European Door and Shutter Federation e.V

Technical Definition of a European Energy Label for Automatic Doors

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Abstract

The object of this paper is to describe a technical scheme for the definition of an energy label and energy performance classification for energy certification of automatic doors promoted by the European Door and Shutter Federation, e.V. (E.D.S.F.).

Automatic doors include industrial doors, residential garage doors and pedestrian doors incorporating an automatic system electrically powered able to open and to close the door with no human force involved.

E.D.S.F. is the European roof association for national associations and manufacturers of door and gate industries, formed in 1985 by national manufacturers associations to support and promote harmonized standards for doors and shutters in Europe.

This second edition includes latest label design modifications.

Content

1. Introduction

An energy label gives information to the consumer about the energy performance of a certain product, including a certification of its energy efficiency classification. It helps consumers to make an informed choice, emphasizing those products that are energy-efficient through the provision of accurate, relevant and comparable information.

It is quite extended in several areas, like electrical household appliances. Furthermore, Directive 2010/30/EU extends the scope of energy labelling to energy-related products, like windows, that do not directly consume energy, but indirectly affect the energy consumption of a wider system such as a building.

The Energy Certification of buildings is a requirement derived from 2002/91/CE and 2010/31/UE directives, and it has been deployed in several ways in different EU countries. This fact and the objective of the EU towards Nearly Zero-Energy Buildings (NZEB), which are to become the norm for all new buildings in the EU by the end of 2020, have been an impulse to energy certification and labelling of construction materials involved in the entire building performance.

In this sense, in several countries in Europe some energy labels have been developed for windows of residential buildings, but almost nothing has been developed for doors, except on BRFC (UK) and E2MF (France) labels for manual doors, always for residential buildings, similar to the windows one.

Specifically, there has not been any development for automatic doors, so there is a space for the creation of a European level label that could be accepted as a standard.

In the latest years, a lot of work has been done inside E.D.S.F. to show the importance of the automatic entrance doors in the energy performance of buildings, like the E.D.S.F. Energy Calculator, with technical results supported by the research made by the Technical University of Munich [4], E.D.S.F., Hörmann and Mequonic [1].

Our aim is to design a method to make an energy certification of the doors that contributes to the energy certification of the entire building. As a result, the energy performance analysis of the door is then essentially related to how it contributes to the energy performance of the whole building.

The classification method is based on verified and approved standards that are already in use in the market.

2. Development

2.1. General concept

To reach our objective, the methodology for the energy performance classification and labelling should accomplish the following nine principles, according to EN ISO 14020 [2]:

1. Correct, exact, verifiable, appropriate.
2. Prevention of trade barriers.
3. Verifiable methods, based on accepted scientific basis.
4. Open information to interested circles.
5. Considering relevant aspects of product lifecycle.
6. Prevention of innovation barriers.
7. Limited labelling requirements.
8. Open process for label acceptance.
9. Open access to related environmental information.

In point 4 we will review that our model verifies those conditions.

In annex 5.1 we present a summary of the analysis of the existing energy labels for windows. To develop a classification and labelling scheme for automatic doors based on window experiences we find that:

- Air infiltration due to door opening it is not considered, and we know from references [4] and [5] that it is the main factor in door energy performance related to building.
- An automatic door is a machine and, in that sense, is more similar to an electrical appliance than to a window. Parameters like electrical energy consumption have to be taken into account.
- The variability in door types and applications requires a more complex definition of reference values.

These facts take us to the development of a model that it not based on ISO 18292 [6], as it does not take into account these factors properly. The energy performance of a door was initially analysed according to the CEN technical report CEN/TR 16676 [3], but further studies showed the limitation of this approach.

A new research project was commissioned by E.D.S.F. to the company Mequonic Engineering S.L. to develop a new analytical model to allow a better understanding of the phenomena, that has been validated by specific experiments carried out in collaboration with Hörmann KG. Its results are explained in detail in [1] and they can be verified in the E.D.S.F. Energy Calculator [5].

As explained in [1], the energy losses in a building due to a door are essentially of five kinds:

- Heat transmission through door leaves when the door is closed.
- Air leakage through the door leaves when the door is closed.
- Solar radiation through transparent surfaces when the door is closed.

- Long wave radiation, or the thermal radiation spontaneously emitted by objects when the door is closed.
- Air infiltration when the door is open, due to wind and chimney effects.

Additionally, we find that the power consumption of the door drive, although is not included in [1] as it is a factor of a different nature, should be taken into account in classification since its contribution to the total energy losses may not be negligible in certain conditions.

These energy losses are dependent on several main variables:

- Location of the building and its temperature and wind conditions.
- Characteristics of the building, mainly volume and height.
- Door size.
- Traffic across the door, expressed in number of opening cycles.
- Door type.
- Thermal transmittance of the door.
- Air permeability of the door.
- Solar factor of the door.
- Glass area of the door.
- Emissivity of de door surfaces.
- Opening time per cycle of the door.
- Door power consumption during operation cycles and in stand-by status.

These variables can be divided in three groups:

- Variables related to the environment: building and location.
- Variables mainly related to the door application: size and number of cycles.
- Variables related to the door itself: type, thermal transmittance, air permeability, solar factor, glass area, emissivity, opening time, electrical power.

To be able to compare doors between them, the energy classification A, B, C… has to be done referring only to the variables related to the door itself. To do so, we have to normalize the door according to the rest of variables by means of classifications.

The workflow diagram of the complete classification process is shown in figure 1.

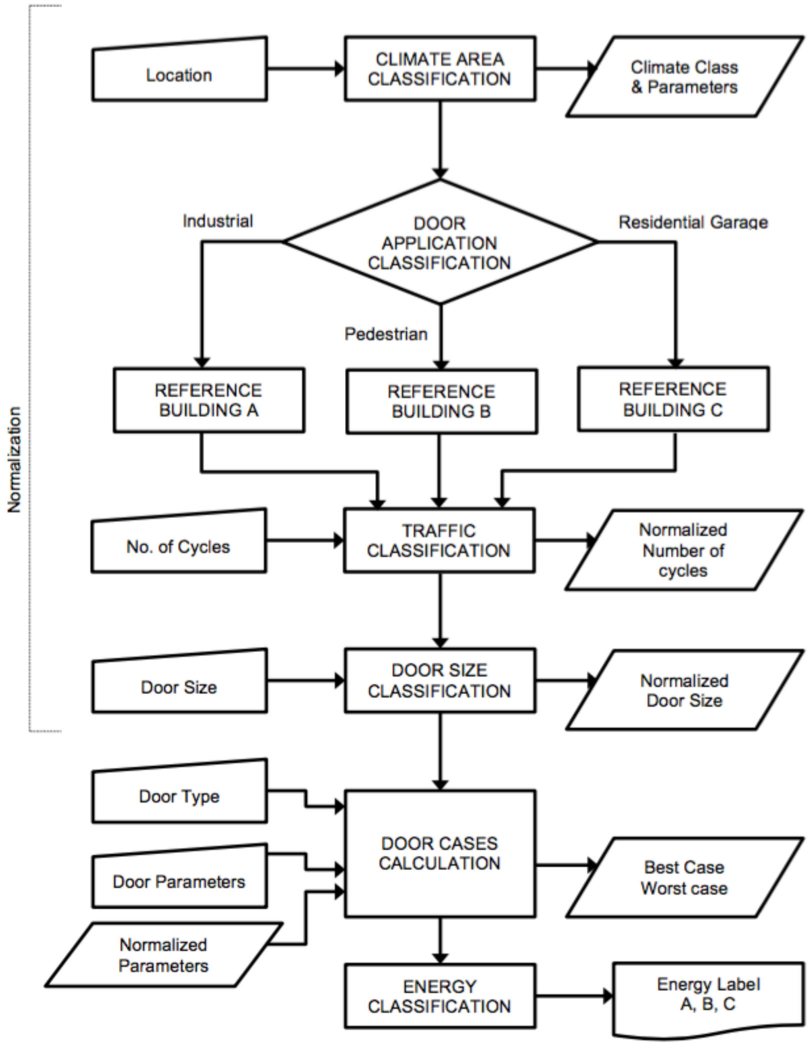


Fig. 1: Workflow diagram

It is important to remark that all tasks and calculations in the process are focused on having an energy classification valid for multiple situations, not a precise calculation of the energy losses in a real and particular situation.

