Electrochromic glass: testing in the Mediterranean area

Gianraffaele Loddo*

Highlights

The main aims of the experimentation were: to compare the energetic behaviour between the Electrochromic glass (EC) and Low Emissive glass (Low-e); then to evaluate the benefits due using EC. This project has been possible increasing, at every step of the research, the window surface. The principal result of the experimentation allows to assess that the Electrochromic glass is able to considerably shield the solar radiation, and to greatly let down the peaks of internal temperature. From this major outcome arise several positive effects like energy saving and lower CO2 emissions.

Abstract

The Electrochromic glass is able to change its optical features on command and to modify the level of shielding of the light and solar incoming radiation. The research is focused in two wide thematic fields: the comparison of the performance of the EC and the Low-e; the evaluation of the contribution by the EC to the energy saving, using more increasing window surface in relation to the blind components of the envelope. Data collected allow to extrapolate interesting element of debate about the design of the building envelope, with a particular reference to the areas where sunshine is intense and prolonged.

Keywords

Energy saving, Mediterranean Area, Building envelope, Electrochromic glass, Test

1. INTRODUCTION

The overall performance of the building envelopes can contribute in a sensible way to the solution of the questions related to the sustainability and the energy saving. All components must contribute to reach the fixed goals. We must find out materials and integrated systems to enhance this performance. The losses are extremely variable in relation to the features of the windows such as: typologies and building system, orientation, location etc. Anyway is confirmed a consistent average value assignable to these components in the calculation of losses.

In the frame-panel system has been found great importance innovations concerning the evolution of the new glass generation. The active dynamic glass, specifically the EC pane, puts together the optical performance and an interesting flexibility in use due to the possibility to manage by the customer.
2. THE SPECIAL AND INNOVATIVE GLASS

The glass was, for centuries, one of the most used materials both in architecture and several fields. It has remained virtually unchanged over time, especially in the building sector, and used as an ordinary panelling of the windows or for the production of the stained glass. Only the architecture of the large greenhouses of the mid-nineteenth century and some proposals of some principal representatives of the Modern Movement have conferred the glass a new structural function and increased its expressive characters. In any case it was a product that, apart from the transparency, did not possess relevant physics and energy performance. Its use was indeed particularly problematic, especially in the warmer regions, because of the internal over warming due to high irradiation. The real evolution took place only in the last decades. It allowed to move from the production of common slabs to that of laminated glass to the structural glass, to reach the current special and innovative window-panes. The special windows have particular characteristics, we can find among these ones: antibacterial, self-cleaning, holographic, luminous (LED) and sounding panes etc. The innovative window- pane is an evolution of the low emissive (Low-e) glass. This pane is able to stop and/or modulate a variable percentage of the incoming solar radiation and its transmission. According to the operating mode, the innovative glass is classified into two main categories: static and dynamic. The window-panes, the features of which remain unchanged over time respect to the external conditions, form part of the first group. For example: the reflective pane or the - coloured or not - low emissive pane. The dynamic glass is surely better performing; since it is able to reversible change of its own optical features. For this reason, it is also called smart-glass. The dynamic (or chromogenic) window-panes are in turn classified into passive and active. For example, are included in the first group the photo-chromic panes which modify its own intensity according to the environmental brightness, and the thermo-chromic ones, whose changes depend by the changes of the temperature. Anyway they are not specifically used in architecture. Seems to be more susceptible of direct application the active dynamic window-pane, whose characteristic is to be managed by the user. In this case the variations are directly activated by the customer. We find two main typologies in the category: LCD and electrochromic window-panes. The LCD pane is equipped with a film containing molecules of liquid crystals. In the OFF state, these present a disordered configuration which prevents the direct passage of the light and gives an opal appearance
to the pane. In the ON state, because a weak current flows, the molecules reach a unidirectional orientation which leaves to pass rays without to deflect them, so becoming the pane transparent. The electrochromic (EC) pane is able to modify the colour intensity of the glass, according to the threshold value of a selected parameter, or on the basis of a pre-set timetable or on direct command by user. The variation occurs by applying a voltage to a multilayer film that induces a reversible redox reaction.

