WINDOW ENERGY LABEL. AN EUROPEAN METHODOLOGY APPLIED TO THE ITALIAN CLIMATE CONTEXT.

Emilio Antoniol[1]*

1: PhD candidate in New technologies for the City and the Environment
School of Doctorate Studies in architecture, city and design
Iuav University of Venice
Palazzo Badoer, San Polo 2468, Venice
e-mail: antoniolemilio@gmail.com

Keywords: Windows, Energy balance, Energy label, Italy

Abstract *A window may represent one of the most influent elements in the building energy balance calculation. According to the construction technology, windows can contribute to the final building energy consumption rate for a value set between 15% and 40%. Even if windows are not energy-using products, they can ensure a reduction in energy demand. Indeed, a window can be crossed by sunlight, air and thermal energy, so the choice of the correct window system allows to obtain an energy saving on heating, cooling and lighting.*

With the European Directive 2009/125/CE "Establishing a framework for the setting of ecodesign requirements for energy-related product" the labelling system idea was extended to the building elements like windows that do not consume energy but contribute to its conservation. Nowadays, in Europe there are many different types of windows energy labels, developed with different methodological approaches. Some of these are based on regional equations and allow a comparison only between products used in the same climate context. For this reason, that type of labels can be used only within national borders while other labelling schemes can be applied all over Europe. In this second case, they generally use average climate conditions to define simplified equations that can not well describe the variety of European climate conditions.

The paper presents a window rating system based on a five steps method that can be applied to all European regions. It is based on ISO18292:2011 and it uses seasonal equations to define an energy balance through the window both in summer and winter period. The method will be applied, as a case study, to the Italian climatic context with the aim of defining a specific windows label for Italy. The chosen equations are based on three window-specific parameters (thermal transmittance U_w, solar heat gain g_w and air leakage L), and on some other coefficients related to the regional climate. The three parameters are valid all over Europe while regional coefficients can be calculated for each European country or for every regional climate condition. In that way the energy label can be used not only for the ranking of window systems but also as a tool for the choice of the correct window in a specific climate condition.

1. INTRODUCTION

Windows have many different functions in buildings, like to provide outlook, daylight and thermal insulation, allow natural ventilation, give access to the building and ensure other safety features. For that reason, the evaluation of window energy efficiency is one of the most complex analysis among all other building elements. The thermal losses through a window can contribute to the final building energy consumption for a value ranging from 15% to 40% [1],[2] according to the construction technology, orientation, dimensions and climate context. The influence of windows is relevant in both winter and summer season so only with an annual energy balance analysis is possible to evaluate the real efficiency and to achieve the lowest energy impact [3]. According to recent studies, the energy saving potential in European windows market is really big, with more than 44% of single glass panes installed on buildings [4]. The use of new products with low-e double glasses, in both new and existing buildings, may provide an annual reduction of energy consumption of 912.493 TJ and an annual CO_2 emissions reduction of 90.077 Kt [5]; at the same time, the use of solar control glasses may reach similar results [6]. However, the choice of the appropriate window for a specific climatic condition is not so simple due to the many parameters that have to be considered. Starting from 2000 an European project called EWERS [7] tried to define a rating system for windows. The rating has been based on a simplified calculation method that had the aim to define a window classification label. In the following years, many European countries like United Kingdom, Denmark, Sweden, and Ireland proposed their own window labels. Recently, after the adoption of European Directive 2009/125/CE [8], other labelling systems have been proposed in Poland, France, Spain, Portugal and Italy. Nowadays, in Europe there are many different types of window energy labels, developed with different methodological approaches and calculation systems. On one hand we have many 'national labels' applicable only in the national climate context with a specific calculation method. Many North-European labels do not consider the summer season while in other countries, like Sweden, only the thermal transmittance is used for the ranking. Mediterranean countries analyze both winter and summer conditions but, while France and Italy divided their national territory into several climate zones, Spain and Portugal used a single medium national climate context. Also calculation methods are not the same all over Europe with the inclusion of different parameters into the equations. On the other hand we have an 'European approach' proposed by Rosenheim's Ift. The Ift's label is based only on two general equations, derived from ISO 18292:2011 [9], and it is applicable all over Europe. It uses an artificial heating and cooling day to define the medium climate condition in Europe; in that way a common rating system can be developed for all countries while regional and climatic differences are not considered. Both approaches have a methodological restriction. In the first case the outputs are not comparable to each others because energy performance calculation is not based on a common procedure; in the second one we have an unique evaluation and calculation system but the specific context and the climate influence are not evaluated. The aim of this paper is to define a methodological approach based on some common European equations but able to consider also the national context and climatic conditions, using some specific coefficients for each country. Italy will be the case study for this application.