On summary, the process consists in the following steps:

- Normalization of the parameters to be able to compare our door with a standard worst case and a standard best case according to the state of the art of the industry.
- Calculation of the energy losses of the door under classification in the real installation circumstances, as well as normalized, best and worst cases.
- Classification and labelling depending on the comparison between normalized and best and worst cases.

2.2. Normalization

In this phase all reference values are defined.

2.2.1.-Climate classification

First of all, location is classified according to different climate areas across Europe to standardize climate parameters influencing energy losses.

The definition of the climate areas is made according to the *Köppen-Geiger* climate classification model, which is widely accepted in the scientific community.

According to this model, the world is divided in several different climate areas depending on climate conditions. In figure 2 we find these areas in Europe:

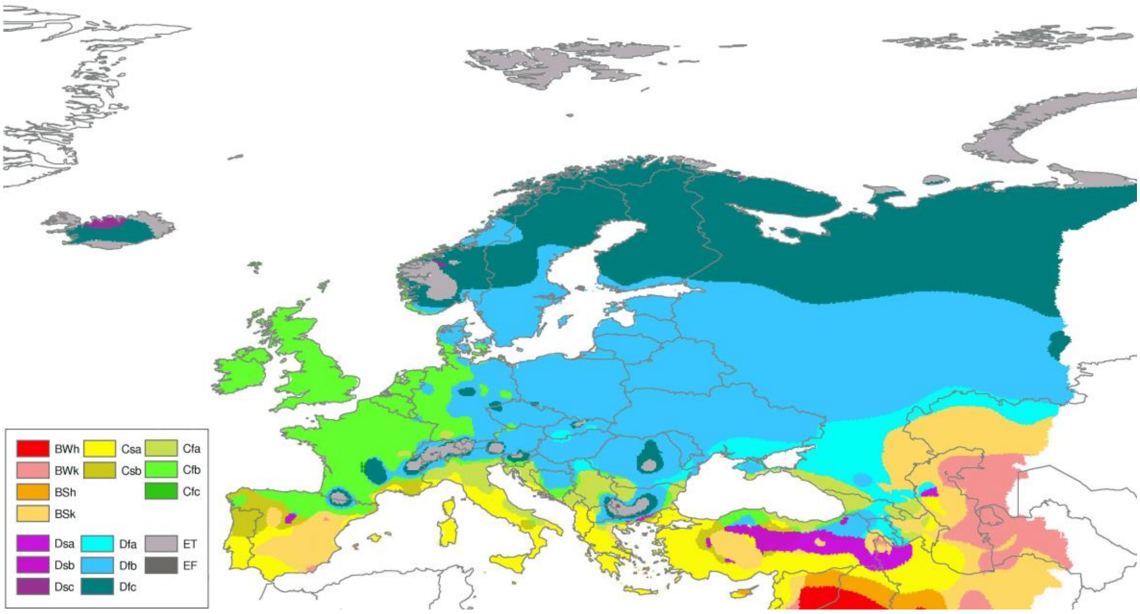


Fig. 2: Updated Köppen-Geiger map of Europe, ref. (7), (8)

It is obvious that there are microclimate areas inside Europe not covered with this model, but E.D.S.F. is assuming that this classification is enough for our purposes of normalization and comparison.

In references (6), (7), (8) and (9) more detailed data could be found about this climate model.

In Europe we find these climate classes:

Code	*Class*	*Description*
BSk	Mid-latitude Dry semiarid	Mid-latitude dry.
BWk	Dry arid	Mid-latitude very dry.
Cfa	Humid Subtropical	Mild with no dry season, hot summer.
Cfb	Oceanic	Mild with no dry season, warm summer.
Csa	Interior Mediterranean	Mild with dry, hot summer.
Csb	Coastal Mediterranean	Mild with cool, dry summer.
Dfa	Hot Humid Continental	Humid with hot summer.
Dfb	Warm Humid Continental, wet all year	Humid with severe winter, no dry season, warm summer.
Dfc	Subarctic With Cool Summer, wet all year	Severe winter, no dry season, cool summer.
Dsa	Hot Humid Continental, dry winter	Humid with hot summer, dry winter
Dsb	Warm Humid Continental, dry winter	Humid with severe winter, dry winter
ET	Polar Tundra	Severe winter, no summer

Table 1: Kopper-Geiger classes in Europe

For our energy classification purposes, we make several simplifications in order to improve system usability:

a) Some climate classes can be assimilated to similar classes from temperature point of view:

- BWk: Very small areas in Spain. We can assimilate it to BSk.
- Dsa: Very small areas in Spain and Bulgaria and center Turkey. From the point of view of classification, we can assimilate it to Dfa.
- Dsb: Small areas in Norway and a wider area in north of Iceland. From the point of view of classification, we can assimilate it to Dfb
- ET. Only in high alpine areas. From the point of view of classification, we can assimilate it to Dfc.

b) We identify the prevailing climate class in each second level administrative division in Europe (regions, provinces, counties…). Each location inside each region will have the same climate class for classification purposes. The figure 3 we find this divisions:

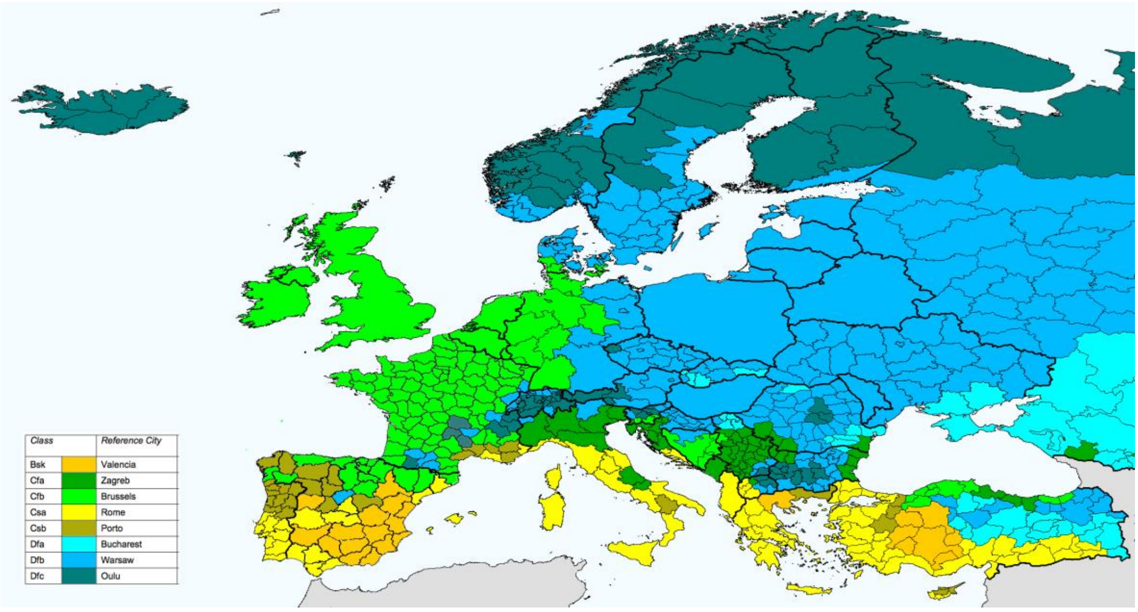


Fig. 3: Simplified Climate Areas

c) For each climate class we select a reference city where there is an intermediate climate performance regarding the parameters involved in our model. It is not a precise average value inside every climate area, but we consider it is acceptable for our classification purposes.