The substantial difference of performance between the two typologies is: into the LCD pane, during the OFF state, the glass appears translucent-opalin, while it is transparent in the ON state. In the EC pane instead, the glass is always transparent both in the ON and OFF phase, but in a colour version, which goes, through two intermediate states, respectively from the fully clear colour to the fully tinted.

3. THE ELECTROCHROMIC GLASS

The legend has it that Alexander the Great would already use tungsten oxides on his soldiers’ armours to make sure that the magic colour changes would terrify his enemies. The history tells that at the dawn of the ‘700, the painter and physics passionate man Heinrich Diesbach discovered the iridescent properties of Prussian blue. We must get to the ‘90s of the last century to bring about large-scale applications of electrochromic materials in aerospatial, aeronautical (Aerospace Dornier®) and automotive (Toyota®). Several glass industries made trials in building during the same years. Asahi Glass®, Pilkington® and Saint Gobain® applied the chromogenic glass specifically in existent building. All these initiatives, however, never got out of the stage of demonstration prototypes.

Researches about the production and marketing of EC glass have been developed by Sage Electrochromics® in the US. The company, founded in 1989, is currently able to commercialize the glass in the American market. Nowadays the corporation is wholly owned by Saint GOBAIN®, keeping the SageGlass® mark on the product, and beginning to spread EC glass also in Europe. The listed below data concern the features which have been tested by this company, based in Faribault (Minnesota, USA.), because they were the only available at the start of the research [1]. The German company EControl-Glas® which was part of the Pilkington® Corporation, has recently started to produce EC window-panes with slightly lower performance compared with those produced in the US at present. An Electrochromic IGU pane (Insulating Glass Unit) normally consists of two slabs: one outer tempered

dinamici (o cromogenici) vengono a loro volta suddivisi in Passivi e Attivi: dei primi fanno parte i vetri fotocromatici (che modificano la loro intensità in relazione alla luminosità ambientale) e quelli termocromici (le cui modificazioni sono indotte dalle variazioni di temperatura). Si tratta in ogni caso di prodotti che di norma non interessano in maniera specifica il campo architettonico. Al contrario un’applicazione specifica la consentono invece i vetri dinamici attivi, cioè gestibili dall’utente, in questi ultimi la variazione è attivata direttamente dall’utilizzatore. Nella categoria troviamo due principali tipologie: vetri a cristalli liquidi e vetri elettrochromici. I vetri a Cristalli Liquidi contengono molecole di cristalli liquidi che, nello stato OFF, assumono una configurazione disordinata, che diffonde la luce impedendone il passaggio diretto e determina un aspetto opalino; nello stato ON, ovvero al passaggio di una corrente elettrica, i cristalli si dispongono secondo un orientamento monodirezionale, che lasciando passare i raggi senza deviarli conserva la trasparenza del vetro. I vetri Elettrochromici (EC) possono modificare l’intensità della colorazione del vetro. Ciò avviene in relazione ad una soglia di parametro scelto (a orari prefissati o per intervento diretto dell’utente). Il cambiamento è ottenuto applicando una variazione di potenziale ad un film multistrato che induce una reazione di ossido – riduzione reversibile. La sostanziale differenza prestazionale tra le due tipologie risiede nel fatto che negli LCs il pannello appare opalino allo stato OFF e diviene trasparente allo stato ON; mentre negli EC il vetro è trasparente nella fase OFF e diventa trasparente - colorato all’interno e riflettente all’esterno nella fase ON.
glass slab (6mm), sometimes laminated, on the inner surface of which the electrochromic film is applied; the second one is the inner tempered or laminated glass slab (6mm). The hollow space between the two glass slabs is filled with Argon gas. The pane is completed by a sealant and a stainless steel spacer placed on the whole perimeter of the frame. The five layers which form the electrochromic film are set in sequence by a process that exploits nanotechnology. This method is very similar to that used for the production of low-emissivity glass. The process, referred as “sputtering”, follows this sequence: 1) the transparent conductor layer (TC); 2) the counter electrode (CE) layer with cathode function (-); 3) the ion conductor layer (IC), generally lithium which undergoes a redox reactions because of the passage of voltage, this cause in the metal an intensity variation in colour; 4) the electrochromic (EC) layer; 5) the counter electrode (CE) layer with anode function (+); 6) the circuit (TC) is closed by the transparent conductor layer (TC). The positive voltage, applied 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 compensating charge of electrons trough the external circuit realizes the passage from the CE layer into the EC layer. The process is of course reversible.

