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Smart Façades: Declination with the Electrochromic Glass

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Energy saving and environmental protection don't represent only a technical problem but also, and maybe most of all, an ethical problem. From this point of view, the Mediterranean area, characterized by a considerable Sunshine for at least 8 months a year, is configured as particularly suitable for the use of all building systems that can reach the objectives provided by the latest global climate conferences. The architectural heritage of the Mediterranean area is various both in typological terms and in relation to building materials used. If you want to find materials and components common to the area certainly the windows, and exacting the glazing linked to them, represent a very significant element that can considerably contribute to energy savings. Our group is concerned, since 2009, to test the behaviour, in the energy field, of electrochromic glass. The phases of the studies, presented at many conferences, have already demonstrated efficiency in terms of savings that can be achieved by envelopes integrated with the EC. The testing, conducted on full scale models, was divided into three steps temporally sequential. We built two identical test rooms each other for exposure, size (4x4x2.70 m) and of the envelope composition. Traditional low-emission panels were put in place in the first room, the EC glass were placed in the second one. Measuring tools were positioned in the test rooms, to detect the most important internal thermo physical parameters. This study is divided in three steps, according to a façade configuration with glass surfaces gradually increasing. The research compares internal conditions, detected during the three phases, and it clarifies the relationships between façade configuration and both inside and outside circumstances.

Keywords: Glass, Electrochromic, Energy-saving, Mediterranean

1. Introduction

Global performance of the building envelopes can considerably help, to solve susteinability and energy saving question. All construction components have to take part in the reaching of the prefixed goals. It's therefore necessary to find materials and systems that, integrate with one another, allowed to improve that performance. Losses, due to only windows, are extremily variable and connected to the features such as: materials of frame and panels, typlogy and building system used, orientation, location and so on. In any case it's determined a very significant average value to ascribe to the portion these elements have in the losses calculation. Interesting innovations are found in the combination frame-pane, mostly related to the new generation glass evolution, that have now achieved high performance. Active dynamic glass, among all, combine optical features with the use flexibility, due to the possibility to manage the system by the customer. The smart façade design needs a careful choice of all elements and technical variables. Electrochromic glass, if integrated to domotic and photovoltaic systems, can play an important role, not only in the sustainabilty field but also, more generally, in terms of a higher housing wellbeing.

2. Electrochromic Glazing

The legend tells that Alexander "The Great" already used tungsten oxides on his soldiers' armour, so that the magical colour change terryfied enemy before battle. The history tells that at the begininng of '700, the painter and passionate about phisics, discovered changing properties of Prussian blue. It's necessary to go to the beginning of the '90 of last century, to have the first application, on a large scale, of electrochromic materials in aerospace, aeronautical (Aerospace Dornier®) and automotive (Toyota®) field. Several glass industries, in the same years, carried out test in the building sector. The Asahi Glass®, Pilkington® and Saint Gobain® company, mostly were able to use chromogenic glazings in existing buildings; all these undertakings remained however to the phase of demonstration prototype. In the USA, the research, about the possibility to produce and to commercialize EC glass, are been developed by Sage Electrochromics®, founded in the 1989. It's now able to distribute regularly the electrochromic porducts in the US market. At present the enterprise is fully controlled by Saint Gobain® company, while maintaining the brand of products, so that to promote them in the European market too. Data of our research refer to the features developed by the aforementioned enterprise, based in Faribault (Minnesota, USA), because they were the only ones available to the start of the experimentation. Some other European enterprise has recently started EC production and commercialization too: these new entry competitors will encourage production and spreading ot the electrochromic technology.