2. METHOD DESCRIPTION

The proposed methodology is based on five main steps.

1. The first one aims to define a reference building for the examined country. The most relevant element of this phase is the windows area definition and its distribution.
2. In the second step one or more climate zones will be defined. For each zone, some reference cities will be chosen collecting their temperature and solar radiation data.
3. The third step defines the heating and cooling seasons duration. In some countries they are already defined by national laws. Otherwise, the seasons can be calculated using specific standards. The reference standard for the Italy is the UNI TS 11300-1 [10].
4. The fourth step aims to define two simplified equations for window Energy Performance (EP) calculation. The starting equations (1) (2) are the two EP seasonal equations defined by ISO 18292:2011 [9]. The new equations, one for heating and one for cooling season, will be only based on few national coefficients.

$$EP_{H,w,seas} = \sum q_{H,w,m} = \sum f_{H,m} \left(q_{H,ht,w} - \eta_{H,gn,w} * q_{H,gn,w}\right) \quad (1)$$

$$EP_{C,w,seas} = \sum q_{C,w,m} = \sum (1 - f_{H,m}) \left(q_{C,gn,w} - \eta_{C,ls,w} * q_{C,ht,w}\right) \quad (2)$$

   $q_{w,m}$ is the net heat loss through the window, for the heating (H) and cooling (C) mode per m^2 of window area (A_w) per month (m);
   $q_{ht,w}$ is the overall heat transfer by transmission and infiltration through the window for heating (H) and cooling (C) mode;
   $q_{gn,w}$ is the solar heat gain through the window for heating (H) and cooling (C) mode;
   $\eta_{H,gn,w}$ dimensionless gain utilization factor for the winter season;
   $\eta_{C,ls,w}$ dimensionless loss utilization factor for the summer season;
   $f_{H,m}$ is the fraction of the month that is part of the heating season;
5. In the last step the defined equations will be applied on a windows set to validate the proposed method and to analyse the final EP results.

3. METHODOLOGY APPLICATION

In order to illustrate the methodological approach, the five steps were applied to the Italian context. The choice of Italy as case study is based on two different elements. First of all, in Italy there is a great climate variability between north and south. For this reason a careful evaluation of windows functioning in both seasons and a specific analysis of the national climate zones division is required. Secondly, in Italy there is not yet an official energy label for windows and a detailed study on this subject is recommended.

3.1 Step one. Reference building.

In the first step a reference building was defined. A building stock analysis was performed through the evaluation of two main sources: some statistical data from the 2001 and 2011 censuses by ISTAT (Italian National Institute of Statistics) and the result of an European research called TABULA, Typology Approach for Building Stock Energy Assessment [11]. The selected reference building is a detached house, with two floors for a total size of 160 m^2. The plant dimension are 10 per 8 m. It has a pitched roof (30 ° inclination) with a non habitable attic. For this reason roof windows will not be considered in the study. The total window surface is equal to 20% of the floor area for each level. This value is obtained considering the minimum share of 12.5% (defined by the Italian standard) increased by 7.5% to evaluate the incidence of the frame and external doors. On both floors 16.38 m^2 of windows are placed. The total surface is 32.76 m^2 where each window has a size of 1230x1480 mm. The windows distribution on the four orientations is defined as follows: on the south side there are six windows, for a total of 10.92 m^2 (34%); on the east, north and west side there are four windows, for a total of 7.28 m^2 (22%). These values reflect the average distributions used in the other European analyzed studies [12],[13].

3.2 Step two. Climatic zones.

In the second step some climate zones were defined for the Italian context. Italy is divided into six climatic zones, from A to F, depending on the Degrees Day value. However zone A includes only two municipalities with less than 600 DD. So in this study zone A will be merged to zone B. In this way the final analyzed zones are only five and for each one three reference cities were chosen.