The electrochromic layers are in total 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 150 m² sized EC glazing has a daily consumption equal to that of a light bulb of 60W. All panes must be connected to a programmable control system unit, according to a time table or other parameters such as the limits of solar radiation and temperature. In early models, the adjustment of ON – OFF was only possible in two steps: 0% - that is fully clear OFF state - and 100% - that is fully tinted ON state. The maximum size of the pane was 1,016x1,524 mm; the time occurred from the fully clear to the fully tinted state depends by the outside conditions and by the dimension of the pane. It can vary from about 3’ to 10’. At the current time available colours are blue, green and brown, with a widespread preference for the blue variant. Tests demonstrated a reliability up to 100,000 running hours; the warranty certifies 50,000 hours (NREL Test E-2141). The weight of the pane is about 28 kg/m²; the electric power is the normal home network. A triple EC pane is currently on production, with performances slightly better than the double one, but in this case, the IGU is thicker.

The composition of the pane has been recently modified (Figure 1) and it includes: an external laminate slab, a cavity by 12.2 mm thick and an inner temperate glass pane, for a total around 25 mm thick. The outer laminate slab is composed of: a hardened panel by 4 mm which can be coloured on
choice (Heat Strengthened HS), an ion plastic interlayer film by 0.9 mm and an annealed glass slab (Annealed - AN) by 2.2 mm. The electrochromic layer is posed on the inner surface of the annealed glass slab, while the inside panel is hardened (Heat Strengthened HS) by 6 mm. The current maximum size of the IGU is 1,500x3,050 mm. The related control system uses software that allows scheduling each pane according to the selected parameters. The ON-OFF adjustment is possible in four steps: 0%, fully clear state, intermediate 1, intermediate 2 and 100%, fully tinted state. The opportunity to regulate every single pane enables to obtain different combinations in colour composition of the glass. It permits also to optimize the selective management of the incoming solar and visible radiation.

4. PERFORMANCE OF THE ELECTROCHROMIC GLASS

The comparison of the performance of different types of window-panes allows to identify what are the potential and the most salient features of products for the current market. The considered physics quantities are: the g solar factor (also called Solar Heat Gain Coefficient SHGC) which represents the percentage of solar energy transmission; the transmittance U [W/m²K] and Tv (visible light transmission), which is the percentage of visible radiation passing through the pane. We compare three typologies of glass: reflective, low emissive and electrochromic.

Reflective (mirrors) g = 14%, U = 4.4÷5, Tv = 4%;
Low Emissive (Low-e glass) g = 42%, U = 1, Tv = 71%;
Electrochromic g = 48% ± 10%, U = 0.28, Tv = 62% ± 2% (ranges refer respectively to the OFF and ON state).

The performance of the last generation of EC is still improved reaching the following values: g = 42% ± 10%, U = 0.28, Tv = 60% ± 1%.

The use of EC windows must be assessed, not only in terms of energy saving and comfort, but also in terms of energy saving. The comparison of the performance of different types of window-panes allows to identify what are the potential and the most salient features of products for the current market. The considered physics quantities are: the g solar factor (also called Solar Heat Gain Coefficient SHGC) which represents the percentage of solar energy transmission; the transmittance U [W/m²K] and Tv (visible light transmission), which is the percentage of visible radiation passing through the pane. We compare three typologies of glass: reflective, low emissive and electrochromic.