An EC pane (IGU – Insulating Glass Unit), is composed by: an external tempered glass sheet (6mm thick), on the inner surface of which the electrochromic is applied, an hollow space with Argon (12,7mm thick) and an inner laminate or tempered sheet (6mm thick), the pane is completed by a sealing and a perimetral stainless steel spacer. The five layers that make up the electrochromic film, are laid, exploiting nanotechnology, in sequence by a similar method to that used to produce Low E glass. The coatings are applied using sputter deposition following this sequence: the transparent conductor (TC) layers form a sandwich around the electrochromic (EC) layer, the ion conductor (IC) and the counter electrode (CE). Applying a positive voltage to the TC in contact with the CE causes lithium ions to be driven across the IC and inserted into the EC layer, while a charge compensating electron is extracted from the CE, flows around the external circuit, and is inserted into the EC layer. The process is obviously reversible. The layers of coatings on glass, in total are less than 1/50th the thickness of a human hair.

The power consumption, to the activation, is 2.8 W/m² and 1 W/m² for running; an EC glazing, 150m² sized, has a daily consumption equal to that of a light bulb of 60W. all panes must be connected to the control system, consisting of a prgrammable control unit, according to a time table or other parameters, such as the threshold of solar radiation or temperature. In early models, the running adjustment was possible in only two steps: 0%-100%, i.e. fully clear, state OFF and fully tinted, state ON. Pane maximum size was 101x1524mm, the time occurred from the fully clear state to the fully tinted state, related to the outside conditions and pane dimension, can vary from about 3' to 10'. Color options in blue, widespread, green and brown are at present available. Tests demonstrated a reliability up to 100.000 running hours, the warranty certifies 50.000 hours (NREL Test E-2141). Pane weight is about 28kg/m², the power is the normal home network.

A triple EC pane is, at present, under production with slightly higher features than the double pane, but with higher IGU thickness too. The pane composition has been recently modified and it includes an external laminate sheet, a cavity 12,2mm thick and an inner tempereted glass sheet, in total about 25mm thick. The external laminate sheet is composed of more layers, which the outside are: a Heat-Strengthened – HS sheet 4mm thick, that can be also coloured, a ionoplast interlayer 0,9mm thick, a clear Annealed - AN 2,2mm thick, on the inner surface of which the electrochromic layers are laied, the inner layer is a Heat-Strengthened – HS sheet 6mm thick. The current maximum IGU size is 1500x3050mm. The related control system uses a software that allows to schedule each pane in according to the choiced parameters, the running adjustment is now possible in four steps: 0%, fully clear, intermediate 1, intermediate 2 and 100%, fully tinted. The ability of individual setting enables to have different configurations of the façades and the envelope, thanks to the pane setting variables, trough which it's possible to optimize the selective management of the incoming solar radiation and the visible one.

3. Test Rooms

The experimentation has been carried out into two test rooms, constructed on the flat roof of the building, that houses the Civil, Environmental Engineering and Architecture of the University of Cagliari. Into these rooms, EC pane performance are compared to those of the Low-E glass at present on the market. The construction was completed within five months (2011 July-November) thanks to the help of some local entrepeneurs. Test rooms are identical in size (outside 4,00x4,00x3,00m, inner 3,60x3,60x2,70m), building system, orientation and windows size and position. The floor area is 12,96 m^2 and the each external wall surface is 12,00 m^2 , the gross volume is 48,00 m^3 the inner one 35,00 m^3. Each room has tools to collect environmental internal parameters and to detect them. An extrnal control unit collects the weather daily conditions. Measurements began in December 2001 and since then they go on up to now, discontinued only for short periods to verify tools and to modify façades.

In the first configuration, total windows surface complies with the minimum ratios required by the local Building Regulations. South – East façade, in which the main door is, didn't change during the whole of the experimentation, instead South – West façade, that houses windows, gradually changed to place growing glazing surfaces. The balloon frame building system (A energy class) has been choiced for logistic reasons and most of all to easily realize with dry machining, different configurations of the windows such as to allow a fast up-grade of the façade.