3.3 Step three. Seasons length.

In the third step the heating and cooling season length was calculated for each defined city. The reference equations for season length calculation are derived from the Italian standard UNI TS 11300-1 [10] as reported:

$$t_e < t_{set} - \frac{Q_{gn}}{H * t_{day}} \tag{3}$$

$$t_e > t_{set} - \frac{Q_{gn}}{H * t_{day}} \tag{4}$$

t_e is the external temperature, expressed in °C;
t_{set} is the set point internal temperature, expressed in °C;
Q_{gn} is the sum of internal and solar gains, expressed in MJ;
H is the heat transfer coefficient due to air leakage of the window, expressed in W/K;
t_{day} is the day length, expressed in Ms (equal to 0.864 Ms);

Considering the average values obtained from the cities in the same climate zone it was possible to define the seasons length for each climate zone. (Table 1)

Cimate zone	Winter Season		Summer Season	
A+B	01.12	31.03	25.05	05.10
C	15.11	31.03	20.05	05.10
D	01.11	15.04	20.05	30.09
E	15.10	15.04	01.06	15.09
F	05.10	22.04	15.06	31.08

Table 1. Season length.

3.4 Step four. Energy performance equations.

In this phase the equations (1) and (2) are simplified turning some variable values into fixed coefficients. The energy balance equation through a window is based on the evaluation of the difference between the heat transfer by transmission and infiltration $q_{ht,w}$ and the total solar heat gain $q_{gn,w}$, and it is expressed with the equations (5) and (6).

$$q_{ht,w} = \left(U_w + \frac{H_{ve,w}}{A_w}\right)\left(\theta_{int,set} - \theta_e\right)\frac{t}{100} \quad (5)$$

$$q_{gn,w} = F_{sh} * g_w * I_{sol}\frac{t}{100} \quad (6)$$

U_w is the window thermal transmittance, expressed in W/m^{2}K;
$H_{ve,w}$ is the heat transfer coefficient due to air leakage of the window, expressed in W/K while A_w is the window area;
$\theta_{int,set}$ is equal to the set point temperature in winter (H) and summer (C), expressed in °C;
θ_e is equal to the time-average external air temperature, expressed in °C;
t is the total length of the season period;
F_{sh} is the factor due to glazing maintenance and shading effects; for a vertical window it can be considered as 0.7 in respect of ISO 13790:2008;
g_w is the dimensionless total solar energy transmittance of the window;
I_{sol} is the average solar irradiance for the considered time period on the window plane;

Thanks to the Design Builder software and using the hourly data for each selected city, it was possible to define two coefficients $D_{H/C}$ and $I_{H/C}$ for the two main seasons (Table 2).

City	Zone	Heating		Cooling	
		I	D	I	D
		[kWh/m^2]	[kKh]	[kWh/m^2]	[kKh]
Palermo	B	187,1	20,3	298,5	7
Trapani	B	142,7	22,6	262,3	9,3
Catania	B	133	26,1	255,2	7,8
Cagliari	C	142,8	30	268,6	12,4
Napoli	C	135	33,4	269,1	9,1
Bari	C	135,6	33,8	270,1	12,3
Roma	D	165,2	40	263,2	14
Genova	D	196,1	41,1	288,9	14,1
Firenze	D	149	47,9	260,5	13,9
Bologna	E	158,1	61,5	214,9	8,4
Milano	E	203,3	63,9	242,1	11,4
Torino	E	221,8	68,3	235,3	15,1
Bolzano	E	159,6	70,9	203,2	16,6
Tarvisio	F	168,9	89,8	150,3	18,5

Table 2. Cities coefficients.

D are the Degree Hours, in winter or summer season, calculated as the sum of the positive difference between the set point temperature and the external temperature along all the season time, expressed in Kkh (7). I is the average solar direct irradiation on windows during all the season time, expressed in W/m^{2}K (8).

$$D = \left(\theta_{int,set} - \theta_e\right)\frac{t}{100} = \sum_{i=season\ start}^{season\ stop} \theta_{int,set} - \theta_e \qquad (7)$$

$$I = I_{sol}\frac{t}{100} = \sum_{i=season\ start}^{season\ stop} (0{,}34 * I_{south} + 0{,}22 * I_{west} + 0{,}22 * I_{east} + 0{,}22 * I_{north}) \qquad (8)$$

The last needed coefficient is $\eta_{gn,w}$, the dimensionless gain utilization factor for winter and summer season (Table 3); it is linked only to the reference building and to the climatic zone and it can be calculated for each city and zone using as reference the ISO 13790:2008;

Zone	η_H	η_C
A-B	0,76	0,90
C	0,78	0,88
D	0,82	0,86
E	0,87	0,85
F	0,89	0,74

Table 3. Dimensionless gain utilization factors.