Reflective (mirrors) g = 14%, U = 4.4÷5, Tv = 4%;
Low Emissive (Low-e glass) g = 42%, U = 1, Tv = 71%;
Electrochromic g = 48% ± 10%, U = 0.28, Tv = 62% ± 2% (ranges refer respectively to the OFF and ON state).

The performance of the last generation of EC is still improved reaching the following values: g = 42% ± 10%, U = 0.28, Tv = 60% ± 1%.

The use of EC windows must be assessed, not only in terms of energy saving and comfort, but also in terms of energy saving. The comparison of the performance of different types of window-panes allows to identify what are the potential and the most salient features of products for the current market. The considered physics quantities are: the g solar factor (also called Solar Heat Gain Coefficient SHGC) which represents the percentage of solar energy transmission; the transmittance U [W/m²K] and Tv (visible light transmission), which is the percentage of visible radiation passing through the pane. We compare three typologies of glass: reflective, low emissive and electrochromic.

Reflective (mirrors) g = 14%, U = 4.4÷5, Tv = 4%;
Low Emissive (Low-e glass) g = 42%, U = 1, Tv = 71%;
Electrochromic g = 48% ± 10%, U = 0.28, Tv = 62% ± 2% (ranges refer respectively to the OFF and ON state).

The performance of the last generation of EC is still improved reaching the following values: g = 42% ± 10%, U = 0.28, Tv = 60% ± 1%.

The use of EC windows must be assessed, not only in terms of energy saving and comfort, but also in terms of energy saving. The comparison of the performance of different types of window-panes allows to identify what are the potential and the most salient features of products for the current market. The considered physics quantities are: the g solar factor (also called Solar Heat Gain Coefficient SHGC) which represents the percentage of solar energy transmission; the transmittance U [W/m²K] and Tv (visible light transmission), which is the percentage of visible radiation passing through the pane. We compare three typologies of glass: reflective, low emissive and electrochromic.

Reflective (mirrors) g = 14%, U = 4.4÷5, Tv = 4%;
Low Emissive (Low-e glass) g = 42%, U = 1, Tv = 71%;
Electrochromic g = 48% ± 10%, U = 0.28, Tv = 62% ± 2% (ranges refer respectively to the OFF and ON state).

The performance of the last generation of EC is still improved reaching the following values: g = 42% ± 10%, U = 0.28, Tv = 60% ± 1%.
and sustainability, but also in terms of other benefits: i.e. psychological (therefore hard to quantify) maintaining the inside-outside visual connection, better interior comfort. We can also add: glare decrease, lower expenses for shielding systems and a better control of the fading, due to the direct exposure of the furniture and internal building finishes to solar radiation.

5. THE RESEARCH

The activities of the research group began in 2008. The group is coordinated by the Prof. G. Loddo and composed by engineers D. Ludoni, G.P. Cossu and M. Pittaluga. A first paper was presented in occasion of the Glass Performance Days Conference which held in 2009 in Tampere. In the same year in October, an agreement with Sage Electrochromics inc. was signed for the data exchange and the support to the experimentation. The American company provided the group with the first EC panes in September 2010, thanks to the signed agreement of collaboration.

The initial objective was to evaluate the contribution of the EC windows in the field of energy saving, with specific reference to the Mediterranean area. In particular, we wanted to compare the performance of the EC, in summer and in winter, with those of the most widespread low-emissivity windows and evaluate the economic viability of the interventions.

We soon added others studies to those topic concepts, such as: to verify the performance and features declared by the companies that sell EC panes, testing them in real internal conditions, and, at the same time, to evaluate the action against the fading phenomena.

The research has been developed following two methods: a) simulations conducted using specific software; b) experimentation on real scale models. This paper specifically introduces some applications of second approach.