Class	*Reference City*	T_{oh} [ºC]	C_h [days]	T_{oc} [ºC]	C_c [days]	v [m/s]	p [Pa]	I_{sh} [kWh/m²]	I_{sc} [kWh/m²]	t_{psh} [hours]	t_{psc} [hours]
Bsk	Valencia	10,50	210	22,50	120	7,50	36,36	129,12	104,02	8,33	10,53
Cfa	Zagreb	8,38	210	22,50	90	5,17	17,28	75,59	96,27	5,83	9,72
Cfb	Brussels	9,80	240	19,70	60	8,42	45,83	62,59	87,81	4,47	8,00
Csa	Rome	12,80	180	23,70	150	8,17	43,15	107,64	107,57	7,28	11,05
Csb	Porto	14,20	150	21,00	120	8,08	42,21	110,25	104,22	6,15	8,87
Dfa	Bucharest	7,00	210	23,40	90	6,08	23,92	54,12	97,87	3,63	9,85
Dfb	Warsaw	7,67	210	21,30	90	8,67	48,60	49,12	95,99	2,44	6,79
Dfc	Oulu	2,72	330	19,00	0	7,42	35,59	129,12	104,02	8,33	10,53

Table 2: Reference cities per Climate Class

The required parameters for the energy calculation according to (2) are the following:

T_{oh}: Average external temperature in heating season
T_{oc}: Average external temperature in cooling season
C_h: Number of heating days per year
C_c: Number of cooling days per year
v: Wind speed
p: Wind pressure
I_{sh}: Solar irradiance in heating season

I_{sc}: Solar irradiance in cooling season
t_{psh}: Peak solar hours per day in heating season
t_{psc}: Peak solar hours per day in cooling season

2.2.2 Application classification

The scope of the label is limited to Industrial doors, Pedestrian doors and Residential Garage doors, classification that we find useful from technical, commercial and standards points of view.

As a second step, we have to indicate to which of these three groups or classes the door belongs, as this classification is necessary for further range definitions.

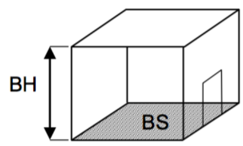
2.2.3.-Reference building

Obviously, there are enormous variations in building configurations and volumes that make too complex to divide them in separate classes.

Following what has been done for the window classifications, the most logical option to standardize the building is to choose a reference building with defined dimensions.

In practice, as there can be substantial differences in size of industrial, tertiary and residential use buildings, we define three different buildings depending on the application class.

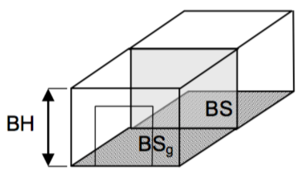
For Industrial and pedestrian doors, the building is a cuboid with no internal divisions.



Building	*Height BH* [m]	*Floor Area BS* [m²]
A - Industrial	8	5000
B - Pedestrian	4	1000

Table 3.1: Reference building dimensions (industrial and pedestrian)

For residential garage doors, as the garage room is not usually an air-conditioned or heated area, the reference building is divided in “Home Room” and “Garage Room”. This implies a different energy calculation as explained in 2.3.6.



Building	*Height BH* [m]	*Home Area BS* [m²]	*Garage Area* BS_g [m²]
C - Garage	3	150	50

Table 3.2: Reference building dimensions (residential garage doors)

2.2.4.-Door size

Window labels usually consider a reference window with fixed dimensions. This is feasible because all energy losses are linearly dependent on the area. This is not the case for the doors.

Dimensions of the door are also related to door application, as they depend basically on the type of vehicle that crosses through the door, traffic amount, building design, etc.

Industrial doors, garage doors and pedestrian doors are in different scale of dimensions, so we consider different reference dimensions for each of them.

Every size class is determined by door area. Like before, an intermediate value of the interval is used as a reference for the doors belonging to that class. We also set a reference clear height and reference clear width that will be used for the reference opening time calculation.

In the following table we have the reference values:

	Class	*Min. Area [m²]*	*Max. Area [m²]*	*Ref. Area [m²]*	*Ref. Width [m]*	*Ref. Height [m]*
Industrial	S1	0	8	6	2,00	2,00
	S2	8	12	10	3,00	3,33
	S3	12	16	14	4,00	3,50
	S4	16	25	20	5,00	4,00
	S5	25	-	30	6,00	5,00
Pedestrian	S1	0	3,5	2	1,00	2,00
	S2	3,5	4,5	4	2,00	2,00
	S3	4,5	6,5	5,5	2,50	2,20
	S4	6,5	8,5	7,5	3,00	2,50
	S5	8,5	-	10	3,50	2,86
Residential Garage	S1	0	8	6	2,00	2,00
	S2	8	12	10	3,00	3,33
	S3	12	16	14	4,00	3,50
	S4	16	25	20	5,00	4,00
	S5	25	-	30	6,00	5,00

Table 4: Size classification

2.2.5.-Door traffic

Door traffic means the amount, of vehicles or pedestrians that crosses through the door, what is directly related to door use, obviously depending on what kind of activity is developed in the building.

The parameter that characterizes this concept is the number of opening cycles of the door per year. Since there is a very large variation, we make an approach using a logarithmic scale.

In this case a similar approach to the reference building size is done, considering three classes with the following typical number of cycles per year:

Class	*Traffic*	*Number of cycles per year*
T1	Low	1500
N2	Medium	15000
N3	High	150000

Table 5: Traffic Classification

The classification is made for these three traffic classes, so in practice the label will show three classifications: T1, T2 and T3.

2.3. Energy performance calculation

As we explained in 2.1, the energy losses are calculated according E.D.S.F. model developed in [1] to substitute CEN/TR 16676, adding energy losses due to the door electrical energy consumption. We do it for three cases:

- Normalized door
- Reference worst case
- Reference best case

For every case, the total energy losses E in kWh are calculated according to the simplified transient model as described in [1] with five intervals:

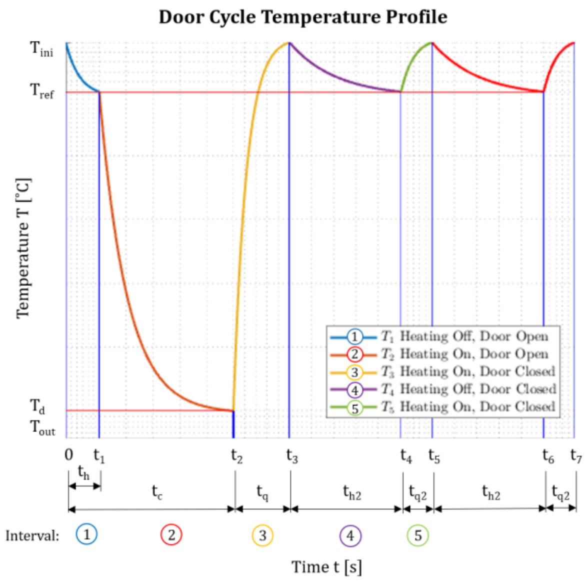


Fig. 4: Door cycle temperature of physical model (heating)

The model is based on a balance between energy contributions of heating/cooling systems and solar radiation on one side, and energy losses due to four main effects (heat transmission, long wave radiation, air leakage and air infiltration) on the other side.

When the door is closed, heat transmission, long wave radiation and air leakage are the source of losses, and when the door is open, losses are generated only by air infiltration. All these effects are defined by key parameters for door classification.

As explained, electrical consumption from the door driver is also considered for classification means but does not take part in the transient energy balance calculation.

2.3.1 Door type

To apply in each case the right equations, we need first a complete definition of the door type. According to the work developed in the Energy & Sustainability workgroup inside E.D.S.F., the following door types where identified by the different door manufacturers:

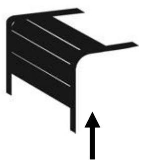
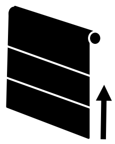
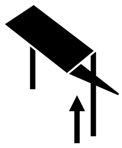
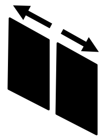
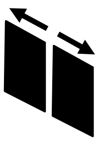
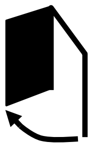
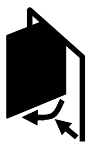
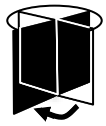
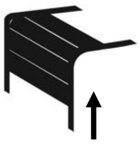
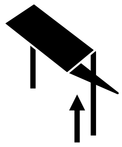
Industrial	*Overhead sectional*	*Roller Shutter*	*High Speed*	*Bi-folding vertical*	*Bi-folding horizontal*	*Sliding industrial*
						
Pedestrian	*Sliding pedestrian*	*Bi-folding pedestrian*	*Swing*	*Balanced*	*Revolving*	
						
Residential Garage	*Overhead sectional*	*Roller Shutter*	*Up and Over*	*Bi-folding vertical*		
						

Table 6: Automatic door types

These door types do not limit the possibility of variants slightly different that can be assimilated to one of them. In this sense, except on revolving doors, the door type definition is only related to the parameters that are influenced by the cinematic characteristics of the door (vertical, horizontal or rotating movement).