The starting equations (1) and (2) can so be rewritten as follows:

$$EP_H = \eta_h * I_H * F_{Sh} * g_w - D_H * (U_w + L) \qquad (9)$$

$$EP_C = I_C * F_{Sh} * g_w - \eta_c * D_C * (U_w + L) \qquad (10)$$

The equations (7) and (8) are the general energy performance equations applicable in all European contexts. Into the two simplified equations, the only considered variables are g_w, U_w and L, that are all parameters directly linked to the window. I and D are fixed national coefficient depending only on the location, F_{sh} is a fixed medium value and η depends on the reference building and climate zone.

3.5 Step five. Results validation.

In the last step the equations (9) and (10) are applied on a set of 32 different windows using the coefficients calculated in the preview phases for each reference city. Four different frames, with thermal transmittance U_f from 0,8 to 2,6 W/m^{2}K, have been chosen to define windows characteristics. They are combined with eight different glass panes: four double glasses, two triple glasses with argon and two triple glasses with krypton. The application results are reported in the Figure 1 and Figure 2. The energy performance was calculated for heating and cooling season for each solution. In red we have the worst results, while the best one are in green. A medium national value was also performed, using as coefficients the average value of the different cities coefficients. Starting from this analysis it is possible to evaluate the influence of the different parameters used and to make a comparison between different zones. Indeed, the aim of this phase is to simplify and reduce the equations number.

Heating season			Double glass															
			4-16-4, Ar Normal glass				4-16-4, Ar Low-E				6-16-4, Ar Solar Control				6-16-4, Ar Low-E + Solar Ctr.			
Fs	0,7	Uw	2,5	2,6	2,7	2,9	1,2	1,4	1,5	1,7	1,6	1,7	1,9	2,1	1,2	1,3	1,5	1,7
L	0,16	gw	0,60	0,60	0,60	0,60	0,52	0,52	0,52	0,52	0,29	0,29	0,29	0,29	0,19	0,19	0,19	0,19
Combination			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
ITALIA		Zone	-67	-72	-76	-86	-14	-24	-28	-37	-54	-59	-68	-78	-45	-50	-59	-68
Palermo		B	5	3	1	-3	24	20	18	14	-7	-9	-13	-17	-9	-11	-15	-19
Trapani		B	-15	-17	-19	-24	9	4	2	-3	-18	-20	-25	-29	-16	-19	-23	-28
Catania		B	-27	-30	-32	-37	1	-4	-7	-12	-25	-28	-33	-38	-22	-25	-30	-35
Cagliari		C	-33	-36	-39	-45	0	-6	-9	-15	-30	-33	-39	-45	-26	-29	-35	-41
Napoli		C	-45	-48	-51	-58	-7	-14	-17	-24	-37	-41	-47	-54	-31	-35	-41	-48
Bari		C	-45	-49	-52	-59	-7	-14	-18	-24	-38	-41	-48	-55	-32	-35	-42	-49
Roma		D	-50	-54	-58	-66	-5	-13	-17	-25	-43	-47	-55	-63	-36	-40	-48	-56
Genova		D	-42	-46	-50	-58	3	-6	-10	-18	-40	-44	-52	-60	-35	-39	-47	-55
Firenze		D	-76	-81	-86	-95	-21	-30	-35	-45	-60	-64	-74	-83	-49	-54	-63	-73
Bologna		E	-106	-112	-118	-130	-34	-46	-52	-64	-80	-86	-99	-111	-65	-71	-84	-96
Milano		E	-96	-102	-108	-121	-23	-35	-42	-54	-77	-83	-96	-109	-63	-70	-83	-95
Torino		E	-101	-107	-114	-128	-23	-36	-43	-57	-81	-88	-102	-115	-67	-74	-88	-101
Bolzano		E	-130	-137	-144	-159	-46	-60	-67	-81	-97	-104	-118	-132	-78	-85	-99	-113
Tarvisio		F	-176	-185	-194	-212	-67	-85	-94	-112	-128	-137	-154	-172	-102	-111	-129	-147