5.1. SIMULATIONS

The simulation takes in account existent buildings. Once the 3D model of the building is realized, we use a specific software to evaluate the contribution that the use of the EC pane can give, both related to energy saving and environmental sustainability in terms of thermo hygrometric comfort (Fanger index). These methodologies have been applied to historical and contemporary buildings. We supposed both minimal and complicated works such as: the simply replacement of existing windows with EC panes, and more complicated, like the renovation of the entire building envelope.

The data collected are very interesting because they clearly show how, even
with minimally invasive interventions in the historic architecture, is possible to achieve a significant reduction of CO2 emission (-25%), primary energy consumption because of a lower use of the summer cooling plant (-40%) and an important improvement of the internal comfort. The use of the EC window-panes also allows to keep the visual contact between inside and outside and to remarkably decrease the glare phenomena.

5.2. EXPERIMENTATION

The second methodology of the research relates to conduct experimental tests in two test rooms, built on the terrace of DICAAR of Cagliari. There, gradually increasing the window surface, we compared the performance of the EC panes and the Low-e panes, currently on the market. Test rooms are identical in size (outside 4.00x4.00x3.00 m, inside 3.60x3.60x2.70 m), in building system, in orientation and windows dimension and position. The floor area is 12.96 m² and each external wall surface is 12.00 m².

Tools to collect and to detect environmental internal parameters have been set inside the rooms. Measurements are carried out continuously every 15’. In the first configuration, the total window surface complies with the minimum ratios required by the local Building Regulations. The South–East facade didn’t change during the whole experimentation, instead the South–West facade, that houses the windows, gradually changed increasing the window surface. The construction was completed in the space of five months (July–November 2011) with the collaboration of some local builders.
We chose the balloon frame building system (in the A energetic class) to fit different configurations of the openings and thus to make an easy upgrade of the facades. The pavement of the rooms is raised on wooden beams and consists of a thin concrete slab (50 mm) and polystyrene panels (30 mm). The walls are made of wooden frames and the envelope consists of (from inside to outside): OSB panel (2.5 mm); mattress of rock wool (180 mm); OSB panel (2.5 mm); polystyrene panel (50 mm); thermal insulating plaster (3 mm). The roof is flat, windy, slightly sloping and waterproofed with an adhesive slate sheath. The frames of all windows are made of thermal break painted aluminium [2]. The average transmittance of each element complies with the terms of the Italian legislation, which provides a value of 0.17 [W/m²K] for the walls, of 0.26 [W/m²K] for the flat roof and of 0.36 [W/m²K] for the floor. The instruments located in each room are able to measure the dry and wet bulb internal temperature, the relative humidity and the global incoming solar radiation. The sensors can work with a temperature between -20 °C and + 80 °C (with an accuracy of ± 0.30 °C) and for humidity between 5% and 98% (with an accuracy of ± 2%). The pyranometer measures the global incoming solar radiation between 305 and 20,000 μW/m² to within 10 μW/m². The experimentation was temporally divided in 3 Steps, corresponding to the increase of window surfaces and some intermediate phases by inspections and adjustments.

Step 1: from November 2011 to December 2013. Net window surface on the door facing South-East = 0.80 m² (this surface is unchanged for all steps). Net window surface on South-West facades = 1.34 m². The ratio between the entire window surface and the useful surface, WS/US, is 16%: the ratio between the window surface and the blind surface, WS/BS, in the SW facade is 11%. In this period the EC glazing were in ON state even in winter time.

Intermediate Phase 1: from January to march 2014. All instruments were located in the same room to verify the coincidence or less of the measurements coming from the two stations. From April to October 2014: same configuration in Step 1. From November to December 2014, always the EC pane was in OFF state to test his behaviour like a Low-e pane.

Intermediate Phase 2: from January to February 2015. The just arrived new EC panes were mounted in the room which held, during the Step 1, the Low-e panes. The first generation of EC pane was still in the other room, to compare performance between the two versions. From March to April 2015. In the EC room: management and programming of the ON and OFF state in the EC room, with a remote control of the system by SageGlass® Company, done through an Internet connection.
Step 2: from May to June 2015. Removal of the old EC panes; replacement with the Low-e ones and increasing of the window surface on the South-West facades (WS/US=25%, WS/BS=20%).