The basement rooms is raised on wooden beams and it's formed by a thin concrete slab (50mm). The walls are composed by wooden frame and an envelope made by different layers, from the inside: OSB panel (2,5mm), rock wool mat (180mm), OSB panel (2,5mm), polystyrene panel (50mm), insulating plaster (3mm). the roof is flat, slightly tilted, waterproofed with slated adhesive sheath. All windows frames are by painted thermal break aluminum. The average transmittance of every buiding component complies the value required by Italian Law concerning the C classified areas: walls 0.17 [W/m^2K], flat roof 0.26 [W/m^2K], floor 0.36 [W/m^2K].

The tools, placed in each room, are able to measure the internal dry and wet bulb temperature, humidity and the global incoming solar radiation. Sensors can work in a range of -20°C and +80°C with an accuracy of ± 0.30°C about the temperature, a range of 5% - 98% with an accuracy of ± 2% for the humidity. The pyranometer measures the incoming solar radiation in a range of 0 and 20.000 μW/cm² with an accuracy of 10 μW/cm².

Fig. 1 Building phases and aerial view of the test rooms (July – November 2011).

a) b) c)

Fig. 2a), b) and c): Step 1 (December 2011- April 2015), Step 2 (May – June 2015), Step 3 (since July 2015).

4. Step 1 vs. Step 2

The Step 1 (unchanged since December 2011 till April 2015) has a glazing surface of [(0,711x1,186) + (1,454x0,972)]= 2,25m², this surface represents the 17% of the floor surface. The wall, facing South-West (involved by change) has a glazing surface equal to the 12% of the whole wall surface. The period in question, in this case, is between May and June 2013. In the month of May, the average extreme temperatures were: 8,13°C on 25th the minimum, 28,64°C on 10th the maximum. In the month of June: 13,25°C on 5th the minimum, 32,74°C on 18th the maximum. The Step 2 (realized from May to June 2015) has a glazing surface of [(0,711x1,186) + (1,454x0,972) +2x(0,63x0,972)]= 3,47m², this surface represents the 27% of the floor surface. The wall, facing South-West (involved by change) has a glazing surface equal to the 22% of the whole wall surface. The period in question, in this case, is between May and June 2015. In the month of May, the average extreme temperatures were: 9,81°C on 1st the minimum, 33,03°C on 14th the maximum. In the month of June: 14,47°C on 1st the minimum, 34,33°C on 28th the maximum. The glazing surface increase of the South-West wall, in the passage from Step 1 (1,41m²) to Step 2 (2,63m²), is of 86%.

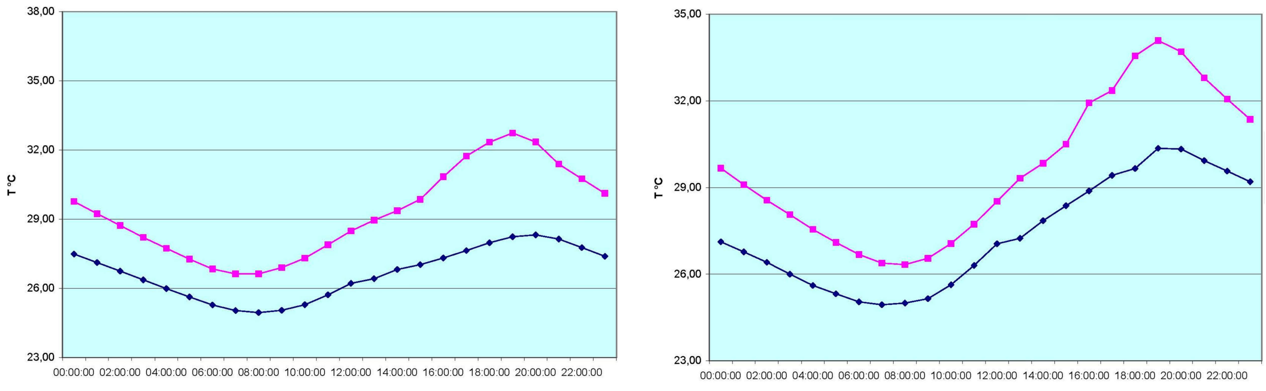
The average temperatures detected in the EC and Low-E room, in the abovementioned days, are displayed in the Table 1 below, with the monthly average.