2.3.2.-Heat transmission

Heat transmission refers to loss due to heat conduction and convection through the door when it is closed. As explained in [1], the variable that defines the heat transmission performance of the door is the thermal transmittance, also known as U-value.

For industrial and pedestrian doors, the heat transmission heat flow in W would be:

$$H_t = A \cdot U \cdot (T_i - T_o) \qquad (1)$$

In the case of residential garage doors, the temperature inside the garage room T_g must be used instead of T_i in formula (1):

$$T_g = \frac{U_g \cdot A_g \cdot T_i - F_h \cdot BH \cdot BS_h \cdot 10^{-3}}{U_g \cdot A_g} \qquad (24)$$

The calculation of T_g is detailed in Annex 5.2.

Reference U values should be calculated in accordance to EN 12428 [11]. The best and worst cases are defined by E.D.S.F. market research for all door types as shown in Table 7:

Door Application	*Thermal transmitance U [W/m², K]*	
	WORST CASE	*BEST CASE*
Industrial	6,00	0,50
Pedestrian	6,00	1,00
Residential Garage	6,00	0,50

Table 7: U reference values

Then energy losses per year are calculated with heating and cooling time per year.

2.3.3.-Long wave radiation

As explained in [1], long wave radiation is the thermal electromagnetic radiation within or surrounding a body in thermodynamic equilibrium with its environment or emitted by a black body (an opaque and non-reflective body). It has a specific spectrum and intensity that depends only on the temperature of the body, which is assumed for the sake of calculations and theory to be uniform and constant. The thermal radiation spontaneously emitted by objects in the form of infrared light can be approximated as black-body radiation.

The net power radiated by doors or walls is the difference between the power emitted and the power absorbed. The heat flow in correspondence to this power is depending on door surface and ambient temperature, as well as the emissivity ε of the door surface.

As emissivity is a data not usually known for doors and not very variable for usual door materials, a standard value of $\varepsilon = 0{,}9$ is used for all doors in the classification calculation.

2.3.4.-Air leakage

Air leakage refers to the exchange of air mass between the inside and outside through door interstices when it is closed. The main characteristic of the door that defines the amount of energy lost by air leakage is the air permeability L.

As explained in [1], air leakage losses are due to two effects: external wind pressure and chimney effect in the building, so the total air leakage is the sum of both.

For industrial and pedestrian doors, heat flow in W due to air leakage would be:

$$H_{vW} = C_p \cdot \rho \cdot Q_{vW} \cdot (T_i - T_o) \qquad (3.1)$$

$$H_{vC} = C_p \cdot \rho \cdot Q_{vC} \cdot (T_i - T_o) \qquad (3.2)$$

H_{vW}: Heat flow due to external wind pressure
H_{vC}: Heat flow due to chimney effect in the building.

Like before, for residential garage doors, the temperature inside the garage room T_g according formula [14] is used instead of T_i in formulae (3.1) and (3.2).

Where volumetric air flow in m^3/s would be:

$$Q_{vW} = L_W \cdot A \cdot \frac{1}{3600} \qquad (4.1)$$

$$Q_{vC} = L_C \cdot A \cdot \frac{1}{3600} \qquad (4.2)$$

L values of the equipment are given for the following air pressure:

- Industrial and Garage doors: 50 Pa according to EN 12426 [12].
- Pedestrian doors: 100 Pa according to EN 12207 [13].

These values have to be corrected into L_W and L_C with the real value of the air pressure to calculate the energy losses. Calculation is described in [1], taking into account:

- External wind pressure values depend on location and building orientation. Yearly average wind pressure value is considered assigning a similar weight to every possible orientation of the door façade (N, NNE, NE, ENE, E, ESE4, SE, SSE, S, SSW, SW, WSW, W, WNW, NW, NNW).

- Air pressure due to chimney effect is mainly dependant on building height.

Reference values of L for best and worst cases are defined by E.D.S.F. market research for all door types:

Door Application	*Air Permeability L [m³/h,m²]*	
	WORST CASE	*BEST CASE*
Industrial (Reference Pressure = 50 Pa)	30	1
Pedestrian (Reference Pressure = 100 Pa)	50	1,5
Residential Garage (Reference Pressure = 50 Pa)	30	1

Table 8: Permeability reference values

2.3.5.-Air Infiltration

Air infiltration or ventilation refers to the massive air mass exchange when the door is open. As seen with air leakage, air flow exists due to the pressure difference between inside and outside the building, mainly by two effects: wind pressure and bulk density flow.

When we have a large opening between fluids at different temperature, even in absence of wind, there is a so-called gravitational air flow or bulk density flow due to the density differences. This is not considered in CEN/TR 16676 and it has a certainly non-negligible contribution to air flow.

The physical model is quite complex, and it is described in [1] their contribution to the energy balance.

Since the number of cycles has been normalized, the main parameter dependant on the door that determines the air flow in infiltration is the opening time, which is defined as the time in every cycle for the door to open and close again. In practice, the opening time is the sum of three intervals of time:

$$t_c = t_{co} + t_{ch} + t_{cc} \qquad (5)$$

Where:

t_{co}: Time to open
t_{ch}: Hold time
t_{cc}: Time to close

As only total cycle time t_c is requested, we consider the following standard values for classification:

$$t_{co} = 0{,}4 \cdot t_c \qquad (6.1)$$
$$t_{ch} = 0{,}1 \cdot t_c \qquad (6.2)$$
$$t_{cc} = 0{,}5 \cdot t_c \qquad (6.3)$$

As time is depending on door dimensions, the variable that is shown in the label is the mean door speed, which is calculated with the following simplified formulas:

- For doors in which leaf movement is horizontal (sliding, folding, balanced):

$$v_d = \frac{2 \cdot CW}{t_{co} + t_{cc}} \qquad (7)$$

- For doors in which leaf movement is vertical (overhead sectional, roller shutter, high speed flexible):

$$v_d = \frac{2 \cdot CH}{t_{co} + t_{cc}} \qquad (8)$$

- For swing doors:

$$v_d = \frac{\pi}{t_{co} + t_{cc}} \qquad (9)$$

Where:

v_d: Mean door speed.
CW: Door clear width
CH: Door clear height

Notes:

- For swing doors, average door speed is referred to leaf linear speed at 1 m radius.
- For balance doors, linear speed is referred to linear movement of vertical rotation axis.
- In bi-part doors (doors with two leaves moving horizontally in opposite sense), door speed doubles the leaf speed. This does not apply to swing doors.

Therefore, the key characteristic of the door to define the energy losses by infiltration is the door speed, expressed in terms of mean door speed during the complete cycle of opening and closing (it is not the peak maximum speed).

If the door is activated with sensors, we make the assumption that sensing activation area is such that the time for the vehicle or pedestrian to approach the door (or leave sensor detection area once the door is crossed) is less than the time for the door to open (or close). Otherwise opening time would be increased by the action of the sensors.

In practice, knowing the real total opening time of a door including hold time, mean speed will be calculated with formulas (7), (8) and (9), and then compared to worst and best cases.

In the following table, we finally show the reference values of speed for the best and worst cases as defined by E.D.S.F. market research for all door types.