Step 3, from July 2015. Further increase of the window surface on the South-West facades (WS/US=48%, WS/BS=41%). The ON-OFF states are selected according to the local solar chart. Up to the intermediate Phase 1, the activation was managed by programming the unit inside the room. The company producer directly monitored through a remote control the management of the new EC panes. The company is so able to check steadily the working of each pane (Figure 3), using a software developed by SageGlass®. In the last step the configuration of the facade is composed of: a pane (670x1,150 mm), on the door facing to South-East; two panes (1,420x950 mm) and four panes (600x950 mm), on the South-West facade. The size is referred to the only exposed glass surface without considering the frame.

The values of measurements have been catalogued in daily and monthly tables and graphs of comparison. The charts represent, at the same time, the average values to give an instant reading of results. The experimental data collection and processing allows to provide a complete framework of the comparison between EC and Low-e. Their analysis shows how the EC panes can give a significant contribution in evolution of building envelopes in the Mediterranean area.

Interesting insights have been obtained in the Intermediate phase 1 (November-December 2014). During the OFF state of EC, a quite perfect coincidence of the temperature was observed into the two rooms. This means that the behaviour of EC pane is very close to that one of the Low-e, with a similar winter gain. The Electrochromic layers shield a little more the solar radiation. Regarding facciate S.W.: rapporto SV/US = 48% e SV/SO = 41%.
Le fasi di ON e OFF degli EC sono scelte (nelle due facciate) in base al percorso solare locale. Sino alla Fase intermedia 1 l’attivazione era regolata programmando in sede la centralina di comando mentre, con i nuovi EC, la gestione viene controllata da remoto direttamente dalla casa produttrice tramite connessione Internet. Il produttore in tal modo è in grado di monitorare costantemente il funzionamento dei singoli pannelli (Figura 3) utilizzando un apposito software. Nello Step 3 la configurazione è composta da un pannello vetrato 670x1.150 mm sulla porta a S.E., due pannelli 1.420x950 mm e quattro pannelli 600x950 mm nella facciata S.W.: le dimensioni si riferiscono alla sola parte vetrata esposta al netto dei telai metallici con cui sono formati i serramenti. I valori strumentali rilevati sono stati raccolti in tabelle e rielaborati in grafici di confronto giornalieri e mensili, nei quali sono riportati i valori medi rendendo così immediata la lettura e l’analisi dei risultati. La raccolta ed elaborazione dei dati sperimentali è sufficiente a dare un quadro esaustivo nel confronto EC - Low-e e mette in evidenza le potenzialità dei vetri EC nell’evoluzione degli involucri edilizi in ambito mediterraneo. Interessanti spunti di riflessione sono emersi nella Fase intermedia 1 (novembre - dicembre 2014) quando, con gli EC in OFF, è stata rilevata una quasi perfetta coincidenza delle temperature nelle 2 stanze indicando come, in tale stato, il comportamento degli Elettrocromici sia molto vicino a quello dei Low-e con un guadagno gratuito invernale molto simile. Rispetto ai Low-e gli strati Elettrocromici schermano leggermente la radiazione nel periodo invernale. Per quanto riguarda la radiazione solare globale è evidente che, in fase OFF, l’andamento della spezzata relativa agli stessi EC è praticamente sovrapponibile a quella relativa ai Low-e. Al contrario, quando gli EC sono in fase ON, l’andamento della spezzata relativa agli EC ha un...
the incoming global solar radiation, we can observe that, when the EC are in OFF state, the trend of the graphs representing the EC and Low-e panes is practically overlapping. On the contrary, the trend of the graph representing the EC in ON state is very regular and it varies with narrow range with average between 100 and 300 μW/cm². The trend of the graph representing the Low-e varies in a wide range with sudden oscillations with average between 300 and 2,000 μW/cm² (see graphs on the left of the Figure 4).