Table 1: Comparison Step 1 to Step 2 in the days in which the lowest and the highest averages were during the period in question.

Date / Period	Step	Glass Surf. [m²]	Ext Temp. [°C]	Room EC Temp. [°C]	Room LE Temp. [°C]	DT (EC – LE) [°C]
2013.05.25th	1	2,25	8,13	17,44	19,27	- 1,83
2013.05.10th	1	2,25	28,64	23,68	26,20	- 2,52
May 2013 average	1	2,25	17,90	20,00	22,14	- 2,14
2013.06.05th	1	2,25	13,25	21,50	23,86	- 2,36
2013.06.18th	1	2,25	32,74	28,28	30,43	- 2,15
June 2013 average	1	2,25	21,40	24,13	26,40	- 2,27
2015.05.01st	2	3,47	9,81	20,52	23,45	- 2,93
2015.05.14th	2	3,47	33,03	26,72	29,34	- 2,62
May 2015 average	2	3,47	19,48	23,25	25,53	- 2,28
2015.06.01st	2	3,47	14,47	24,54	26,76	- 2,22
2015.06.28th	2	3,47	34,33	29,40	31,57	- 2,17
June 2015 average	2	3,47	23,33	27,16	29,61	- 2,45

Data, shown above, are elaborated in according with the daily averages. In the Step 1, in the two months, the external average temperature was 19,65°C, in the EC and Low-E room, the average temperature, in the two month, were respectively 22,06°C and 24,27°C, with a ΔT (EC – LE) = - 2,21°C. In the Step 2, in the same period, the external average temperature was 21,40°C, in the EC and Low-E room, the average temperature, in the two month, were respectively 25,20°C and 27,57°C, with a ΔT (EC – LE) = - 2,37°C. Then, in the passage from Step 1 to Step 2, the average difference of the temperature, in the two rooms, had an increase of 0,16°C.

Measurements collected (every 15') really allow to have a very accurate control of the inner rooms condition. For example the internal temperatures are shown in two peculiar days: 2013 June 21st for the Step 1 and 2015 June 23rd for the Step 2. in these days. Very similar weather conditions were detected in these days, such as to make very significant the comparison between two phases. Especially the day 2013.06.21st in which we detected the following values: 23,13°C, 18,62°C, 28,37°C, 73%, respectively of the average, minimum, maximum temperature and relative humidity. The day 2015.06.23rd, for the same parameters we detected the following values: 23,25°C,19,15°C, 28,72°C, 71%. In the Figure 3, graphs of EC and Low-E room inner temperature, recorded in the above two days, are shown.



a) b)

Fig. 3a), and b) Internal temperatures detected in the 2013.06.21th (Step 1) and in the 2015.06.23th (Step 2). Magenta LE, Blue EC.

Graphs of the two days are similar but non-parallel and tend to diverge with the increase of temperature. In the Step 1, in the day 2013.06.21st, the minimum difference temperature was detected at 7.00 a.m. (1,59°C), from that time onwards, the ΔT has been growing until to reach the maximum peak at 7.00 p.m. (4,60°C), and then it continued to decrease: at 11.00 p.m. the ΔT was 2,73°C. The inner temperature detected at 7.00 p.m. in the EC and Low-E room was respectively 28,14°C and 32,74°C. In the Step 2, in the day 2015.06.23rd, the minimum difference temperature was detected at 8.00 a.m. (1,33°C), from that time onwards, the ΔT has been growing until to reach the maximum peak at 6.00 p.m. (3,92°C), and then it continued to decrease: at 11.00 p.m. the ΔT was 2,14°C. The inner temperature detected at 6.00 p.m. in the EC and Low-E room was respectively 29,64°C and 33,56°C.