Door Application	*Door leave speed [m/s]*	
	WORST CASE	*BEST CASE*
Industrial	0,10	0,80
Pedestrian	0,20	8,50
Residential Garage	0,10	0,80

Table 9: Door speed reference values

Pedestrian Revolving Doors Case:

For revolving doors, air infiltration is the result of a different effect. The door is never strictly open, but there is a dynamic effect of air exchange inside the building due to the leaves rotation movement. The physical phenomenon and the mathematical model is described in references [14] and [15].

In practice, according to our classification goals, we use a simplified approach as explained in Annex 5.1, being the air volume flow:

$$Q_{vI} = (T_i - T_o) \cdot (27{,}45 \cdot D - 22{,}87) \cdot (40{,}26 \cdot CH - 53{,}37) \qquad (20)$$

This air volume flow is referred to a reference speed of 10 rpm as stated in Annex 5.3. In energy calculation, the loss coefficient by infiltration K_{infil} as described in [1] for first and second intervals is calculated:

$$K_{infil} = C_p \cdot \rho \cdot Q_{vI} \qquad (10)$$

For comparison, in practice we consider as best case an equivalent door speed for a revolving door having the same infiltration effect than a conventional single pedestrian door (sliding, swing, folding or balanced). This means an extremely high maximum speed, but it has only meaning for calculation purposes.

2.3.5.-Electrical power

Electrical power energy losses E_e are composed by the sum of two elements:

$$E_e = E_{eOP} + E_{eSB} \qquad (11)$$

Where:

E_{eOP}: Operation power consumption during opening cycles.

E_{eSB}: Stand-by power consumption when the door is closed.

They are calculated with:

$$E_{eOP} = n \cdot t_c \cdot P_{eOP} \tag{12}$$

$$E_{eSB} = (t_{OP} - n \cdot t_c) \cdot P_{eSB} \tag{13}$$

n: Number of cycles per year
t_c: Opening cycle time
t_{OP}: Door operation time per year
P_{eOP}: Operation mean power during opening cycles.
P_{eSB}: Stand-by power consumption when the door is closed.

Reference values are expressed in terms of power per kg of weight of the door leaf, except for swing, balance and revolving doors, in which they are referred to moments of inertia in kg · m^2. Values for the best and worst cases are defined by E.D.S.F. market research for every door type.

Door Application	*Door Type*	*Operation Power [W/kg] (*)*		*Stand-by Power [W]*	
		WORST CASE	*BEST CASE*	*WORST CASE*	*BEST CASE*
Industrial	Overhead sectional	1,5	0,5	25	3
	Roller shutter	15,0	5,0	25	3
	High speed flexible	30,0	10,0	25	3
	Bi-folding vertical	1,5	0,5	25	3
	Bi-folding horizontal	1,5	0,5	25	3
	Sliding industrial	1,5	0,5	25	3
Pedestrian	Sliding pedestrian	1,5	0,3	75	3
	Bi-folding pedestrian	1,5	0,3	75	3
	Swing	5,0	1,0	75	3
	Balanced	5,0	1,0	75	3
	Revolving	5,0	1,0	75	3
Residential Garage	Overhead sectional	1,5	0,5	25	3
	Roller shutter	15,0	5,0	25	3
	Up and over	1,5	0,5	25	3
	Bi-folding vertical	1,5	0,5	25	3

(*) For Swing, Balanced and Revolving Doors values are in *[W/kg,m^2]*

Table 10: Electric power reference values

2.4. Classification

At the end of the previous phase, we have calculated values of total energy losses E for a normalized door and for the best and worst cases. Then the A, B, C… classification is made depending on the distance between the normalized case and the best case, in terms of percentage of relative increment of E:

$$\frac{\Delta E_{norm}}{\Delta E_{worst}} = \frac{E_{norm} - E_{best}}{E_{worst} - E_{best}} \times 100 \qquad (14)$$

Intervals of variation of this value are defined to have the classes:

Class	*Interval*
A+	Less than 0%
A	0% to 15%
B	15% to 30%
C	30 % to 45%
D	45% to 60%
E	60% to 75%
F	75% to 90%
F-	90% to 100 %
F--	More than 100%

Table 11: Energy performance classification

2.5.-Label structure

The last label version has the following structure:

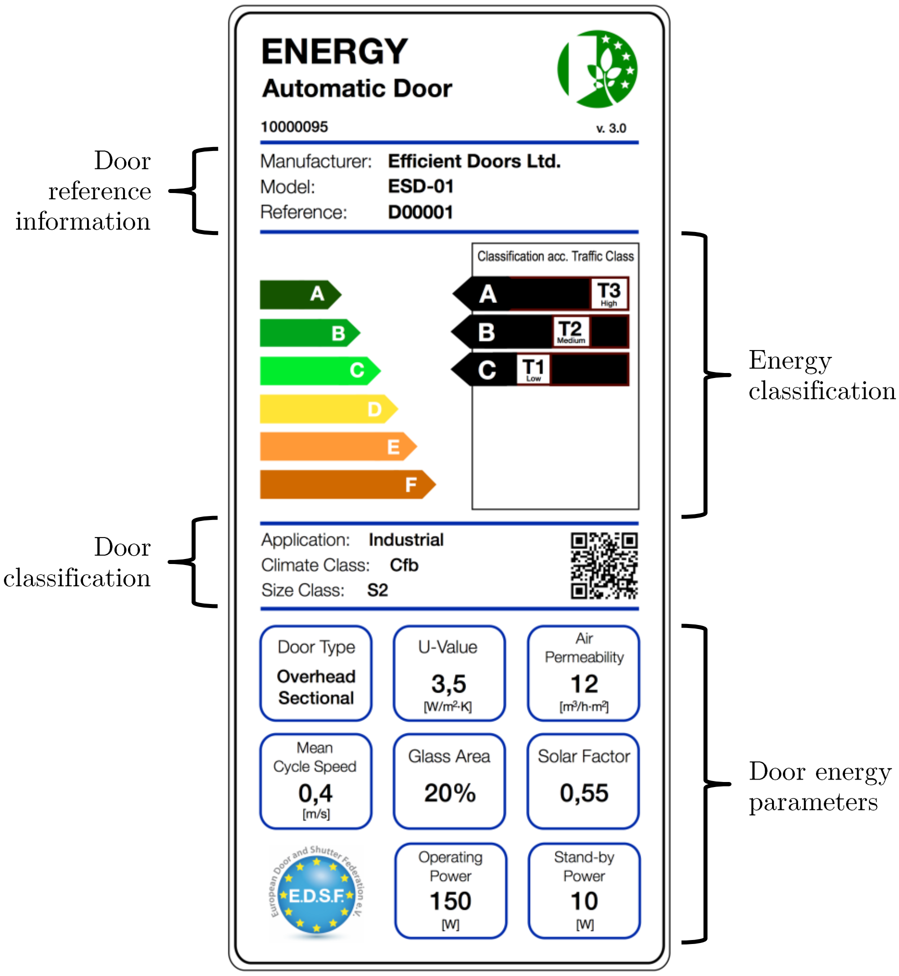


Fig. 5

Only doors with similar “Door Classification” can be compared between them in terms of energy classification.

We consider it may be not convenient to explicit the absolute amount of the energy losses, as they are referred to the reference building and normalized parameters and it can be misunderstood by the user.

3.-Conclusions

With this development, we consider there is a consistent methodology to classify the energy performance of automatic doors, that fulfils the requirements of EN ISO 14020 as we stated in point 2.1:

1	Correct, precise, verifiable, appropriate,	As it is exposed in this document and confirmed by further studies.	✓
2	Prevention of trade barriers.	There is no limitation included for trade and commerce.	✓
3	Verifiable methods, based on accepted scientific basis.	Accepted scientific basis according to international standards	✓
4	Open information to interested circles.	There is public information to sectorial organizations.	✓
5	Considering relevant aspects of product lifecycle.	All relevant aspects related to energy performance are included.	✓
6	Prevention of innovation barriers.	There is no limitation in the methodology to further innovations.	✓
7	Limited labelling requirements.	There is no administrative requirement related to the methodology.	✓
8	Open process for label acceptance.	Scheme to be discussed inside sectorial organizations.	✓
9	Open access to related environmental information	Information of environmental and energy performance of doors is available and public.	✓

As we have seen, door energy classification depends on the door itself, but also on the building and location where it is going to be installed, so labelling can only be done to every single door and not to commercial product ranges.