Heating season			Triple glass								Triple glass with Kripton							
			4-12-4-12-4, Ar Low-E				6-12-4-12-4, Ar Low-E + Solar Ctr.				4-12-4-12-4, Kr Low-E				4-12-4-12-4, Kr Low-E + Solar Ctr.			
Fs	0,7	Uw	0,9	1	1,2	1,5	0,9	1	1,1	1,4	0,8	0,9	1	1,2	0,8	0,9	1	1,2
L	0,16	gw	0,45	0,45	0,45	0,45	0,19	0,19	0,19	0,19	0,45	0,45	0,45	0,45	0,19	0,19	0,19	0,19
Combination			17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
ITALIA		Zone	-7	-12	-21	-35	-31	-36	-41	-55	-2	-7	-12	-21	-27	-31	-36	-45
Palermo		B	23	21	17	11	-3	-5	-7	-13	25	23	21	17	-1	-3	-5	-9
Trapani		B	10	8	3	-3	-10	-12	-14	-21	12	10	8	3	-7	-10	-12	-16
Catania		B	4	2	-4	-11	-14	-17	-19	-27	7	4	2	-4	-12	-14	-17	-22
Cagliari		C	3	0	-6	-15	-17	-20	-23	-32	6	3	0	-6	-14	-17	-20	-26
Napoli		C	-2	-6	-12	-22	-21	-25	-28	-38	1	-2	-6	-12	-18	-21	-25	-31
Bari		C	-3	-6	-13	-23	-22	-25	-29	-39	1	-3	-6	-13	-18	-22	-25	-32
Roma		D	0	-4	-12	-24	-24	-28	-32	-44	4	0	-4	-12	-20	-24	-28	-36
Genova		D	7	3	-5	-18	-22	-26	-30	-43	11	7	3	-5	-18	-22	-26	-35
Firenze		D	-12	-17	-27	-41	-35	-39	-44	-58	-7	-12	-17	-27	-30	-35	-39	-49
Bologna		E	-22	-28	-40	-59	-47	-53	-59	-78	-16	-22	-28	-40	-41	-47	-53	-65
Milano		E	-12	-18	-31	-50	-44	-51	-57	-76	-6	-12	-18	-31	-38	-44	-51	-63
Torino		E	-12	-18	-32	-53	-47	-54	-60	-81	-5	-12	-18	-32	-40	-47	-54	-67
Bolzano		E	-31	-39	-53	-74	-57	-64	-71	-92	-24	-31	-39	-53	-50	-57	-64	-78
Tarvisio		F	-48	-57	-75	-102	-75	-84	-93	-120	-39	-48	-57	-75	-66	-75	-84	-102

Figure 1. Energy performance results in winter season.

Cooling season			Double glass															
			4-16-4, Ar Normal glass				4-16-4, Ar Low-E				6-16-4, Ar Solar Control				6-16-4, Ar Low-E + Solar Ctr.			
Fs	0,7	Uw	2,5	2,6	2,7	2,9	1,2	1,4	1,5	1,7	1,6	1,7	1,9	2,1	1,2	1,3	1,5	1,7
L	0,16	gw	0,60	0,60	0,60	0,60	0,52	0,52	0,52	0,52	0,29	0,29	0,29	0,29	0,19	0,19	0,19	0,19
Combination			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
ITALIA		Zone	77	76	75	72	76	74	73	71	32	31	29	27	19	18	16	14
Palermo		B	109	108	107	106	100	99	98	97	50	49	48	46	31	31	29	28
Trapani		B	88	87	86	85	84	82	82	80	39	38	36	34	24	23	21	19
Catania		B	89	88	87	86	83	82	81	80	39	39	37	36	24	24	22	21
Cagliari		C	84	83	82	79	83	81	80	77	35	34	32	30	21	20	18	15
Napoli		C	92	91	90	89	87	85	85	83	41	40	38	37	25	24	22	21
Bari		C	85	84	82	80	84	81	80	78	36	35	33	30	21	20	18	16
Roma		D	79	77	76	74	79	77	76	73	32	31	29	26	19	17	15	13
Genova		D	89	88	87	84	89	86	85	83	37	36	34	31	22	21	18	16
Firenze		D	78	76	75	73	79	76	75	73	32	31	28	26	18	17	15	12
Bologna		E	71	71	70	68	69	67	66	65	31	30	29	27	19	18	17	15
Milano		E	76	75	74	72	75	73	72	70	32	31	29	27	19	18	16	14
Torino		E	65	63	62	60	68	66	64	62	25	24	21	19	14	13	10	7
Bolzano		E	48	46	45	42	55	52	51	48	16	15	12	9	8	6	4	1
Tarvisio		F	27	25	24	21	36	33	32	29	6	5	2	0	1	0	-3	-5