5. Step 1 vs. Step 3

The Step 1 has ever a glazing surface of [(0,711x1,186) + (1,454x0,972)]= 2,25m², this surface represents the 17% of the floor surface. The wall, facing South-West (involved by change)) has a glazing surface equal to the 12% of the whole wall surface. The period in question, in this case, is between July and August 2013. In the month of July, the average extreme temperatures were: 15,24°C on 2nd the minimum, 38,14°C on 29th the maximum. In the month of August: 18,36°C on 15th the minimum, 36,67°C on 8th the maximum. The Step 3 (realized from July 2015) has a glazing surface of [(0,711x1,186) + 2x(1,454x0,972) + 4x(0,63x0,972)] = 6,12m², this surface represents the 47% of the floor surface. The wall, facing South-West (involved by change) has a glazing surface equal to the 44% of the whole wall surface. The period in question, in this case, is between July and August 2015. In the month of July, the average extreme temperatures were: 20,04°C on 27th the minimum, 37,27°C on 29th the maximum. In the month of August: 18,41°C on 21st the minimum, 36,57°C on 2nd the maximum. The glazing surface increase of the South-West wall, in the passage from Step 1 (1,41m²) to Step 3 (5,28m²), is of 274%.

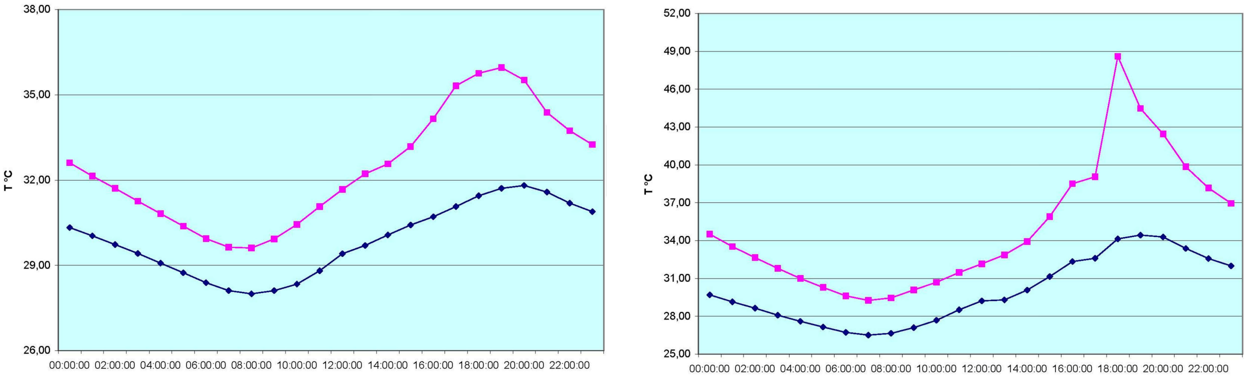
The average temperatures detected in the EC and Low-E room, in the abovementioned days, are displayed in the Table 2 below, with the monthly average.

Table 2: Comparison Step 1 to Step 3 in the days in which the lowest and the highest averages were during the period in question.

Date / Period	Step	Glass Surf. [m²]	Ext. Temp. [°C]	EC . room Temp. [°C]	LE room Temp. [°C]	DT (EC – LE) [°C]
2013.07.02nd	1	2,25	15,24	25,43	28,05	- 2,62
2013.07.29th	1	2,25	38,14	31,74	34,07	- 2,33
July 2013 average	1	2,25	25,70	28,87	31,23	- 2,36
2013.08.15th	1	2,25	18,36	29,02	31,06	- 2,04
2013.08.08th	1	2,25	36,67	32,75	35,14	- 2,39
August 2013 average	1	2,25	25,80	29,18	32,11	- 2,93
2015.07.27th	3	6,12	20,04	29,78	34,56	- 4,78
2015.07.29th	3	6,12	37,27	30,74	35,67	- 4,93
July 2015 average	3	6,12	27,61	31,36	34,15	- 2,79
2015.08.21st	3	6,12	18,41	28,49	33,97	- 5,48
2015.08.02nd	3	6,12	36,57	32,59	36,39	- 3,80
August 2015 average	3	6,12	26,48	30,94	35,68	- 4,74