We consider that the procedure described makes possible to have a useful and accurate energy classification and labelling that can show the importance of the automatic doors in the whole building energy performance.

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5. Annex

5.1. Air infiltration calculation scheme for revolving doors

We use as base the research made by the *Eindhoven University of Technology* and *Concordia University* in Montreal [15], which is based in the previous research made in the 60's by *ASHRAE* in the USA [14].

As a result of their studies, an analytic calculation method is defined. The net air infiltration in terms of volumetric air flow for a four segments door is:

$$Q_{vI} = 240 \cdot N \cdot q_S \qquad (15)$$

The result is in [m³/h], N is the door rotation speed and V the segment volume. q_S is the volumetric flow of cold air that goes from outside to inside in the winter (the opposite in the summer). This is calculated:

$$q_S = q_{I,i} \frac{q_{0,I}}{V} \qquad (16)$$

where $q_{I,i}$ is the total volumetric flow of air that flows from one segment to indoors and $q_{0,I}/V$ is the percentage of cold air in that segment.

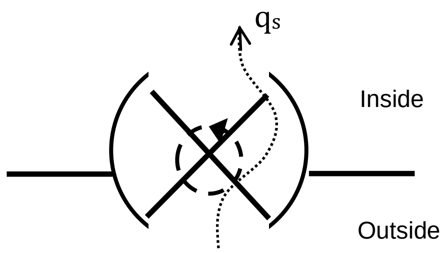


Fig. 6

In every change of door parameters, a differential equation system must be solved numerically to calculate $q_{0,I}$ and $q_{I,i}$, so a precise calculation must be done with a mathematical calculation tool.

The energy loss would be:

$$H_v = C_p \cdot \rho \cdot Q_v \cdot (T_i - T_o) \qquad (17)$$

Taking into account that the real amount of infiltration losses in revolving doors compared to conventional doors is quite reduced, we make an approach based on their numeric results in order to have a simpler but enough accurate calculation scheme for our goals.

For a reference door with the following parameters:

Door Height:	CH = L = 2,08 mm
Door Diameter:	D = 2R = 1,94 m
Segment Volume:	V = 1,53 m^3
Flow Coefficient:	C = 0,5

They found the following performance of the net air infiltration as a function of the temperature difference between indoor and outdoor for three different values of door speed N:

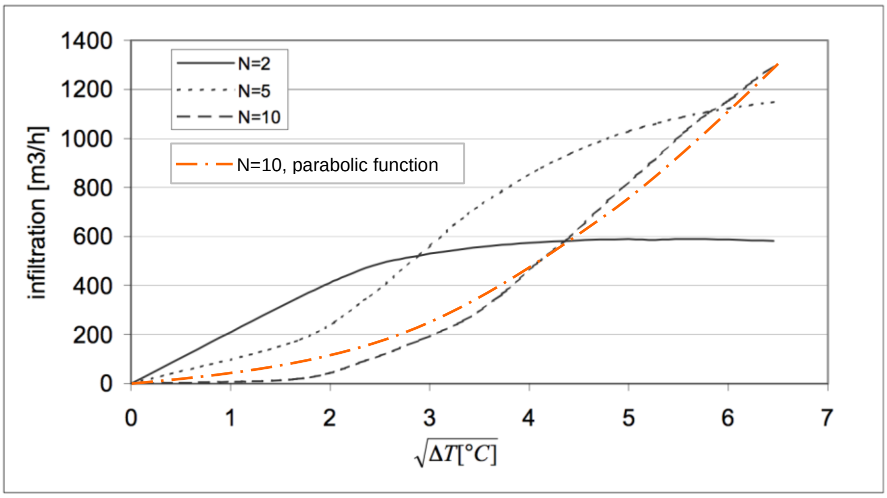


Fig. 7

In revolving doors, the limitation for the maximum speed is fixed, as it is related to the speed a pedestrian can achieve, so we can always use for our calculation a reference door rotation speed of 10 rpm.

As a first acceptable simplification, we can assimilate the performance for N=10 rpm to a parabolic function as seen in figure 7.

Therefore, the equation for the reference door would be:

$$Q_{vRef} = 30{,}5 \cdot \left(\sqrt{T_i - T_0}\right)^2 = 30{,}5 \cdot (T_i - T_0) \qquad (18)$$

They also made in (12) a sensitivity analysis for N=10 rpm, in which we find the variation of air infiltration rate with the change of the different variables from the reference case:

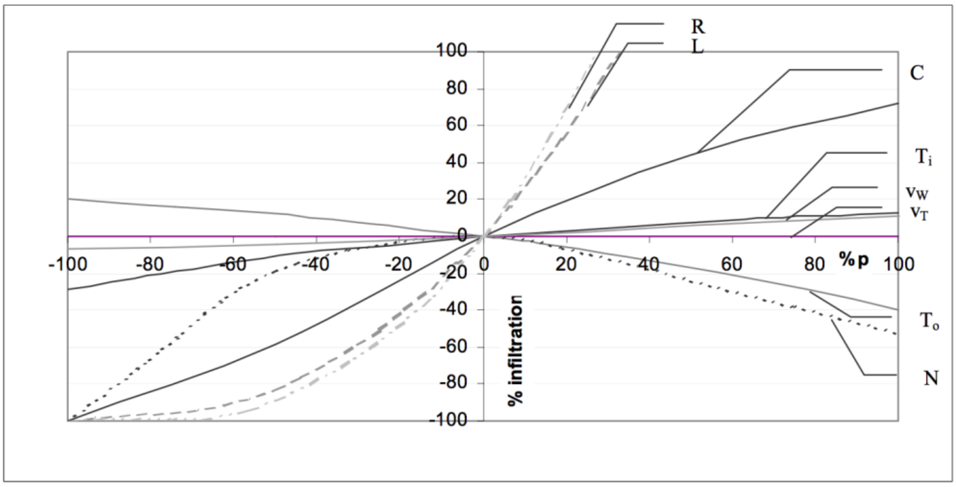


Fig. 8

We find that the main variation is due to door size (diameter and height), and much less due to temperature. In our calculation we always consider the same average value for the flow coefficient.

Based on this result, as a first simplification, approximating a linear variation of air volume flow with L and D from the reference case:

$$Q_{vI} = Q_{vRef} \cdot (0{,}90 \cdot D - 0{,}75) \cdot (1{,}32 \cdot CH - 1{,}75) \quad (19)$$

Substituting and operating we have the equation to use in our label calculation:

$$Q_{vI} = (T_i - T_o) \cdot (27{,}45 \cdot D - 22{,}87) \cdot (40{,}26 \cdot CH - 53{,}37) \quad (20)$$

The results of the study (13) are focused on a four segments door, but the variation of the total amount of air infiltration due to wings movement with the number of segments is low. On the other hand, static air leakage due to different sealing configuration can be quite different, but this is considered in 2.3.3.

5.2. Specific calculations for residential garage door classification

Due to the fact that the garage room in a residential house is not usually air-conditioned or heated, some adaptations are made in the energy losses calculation for classification.

As explained, the reference building for garage doors is divided in two rooms, "garage" and "home". Both are cuboids with no internal walls.

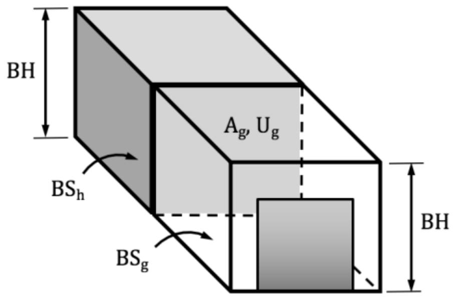


Fig. 9

Home area is BS_h and garage area is BS_g. Their values are given in table 3.2.