Cooling season			Triple glass								Triple glass with Kripton							
			4-12-4-12-4, Ar Low-E				6-12-4-12-4, Ar Low-E + Solar Ctr.				4-12-4-12-4, Kr Low-E				4-12-4-12-4, Kr Low-E + Solar Ctr.			
Fs	0,7	Uw	0,9	1	1,2	1,5	0,9	1	1,1	1,4	0,8	0,9	1	1,2	0,8	0,9	1	1,2
L	0,16	gw	0,45	0,45	0,45	0,45	0,19	0,19	0,19	0,19	0,45	0,45	0,45	0,45	0,19	0,19	0,19	0,19
Combination			17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
ITALIA		Zone	67	66	64	61	22	21	20	17	68	67	66	64	23	22	21	19
Palermo		B	87	87	85	84	33	32	32	30	88	87	87	85	34	33	32	31
Trapani		B	74	73	71	69	26	25	24	22	75	74	73	71	27	26	25	24
Catania		B	73	72	71	69	27	26	25	23	74	73	72	71	27	27	26	24
Cagliari		C	73	72	70	66	24	23	22	19	74	73	72	70	25	24	23	21
Napoli		C	76	75	74	71	27	27	26	23	77	76	75	74	28	27	27	25
Bari		C	74	73	70	67	24	23	22	19	75	74	73	70	26	24	23	21
Roma		D	70	69	67	63	22	21	20	16	71	70	69	67	23	22	21	19
Genova		D	78	77	75	71	26	24	23	20	79	78	77	75	27	26	24	22
Firenze		D	69	68	66	62	22	21	20	16	71	69	68	66	23	22	21	18
Bologna		E	60	59	58	56	21	20	20	17	61	60	59	58	22	21	20	19
Milano		E	66	65	63	60	22	21	20	17	67	66	65	63	23	22	21	19
Torino		E	61	59	57	53	18	16	15	11	62	61	59	57	19	18	16	14
Bolzano		E	49	48	45	41	12	11	9	5	50	49	48	45	13	12	11	8
Tarvisio		F	33	31	29	25	5	4	3	-1	34	33	31	29	7	5	4	1

Figure 2. Energy performance results in summer season.

4 RESULTS AND DISCUSSION

Comparing the results in Figure 1 and 2, it is possible to say that the EP indices calculated into the same climate zone have similar values both in heating and cooling period. So, it is possible to define an average index for the zone using average coefficients in the EP equations. Moreover, the results in zones C and D are not so far from each other, both in winter and summer, while zones B and F present really different results. The index in zone E has a medium value compare with zone D and F. In this situation it is possible to merge together the zones D and C to reduce the number of the needed equations. Looking at the average Italian index we can see that the values are similar to those in zone D but they are very distant from those in zone B or F, so it is not possible to define a single average equation for Italy without admitting a low accuracy in the results. The final choice was to divide Italy into four zones and to define eight equations using average coefficients (Table 4).

	Heating	Cooling
ZONE I	$EP_H = 117*0,7*g_w - 23*(U_w + L)$	$EP_c = 272*0,7*g_w - 7,2*(U_w + L)$
ZONE II	$EP_H = 123*0,7*g_w - 38*(U_w + L)$	$EP_c = 270*0,7*g_w - 10,9*(U_w + L)$
ZONE III	$EP_H = 162*0,7*g_w - 66*(U_w + L)$	$EP_c = 224*0,7*g_w - 11,0*(U_w + L)$
ZONE IV	$EP_H = 150*0,7*g_w - 90*(U_w + L)$	$EP_c = 150*0,7*g_w - 13,9*(U_w + L)$

Table 4. General EP equations for the four Italian climatic zones.