Data, shown above, are elaborated in according with the daily averages. In the Step 1, in the two months, the external average temperature was 25,75°C, in the EC and Low-E room, the average temperature, in the two month, were respectively 29,02°C and 31,67°C, with a ΔT (EC – LE) = - 2,65°C. In the Step 3, in the same period, the external average temperature was 27,04°C, in the EC and Low-E room, the average temperature, in the two month, were respectively 31,15°C and 34,92°C, with a ΔT (EC – LE) = - 3,77°C. Then, in the passage from Step 1 to Step 3, the average difference of the temperature, in the two rooms, had an increase of 1,12°C.

As in the previous case, the internal temperatures are shown in two peculiar days: 2013 July 25th for the Step 1 and 2015 July 27th for the Step 3 in these days. Very similar weather conditions were detected in these days, such as to make very significant the comparison between two phases. Especially the day 2015.07.25th in which we detected the following values: 27,33°C, 20,19°C, 33,76°C, 64%, respectively of the average, minimum, maximum temperature and relative humidity. The day 2015.07.27th, for the same parameters we detected the following values: 27,14 °C, 20,45°C, 34,03°C, 63%. In the Figure 4, graphs of EC and Low-E room inner temperature, recorded in the above two days, are shown.



a) b)

Fig. 4a) and b) Internal temperatures detected in the 2013.07.25th (Step 1) and in the2015.07.27th (Step 3). Magenta LE, Blue EC.

Graphs of the two days are similar but non-parallel and tend to diverge with the increase of temperature. In the Step 1, in the day 2013.07.25th, the minimum difference temperature was detected at 6.00 a.m. (0,85°C), from that time onwards, the ΔT has been growing until to reach the maximum peak at 6.00 p.m. (4,31°C), and then it continued to decrease: at 11.00 p.m. the ΔT was 2,36°C. The inner temperature detected at 6.00 p.m. in the EC and Low-E room was respectively 31,45°C and 35,76°C. In the Step 2, in the day 2015.07.27th, the minimum difference temperature was detected at 7.00 a.m. (2,75°C), from that time onwards, the ΔT has been growing until to reach the maximum peak at 6.00 p.m. (14,47°C), and then it continued to decrease: at 11.00 p.m. he ΔT was 4,96°C. The inner temperature detected at 6.00 p.m. in the EC and Low-E room was respectively 34,14°C and 48,61°C.

During the Step 3, data detected on 2015 July 29th, the hottest day of the year, are much more significant. In this day, the external average, minimum and maximum temperature was respectively: 29,47°C, 22,48°C and 37,65°C. the minimum ΔT temperature was recorded at 7 a.m. (2,65°C), from then on, the ΔT has been growing until to reach the maximum peak at 6.00 p.m. (14,23°C), and then it continued to decrease: at 11.00 p.m. he ΔT was 5,07°C. The inner temperature detected at 6.00 p.m. in the EC and Low-E room was respectively 35,68°C and 49,91°C. The Figure 5 shows the daily graphs of the temperature.

The Figure 6 shows the incoming solar radiation trend [μW/cm²], for the same above day. The trend, on a qualitative level, is very similar to that one detected throughout the experimentation. The value, in the EC room especially, falls within a range between 0 μW/cm² and 452 μW/cm² (detected at 11.30 a.m. when, in the LE room, the value was 765 μW/cm²). in the LE room the range is between 0 μW/cm² and 12˙030 μW/cm² (detected at 6.30 p.m. when, in the EC room, the value was 321 μW/cm²).