For calculation purposes, we consider that there is only one separation wall between both rooms and that all heat flow between both spaces is exchanged through that wall. We define the following values for the reference parameters of the wall:

Área:	$A_g = 12\ m^2$
Thermal Transmittance:	$U_g = 2{,}5\ W/m^2K$

While the door opens the garage room, the heating and cooling system is in the home room.

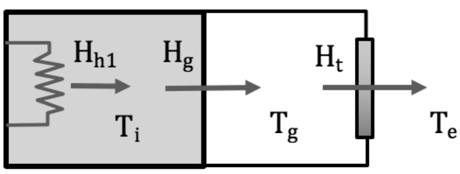


Fig. 10

Calculating the energy flow of heating/cooling system and energy flow through the wall:

$$H_g = U_g \cdot A_g \cdot (T_g - T_i) \qquad (21)$$

$$H_{h1} = F_h \cdot BH \cdot BS_h \cdot 10^{-3} \qquad (22)$$

F_h is the heating or cooling factor in W/m^3 as defined in CEN/TR 16676.

Applying the specifications described we can equal and calculate T_g:

$$H_g = H_{h1} \tag{23}$$

$$T_g = \frac{U_g \cdot A_g \cdot T_i - F_h \cdot BH \cdot BS_h \cdot 10^{-3}}{U_g \cdot A_g} \tag{24}$$

5.3. Energy labels for windows

There are several examples of Energy Label and Classification in the world market. We made a previous research to have a reference for the door label. Here we show a summary.

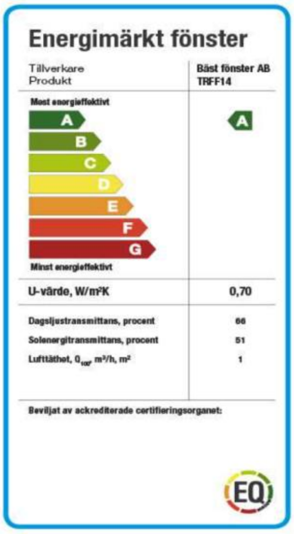
The following national labels where analyzed:

- *Energimärkta EQ-Fönster* (Sweden)
- *British Fenestration Rating Council,* BFRC (UK)
- *Institut für Fenstertechnik Rosenheim,* IFT (Germany)
- *Eficiencia Energética de la Ventana*, ASEFAVE (Spain)
- *Etiquette Energie Menuiserie,* E2MF (France)
- *Sistema de Etiquetagem Energética de Productos*, SEEP (Portugal)
- *Associazione per la tutela della finestra Made in Italy,* ANFIT (Italia)
- *Asiantuntija energian ja materiaalien tehokkaassa käytössä,* MOTIVA (Finland)
- *Schweizerische Zentrale Fenster und Fassaden*, SZFF, and *Schweizerischer Fachverband Fenster- und Fassadenbranche*, FFF (Switzerland)
- *National Fenestration Rating Council*, NFRC (USA)
- *Window Energy Rating Scheme*, WERS (Australia)

There are other labels in Canada (Energy Star) and New Zealand, similar to those of USA and Australia, respectively. Also in Europe there are other experiences.

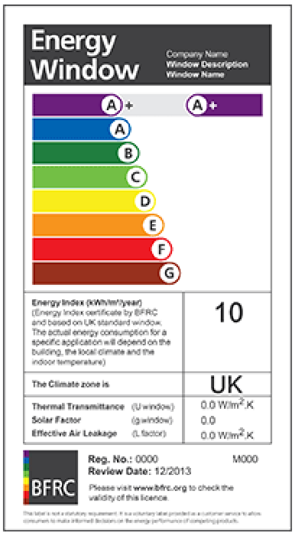
There have been proposals for European labels, for example *Danmarks Tekniske Universitet*, DTU (Denmark). Other institutions and organizations like *Aristotle University of Thessaloniki* (Greece) or *Glass for Europe* have also made statements about a European energy label for windows.

<u>1.- EQ Fönster (Sweden)</u>



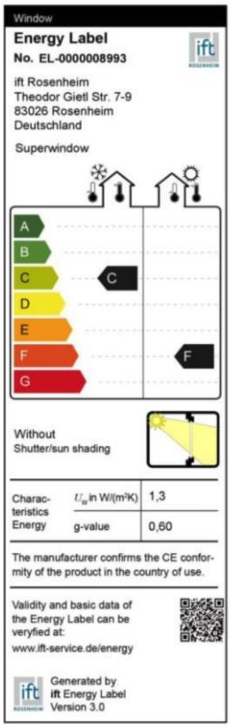
- The classification describes the energetic behaviour of a selected combination of frame, glass and sun protection.
- Energy calculation based on its own method.
- No separate classification for winter and summer.
- No global factor for energy efficiency
- Parameters in the label:
    - Thermal transmittance of the whole window
    - Air permeability
    - Solar Factor
    - Visible transmittance factor
- There is no climate area classification.
- Classification A, B, C… is just made according to reference maximum values of thermal transmittance U and air permeability L, so no normalization is required.

2.-BFRC (United Kingdom)



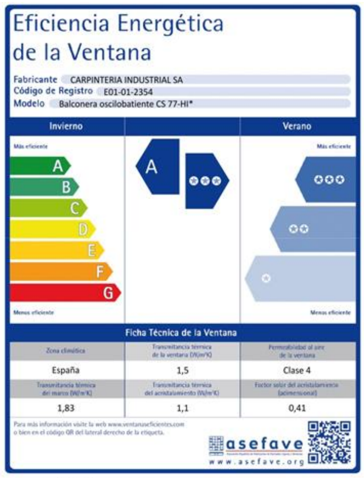
- The classification describes the energetic behaviour of a selected combination of frame and glass. No sun protection included in the label.
- Energy calculation based on its own method.
- No separate classification for winter and summer.
- Global factor for energy efficiency in terms of energy rating in [kWh/m2.year].
- Parameters in the label:
  - Thermal transmittance of the whole window
  - Air permeability
  - Solar Factor
- There is a climate area classification.
- Normalization made with reference room and reference window.

3.-IFT (Germany)



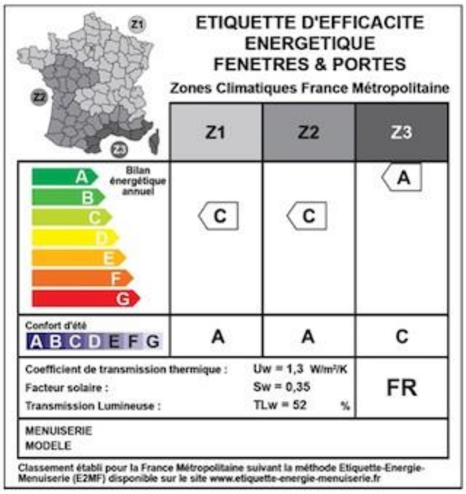
- The classification describes the energetic behaviour of a selected combination of frame, glass and sun protection (shading devices).
- Energy calculation based on ISO 18292.
- Separate classification for winter (heating season) and summer (cooling season) performance.
- Global factor of energy performance in terms of EP (heating and cooling) as per ISO 18292 (energy need for heating and cooling divided by area of the window) in [kWh/m2].
- Also included visual transmittance in terms of DP (daylight potential supply, winter and summer).
- Parameters used for calculations included in the label:
  - Air permeability class
  - Thermal transmittance of the whole window
  - Solar factor
  - Solar factor with solar shading
- Normalization made considering a reference room and reference window with reference climate conditions, so there is no climate classification.
- Classification A, B, C… reference values are based on up to 12 window designs of marketable products from all over Europe.