Another important difference between Figure 1 and Figure 2 is related to the best and worst results. In the winter period the best combinations are n.25, n.26 and n.17. Looking at the summer table, Figure 2, it is possible to see that those combinations are the worst of the set, while the best are n.15 and n.16 that are not good in the heating period. This situation causes an interpretation problem that can affect the correct window choice. So, this study proposes also a Total Energy Performance index (EP_{tot}) obtained by calculating the primary energy consumption value for the window [13] thus defined:

$$EP_{TOT} = -EP_H * PRF_H + EP_c * PRF_C \quad (11)$$

EP_H and EP_C are the Energy Performance indices obtained by equations (9) and (10);
PRF is the conversion factor of primary energy consumption for heating (H) or cooling (C);

The proposed EP_{tot} value is a weighted average of the two seasonal indices, compared with the primary energy consumption for heating and cooling. It defines a window energy balance and allows a simplified comparison between different products. In this way, for a consumer it will be easier to define the better windows solution for his application. To complete the proposal, it is necessary to define also a rating system based on the three previous indices. The chosen system is similar to many other European models. It is based on an eight class classification and it uses a chromatic scale to output the energy performance (Table 5).

Energy Rating	EP Heating [kWh/m^2]	EP Cooling [kWh/m^2]	EP Total [kWh/m^2]
A+	> -10	< 10	< 30
A	-10 / -30	10 / 20	30 / 60
B	-30 / -50	20 / 30	60 / 100
C	-50 / -70	30 / 45	100 / 160
D	-70 / -90	45 / 60	160 / 210
E	-90 / -110	60 / 80	210 / 270
F	-110 / -130	80 / 100	270 / 330
G	< -130	> 100	> 330

Table 5. Proposed rating scheme.

To define each class range this study starts from the rating scale proposed by DTU [12], comparing it with other European classifications. Some adjustments are necessary to evaluate the role of new coefficients like the dimensionless gains utilization factor $\eta_{gn,w}$. In the proposed rating an A class includes windows that comply with the Italian law limits in term of thermal insulation. The A+ class includes the best performing solutions while from B to G class the less efficient products are set. The EP_{tot} class limits are defined starting from the two seasonal values, using the equation (11) to define each class. The proposed rating scheme should be valid all over Europe, using specific national coefficients but, to validate this scheme a more detailed analysis is recommended.

The final output of the study is an energy label for Italy (Figure 3). It is divided into several parts. At the top the main energy parameters such as thermal transmittance, solar factor and air leakage are shown. The central part is divided into four areas, corresponding to the four proposed climatic zones. For each zone, three indices are defined: the total one EP_{TOT}, the winter index EP_H and summer one EP_C. They are identified both by a numerical EP value and by an user-friendly system based on an eight levels chromatic scale.

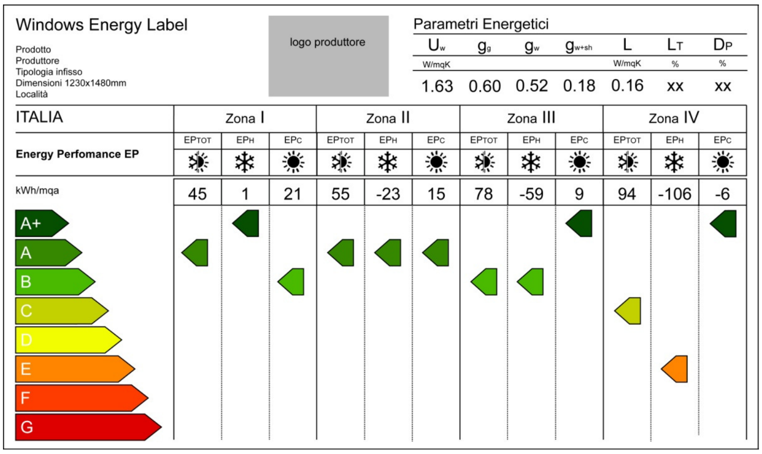

Figure 3. Energy label proposal for Italian context.