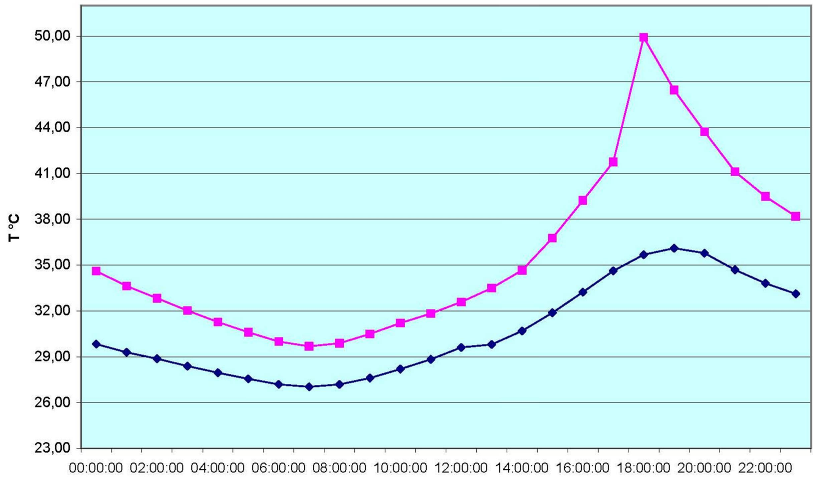


Fig. 5 Internal temperature detected in the 2015.07.29th (Step 3). Magenta LE, Blue EC.

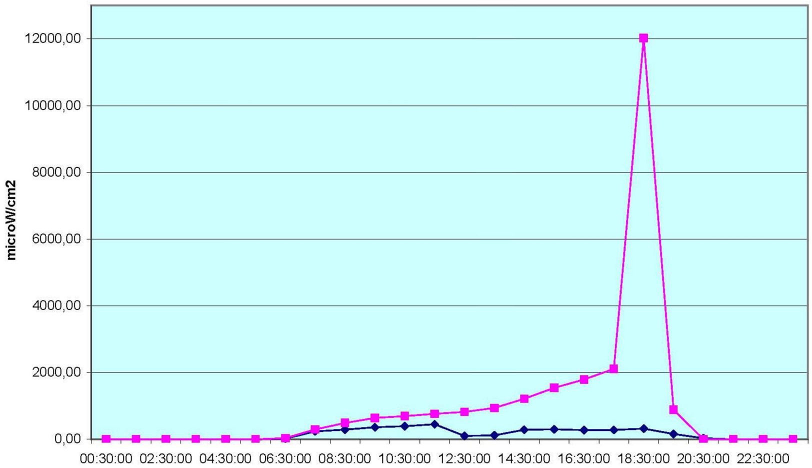


Fig. 6 Incoming global solar radiation, detected in the 2015.07.29th (Step 3). Magenta LE, Blue EC.

6. Summary and the experimentation's analysis

In the two test rooms, the windows' configuration in the façades facing North-West, North East and South-East (where there is a glazing door sized: 0,711x1,186=0.84m²) has been unchanged troughout the research. Then we consider, for our pouposes, the contribute of the above façades is the same in the different steps, and they influence evenly the conditions of two rooms. The variation of the internal parameters, detected troughout three phases, are only or mainly due to the modifications made to the walls facing South-West. This fact allows to take up the results obtained and to define the contribute which can be ascribed to the EC performance and to the Low-E ones, actually on market. If we consider the whole envelope, the phase-displacement has a low value, due the very low value of the mass, but it affects in the same way too. So the study assesses, being equal all other conditions, just the contribute due to the glass.

It highlights, from data collected during the comparison between Step 1 and Step 2, that, for limited glazing surface (respectively 1,41 m² and 2,63m²) and for low ratio (under 0,5) between glass surface and mat surface, even if the increase is, in absolute terms, very high (86%), the internal temperature doesn't show sensible positive effects of this condition. The average ΔT, indeed, between two steps is only 0,16°C. It's important to note that, in the period in question, it has been an increase of the external temperature of almost 2°C.

In the comparison between Step 1 and Step 3, the increase of glazing surface has really been significant (respectively 1,41 m² and 5,28m²) with a rise of 274%. In this case the ΔT is 1,13°C (let's remember that the inner volume of the rooms is 35m$^{3)}$. It's important to note that, in this period too, it has been an increase of the external temperature of almost 2°C. The most significant and encouraging insights of the research come from detected data in the days very similar about weather conditions (2103 July 25th and 2015 July27th). In these days, effectively compared, the ΔT, between two rooms, achieved the peak value of 4,31°C in the Step 1, and well surprisingly the value of 14,47°C in the Step 3.