Figure 4. From top left, comparison of incoming Global Solar Radiation and internal Temperature (July 2015); lower left, comparison of incoming Global Solar Radiation and internal Temperature July, 29, 2015 (the hottest day of the month. Blue colour the EC data, Magenta the Low-E data.

This behaviour is a general trend revealed in all months of the year and it assess that the use of EC pane eliminates or significantly reduces peaks and oscillations. Concerning the internal temperature during the cold season, when the EC are in OFF state, the trend of the graphs representing the EC and Low-e pane is practically overlapping but a negligible difference. In temperate and warm periods, when the EC are in ON state, the trends of the graphs representing the EC and Low-e pane are almost parallel. In this case, the value of temperature detected in the EC room is ever lower than that one in the Low-e room, with a difference around 3 °C, in spring and autumn, and about 6 °C or more, in the summer season (intermediate Phase 2: April to October 2014 and Steps 2-3). This behaviour has been observed in the
various Steps of the experiment and is even more marked if we analyse the graphs produced in a few specific days, as 2015 July 29th, (the hottest day in the month). In this day, the trend of the graph of the Low-e pane has a similar shape of an open bell and reaches, in comparison with the EC pane, values of ΔT higher than 12 °C around 6:30 p.m. (see Figure 4 in the lower right graph).

If we compare data related to 1 and 3 Steps (Figure 5), we can note that with a considerable increasing of the window surface from 2.14m² to 5.76m² the incoming Global Solar Radiation in the EC room, even if referred to different years, doesn’t substantially change, both in values and trend. Instead the measured quantities detect a significant average rise in the room where the Low-e pane is placed. The analysis of the inside temperature in the same period is very interesting: the two graphs are largely parallel but the ΔT in the Step 1 is about 3 °C, while during the Step 3 the ΔT expands to reach average values of around 6 °C.

6. FIRST CONCLUSION AND DEVELOPMENTS

The Electrochromic panes are now marketed in Europe: their availability will inevitably lead to lower prices (currently quite high), and their use will
become more widespread, especially in the Mediterranean area and in all territories with a strong and prolonged sunshine [3]. The considerable amount of data collected in four years of experimentation allows us to state that the Electrochromic window-panes are able to shield quite the incoming global solar radiation, and that they have an action of containment of the peaks. It’s evident that lower values of the inside temperature of an environment means a significant reduction of energy in air conditioning. This happens especially during the summer period when the main differences in the comparison EC–Low-e occur. Indeed, the use of the EC pane has a positive effect on the reduction of power consumption, and in the lowering of CO2 emissions, due to the lower use and low power required in air conditioning plants. The flexibility of their use allows us to take advantage of the thermal energy features of EC panes, since they can be activated throughout the hot season, which in the Mediterranean area covers a much wider period than purely summer, with great benefit derived from the high shielding effect. During the cold period, when they are turned off, they assure the benefits due to the solar heat gain (without to rule out the possibility of their activation also in winter days). It looks quite hopeful a further development of the research especially in relation to the carrying out of integrated systems made by combining photovoltaic plants to the EC glazing. The combinations are composed of small photovoltaic panels located on the bottom of the glass slabs. The trial will test the use of less impact photovoltaic film, enough to guarantee a low power consumption required in the switch on and during the running phase. The EC pane can be part of integrated components combined with domotic plant to realize authentic smart-buildings. Some types already on the market, allow a total management of the ON and OFF state by a smart phone. The possibility to manage by remote control promises interesting developments. Finally, the improvement and the further spread of wireless systems will lead to overtake the current limit to the use of EC: the need to apply the Electrochromic panes only on windows with fixed frames. By this way an innovative configuration and vision of the envelopes could be better improved in the public buildings and also in the residential sector that is a field where EC pane yet finds considerable difficulties.

7. ACKNOWLEDGEMENTS

We thank: LaborVetro for the Low-e and the frames of the windows, and Casaclima for the rooms’ envelope. The Cooperation of Customs and Monopoly for Tuscany, Sardinia and Umbria has been basic.
8. REFERENCES