5 CONCLUSIONS

The presented approach illustrates a possible European method to define an window energy rating system. It is based on simplified equations derived from the ISO 18292 [9] but it is able to consider also different national climatic conditions using specific coefficients for each country. In this way, the same method can be applied to obtain comparable results due to the common parameters and the same rating classes used. The main differences between the proposed system and other labelling schemes are:

1. Both winter and summer conditions are considered thanks to an energy balance through the window while in many countries only the winter period is considered.
2. Different climate conditions can be considered using specific coefficients. In this way it is possible to obtain a more accurate result than the one definable through a single European equation in which the window energy efficiency is not linked to the climatic context. Moreover, a common rating system would allows a comparison inside and outside the same climate zone while, at the current day, each nation uses its own ranking method.
3. The energy efficiency evaluation considers only three main variables linked to the window - thermal transmittance (U_w), solar factor (g_w) and air leakage (L) - while many other labelling systems consider only one of these parameters. The calculation is also implementable with other variables like the introduction of a solar shading device.
4. The introduction of the Total Energy Performance index simplifies the results, making them understandable also for end users and suggesting an average value for the window efficiency. At the same time, the two seasonal indices are very useful for the correct design of the window system. According to each seasonal index it is possible to define whether the window needs a thermal insulation or a sun protection improvement.

The proposed methodology defines a labelling scheme that can be used not only as a simplified tool for the choice of the correct window in a specific climate condition but also as a designing tool for window system. Thanks to this label it is possible to compare different window products, changing the used glass or the frame materials, simply modifying the three basic parameters U_w, g_w and L. It is also possible to add special components like solar shading devices. In this way complex calculations are not necessary to define the new energy performance of the window. Therefore, the energy label could become an effective tool for the dissemination of efficient window idea throughout Europe and to stimulate competition inside windows market. In this way the windows industry would be pushed towards a greater efficiency and an higher quality, developing innovative products able to achieve the highest energy classes.

In conclusion, it is important to remember that energy efficiency is only one of the factors that may affect the final window quality. Other aspects such as durability, safety in use or environmental impacts should be integrated into the labelling system to define a more complete framework. For this reason it is necessary to stimulate future researches with the aim of defining an evaluating system for the overall efficiency and sustainability of a window.

REFERENCES

[1] M. Capolla, "La casa energetica. Indicazioni e idee per progettare la casa a consumo zero", Maggioli, Rimini, Italy, 2011.

[2] K. Nielson, "Window Treatments", John Wiley and Sons, Hoboken, NJ, USA, 1989.

[3] IEA, "Technology Roadmap. Energy efficient building envelopes", IEA publications, Corlet, Paris, France, 2013.

[4] TNO, "TNO Report TNO-60-DTM-2011-00338. Glazing type distribution in the EU building stock", Delft, Netherlands, 2011.

[5] TNO, "TNO Report 2008-D-R1240/B: Potential impact of Low-Emissivity Glazing on energy and CO_2 savings in Europe", Delft, Netherlands, 2008.

[6] TNO, "TNO Report 2007-D-R0576/B: Impact of solar Control Glazing on Energy and CO_2 savings in Europe", Delft, Netherlands, 2007.

[7] SAVE Contract, "Establishment of European Window Energy Rating System (EWERS)", Final Project Report, 2000-2003.

[8] European Directive 2009/125/CE "Establishing a framework for the setting of ecodesign requirements for energy-related product", 2009.

[9] ISO 18292 "Energy performance of fenestration systems for residential buildings - Calculation procedure", 2011.

[10] UNI TS 11300-1 "Prestazioni energetiche degli edifici: Determinazione del fabbisogno di energia termica dell'edificio per la climatizzazione estiva ed invernale", 2008.

[11] V. Corrado (et alii), "Typology Approach for Building Stock Energy Assessment, Building Typology Brochure", Politecnico di Torino, Italy, 2011.

[12] J. Kragh (et alii), "Proposal for Energy Rating System of windows in EU", DTU Civil Engineering-Report R-201, DTU Byg, Brovej, Denmark, 2008.

[13] J. Rucinska, A. Panek, A. Trzaski, "Energy Certification Of Windows In Poland", SB11 Helsinki World Sustainable Building Conference, Helsinki, 2011.