The general trend, detected during the Step 3, is moreover confirmed by data concerning the temperature and the incoming solar radiation in the hottest day of 2015 (July 29th). In this day the maximum ΔT, in the two rooms, was 14,23°C, with peaks of 35,68°C (EC room) and 49,91°C (LE room). About the solar radiation, in the same day, the maximum peak was 452 µW/cm² in the EC room and 12˙030 µW/cm² in the LE room. These results confirm the regularizing action of the electrochromic glass, which allow to stem a lot of glare phenomena and, at the same time, make possible a good preservation of materials and all furnishing by the fading. From this point of view, however, it is necessary to evaluate carefully the states On and Off of the EC glass also in the winter period, when only for those energy aspects an always Off configuration would be appropriate, because the incoming solar radiation is, in this case, a gain. In fact, despite the winter season is characterized by minimum values of radiation, one can not overlook the action of decay of the color on the inner surfaces exposed to sunlight. It's important, then, to consider the protection, provided by EC shielding, to the interior materials and elements. The problem is particularly felt in museums, libraries and even more monumental historic buildings, where the action of sunlight often causes irreparable damage to the decorations or wall finishes: thinking of the frescoes, the wood paneling or tapestries and so on. The possibility of being able to graduate the color intensity on two intermediate levels, depending on the need, also allows to refine the EC glass performance, so as to guarantee, at the same time, a sufficient solar gain and the reduction of fading. To this end their activation should always be managed by a home domotic system, automatic or manual, which optimizes the operation.

7. Conclusion

Concluding, as hoped, the use of the electrochromic technology points out her best performance in relation, over to the envelope materials, mostly to the façade configuration. When the glazing surface is very pedominant, as often happened in the contemporary architecture, Ec glass features allow to obtain a better internal comfort and they need lower power installations. For the energy saving pourposes, it's very interesting, and with a wide chance of works, the energy requalification of the countless glass buidings, dating back to the 70s and 80s. An other field of using is the upgrade of the historical buildings dating back to the first decades of the XX century. The historic buildings of great architectural value, in fact, are characterized by systems and building components that are themselves peculiar elements to be preserved and which can not be changed substantially. With a view to an efficient re-use of this building heritage, especially in the European context, the application of electrochromic glazing, seems to be the most light solution, even the terms of cost / benefit ratio, for an efficient energy achievement, no more postponed.

Will ultimately, in the light of this experimentation, we can make predictions on the evolution of future building envelopes. The building becomes an organism almost totally autonomous from the energy point of view. The construction will be seen as the product of two main components: the opaque and the transparent, wherein the latter may, to specifically, act by "smart" skin constitutive of buildings. The large windows will be designed within an integrated system, involving the increasingly widespread photovoltaic technology, with reference to the BIPV (Building Integrated Photovoltaic), which allows to obtain electric power from solar radiation. In this perspective, the glass element is designed as a complex building-component, included into the envelope system. Its use will also offer designers a wide range of choices both from the aesthetic and technical point of view, able to attribute an added architectural value to the edifice. Its composition will work synergistically applying the electrochromic film, acting as a shield to save energy, and the application of thin film photovoltaic, aimed at producing energy needed to run the building organism. The industry, therefore, will have to orientate on specialized glazing panes, already fitted in the production phase, including the assembly of both films EC and PV (possibly colourless), and a wiring easily achievable, especially on metal frames. The EC-PV integrated element will get a wide application, particularly in building typologies on prevalent vertical development, with limited roof surfaces and in those in which the system of roofs doesn't allow or makes problematic and overly burdensome the installation of ordinary PV panes.

The building, well it designed will, effectively, adapt to the requirements of energy efficiency and sustainable architecture, projecting us towards a future technology and environmentally conscious.

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