58	17	44	2	30
Helsinki	-23	8	-15	16	-19	13	-43	-11	-66	-35
Copenhagen	4	36	17	49	22	53	4	35	-14	17
Frankfurt	0	26	11	36	13	39	-2	24	-17	9
London	24	57	42	75	53	86	38	71	23	56
Paris	34	70	55	91	69	104	55	90	40	76
Vienna	23	59	42	78	53	88	36	72	19	55
Debrecen	20	54	37	71	46	81	30	64	13	47
Paris	46	86	71	111	89	129	74	114	59	99
Vienna	37	78	61	102	76	117	59	100	42	83
Debrecen	29	66	50	87	62	100	45	83	28	66
Lisbon	79	116	110	147	137	174	130	168	124	161
Rome	61	96	87	122	109	143	101	135	92	127
Athens	58	89	82	112	103	133	96	126	90	120
Lisbon	89	129	123	163	153	194	146	187	140	180
Rome	64	99	90	126	113	148	104	140	96	131
Athens	62	94	87	119	109	140	102	134	96	127

(green)	Best performing product
(cyan)	2. best performing product
(yellow)	3. best performing product
(light orange)	4. best performing product
(red)	Worth performing product

Notes

The European Commission has proposed to expand the labelling directive to include energy saving products like windows. This report shows that it should be possible to develop an European scheme for windows where Europe is divided into three zones. As the solar gain becomes high in the summer period, it is necessary to include summer conditions for windows in a labelling scheme where dynamic solutions for summer conditions could be used also.

Due to solar gain roof windows and façade windows have different performances and therefore different calculations methods are needed, however the same classification could be used. The best performing façade window on an overall evaluation will be a window with a U-value of approximately 1.2 W/m²K and a g-value of approximately 0.48 for the whole window.

The performance of best sloped windows for replacement is the same for all Europe, with a U-value of 1.2 W/m²K and a g-value of 0.48 for the whole window.

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