4.-ASEFAVE (Spain)



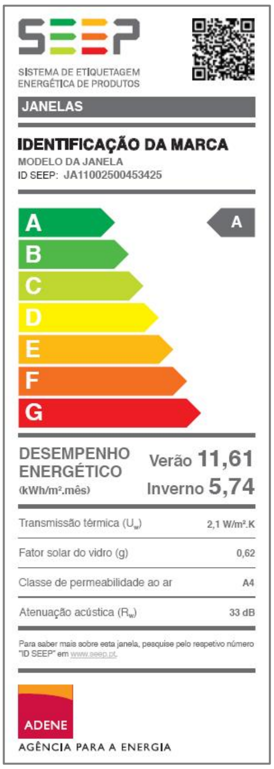
- The classification describes the energetic behaviour of a selected combination of frame and glass. No sun protection included in the label.
- Energy calculation based on its own method.
- There is a separate classification for winter and summer. In this case, in winter the classification is A, B, C, D, E, F, G and in summer there are only three classes: *, **, ***.
- No explicit global factor for energy consumption or efficiency.
- Parameters in the label:
  - Thermal transmittance of the whole window
  - Thermal transmittance of the glass
  - Thermal transmittance of the frame
  - Air permeability class
  - Solar Factor
- There is a climate area classification.
- Normalization made with reference room and reference window.

5.- UFME-CSFVP (France)



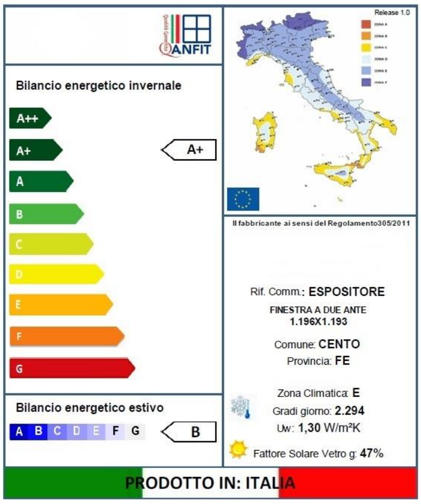
- The classification describes the energetic behaviour of a selected combination of frame, glass and sun protection.
- Energy calculation based on its own method.
- There is a separate classification for winter and summer.
- No explicit global factor for energy consumption or efficiency.
- Parameters in the label:
  - Thermal transmittance of the whole window
  - Solar Factor
  - Visible transmittance factor
- Air permeability is not considered.
- There is a climate classification in three areas. The A, B, C… classification is included in the label for all the areas.
- Normalization is made with a reference window. A, B, C… classification is made in relation with this reference value.

6.-SEEP (Portugal)



- The classification describes the energetic behaviour of a selected combination of frame and glass. No sun protection included in the label.
- Energy calculation based on ISO 18292.
- No separate classification for winter and summer.
- Global factor for energy efficiency in terms of [kWh/m2.month] , calculated both for summer and winter (although there is only one classification).
- Parameters in the label:
  - Thermal transmittance of the whole window
  - Air permeability class
  - Solar Factor
- Acoustic performance also included.
- Normalization made considering a reference room and reference window with reference climate conditions, so there is no climate classification.

7.-ANFIT (Italy)

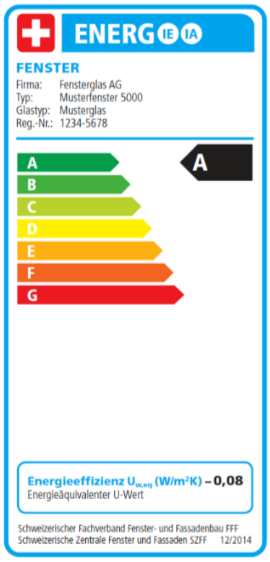


- The classification describes the energetic behaviour of a selected combination of frame and glass. No sun protection included in the label.
- Energy calculation based on its own method.
- There is a separate classification for winter and summer.
- No explicit global factor for energy consumption or efficiency.
- Parameters in the label:
  - Thermal transmittance of the whole window
  - Solar Factor
- Air permeability is not considered.
- There is a climate classification in six areas, with an indication of “degrees per day”.

8.-Motiva (Finland)

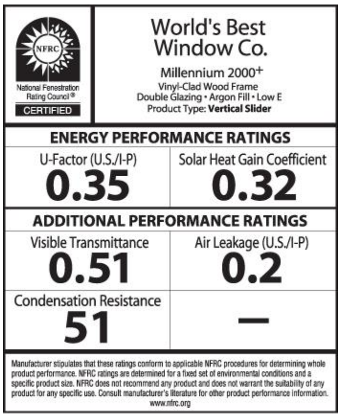
- The classification describes the energetic behaviour of a selected combination of frame and glass. No sun protection included in the label.
- Energy calculation based on its own method.
- No separate classification for winter and summer.
- Global factor for energy efficiency in terms of [kWh/m2.month]
- Parameters used for calculations included in the label:
    - o Thermal transmittance of the whole window
    - o Air permeability
    - o Solar factor
- Air permeability is not considered.
- No climate classification.

9.-FFF-SZFF (Switzerland)



- The classification describes the energetic behaviour of a selected combination of frame and glass. No sun protection included in the label.
- Energy calculation based on its own method.
- No separate classification for winter and summer.
- No global factor for energy efficiency.
- Energy performance summarized in “equivalent” thermal transmittance that takes into account:
    - o Thermal transmittance of the whole window
    - o Solar effect
- No climate classification.

10.-NFRC (USA)



- There is no A, B, C… classification in the label as we do in Europe.
- No global energy calculation.
- No separate classification for winter and summer.
- All parameters are expressed in ratings.
- It shows two energy performance ratings:
  - Thermal transmittance factor
  - Solar gain factor
- It shows also three possible additional performance ratings (not mandatory):
  - Visible transmittance factor (daylight potential)
  - Air leakage factor
  - Condensation resistance
- No normalization required for climate, building or window, as no classification is made.

11.-WERS (Australia)

- The classification describes the energetic behaviour of a selected combination of frame, glass and sun protection.
- Energy calculation based on its own method.
- There is a separate classification for winter and summer, made with stars. 1 star is the worst, 5 stars is the best.
- No explicit global factor for energy consumption or efficiency, no explicit parameters neither.
- Parameters used for calculation:
  - Thermal transmittance of the whole window
  - Air permeability
  - Solar gain factor
  - Visible transmittance factor (daylight potential)
- There is a climate area classification.
- Normalization made with reference room and reference window.

12.-DTU (Denmark)

- Only energy calculation scheme, no proposal for label design.
- Energy calculation based on ISO 18292.
- Separate calculation for winter and summer.
- Global factor of energy performance in [kWh/m2].
- Parameters used for calculation:
  - Thermal transmittance
  - Solar gain

- Air permeability is not considered.
- Daylight potential as per ISO 18292.
- There is a simple climate area classification, dividing Europe in three areas.
- Normalization made with two reference houses and reference windows.

We summarize the main characteristics of the different labels in the following table:

	SE	***UK***	***DE***	***ES***	***FR***	***PT***	***IT***	***FIN***	***CH***	***USA***	***AUS***	***DK***
Calculation according ISO 18292	NO	NO	YES	NO	NO	YES	NO	NO	NO	NO	NO	YES
Seasonal Classification	NO	NO	YES	YES	YES	NO	YES	NO	NO	NO	YES	YES
Climate areas	NO	YES	YES	YES	YES	NO	YES	NO	NO	NO	YES	YES
Reference building/window	NO	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES	YES
Global energy performance	NO	YES	YES	NO	NO	YES	NO	YES	NO	NO	NO	YES
Thermal transmittance	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES
Air permeability	YES	YES	YES	YES	NO	YES	NO	YES	NO	YES	NO	NO
Solar gain	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES
Visual transmittance	YES	NO	YES	NO	YES	NO	NO	NO	NO	YES	NO	YES

About the Author

Miguel Pérez has a wide experience in research and development in the industrial goods sector. He was Technical Director of *Manusa Automatic Doors* from 2009 to 2013, being its representative in EDSF in that period. Before he carried out the roles of Technical Director of the company *Simon Connect* and Head of Mechanical Engineering of *Knorr-Bremse* in Spain. He is author of several patents in different fields including automatic doors, and speaker in various seminars in building equipment and transportation technology. His main academic degrees are *Dottore in Ingegneria Meccanica* (*Politecnico di Milano*) and *Ingeniero Industrial (Universidad Politécnica de Madrid).* Currently he is founder and partner of the engineering and consultancy company *Mequonic*.

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