Electrically heated glass in Mediterranean climate

The study of Electrically Heated Glass (EHG) is important due to the increasing use of highly-glazed façades in commercial buildings. The use of this technology can be considered a different approach to the growing interest in contemporary design of transparent buildings, which does not neglect the occupants' comfort and the sustainability aspects associated with natural daylighting and energy savings. Commercial buildings located in the Mediterranean Regions consume significant amounts of energy for cooling, but require limited heat in winter due the high internal gains from appliances and the mild weather. At the same time, the significant role of radiant temperature in ensuring thermal comfort makes it especially convenient to use EHG during winter season in glazed façades.

Authors

Giuseppe La Ferla [1]
g.laferla.licitra@gmail.com

Jaume Roset Calzada [2]
jaime.roset@upc.edu

Petra Amparo Lopez Jiménez [1]
palopez@upv.es

1) Construction and Architectural Technology Department, Universidad Politécnica de Madrid / Chapman Taylor, Spain
2) ETS Arquitectura Barcelona, Universitat Politècnica de Catalunya, Spain
3) Hydraulic and Environmental Engineering Department, Universitat Politècnica de València, Spain

Description of the technology

There is a growing interest in the use of highly-glazed façades in commercial buildings. With origins in Europe the trend is expanding to all over the world, linked with the concept of hi-tech, modern design, daylighting and energy savings (Lee et al., 2002). Commercial buildings usually have high internal loads, due to information system equipment and the number of occupants (Duska et al., 2007), and short daily use of eight hours per day.

The heat gained or lost through the glazed façade depends on the physical properties of the material (conductivity, absorption, reflection, and transmittance) and on the environmental conditions. These factors determine the glass surface temperature and the amount of heat transferred between the occupants and the building through convection and radiation (Anderson et al., 2011). Thermal comfort conditions are also influenced by the distance between the glass surface and the occupants, the size of the glazing, the occupants' clothing and the activities undertaken within the building. In Mediterranean climates (Csa, with mild to cool wet winters, Chazarra et al. 2011) these buildings have a limited heating demand for most of the cold season.

Where Electrically Heated Glass (EHG) has been integrated into the façade, the exchange area between the environment and the heat source is across the whole extension of the glazing. Thus the total radiant energy emitted by the EHG to satisfy the heat demand is the result of the EHG unitary power multiplied for the whole façade area, which achieves a low increase between the mean radiant surface temperature and the internal temperature, with a consequent reduction of the energy consumption. With the temperature of the glazing near to the comfort range, the low radiant asymmetry temperature (less than 10°C) (Lyons and Arasteh, 2000) ensures thermal comfort and PPD (Predicted Percentage of Dissatisfied) and PMV (Predicted Mean Vote) decrease rapidly (figure 1) (ASHRAE, 2001) (Olesen and Parsons, 2002). This means an improvement with respect to a normal double glazing.

In addition, operating at similar comfort levels, the internal air is kept at a lower temperature than what is necessary with traditional heating systems (around 4 – 5°C) IQ Glass (2014), with consequently energy saving. This means that by maintaining the temperature of the glass surface near or slightly higher than the comfort level (usually 30°C), the indoor air temperature can be maintained to a lower level, saving around 8 % of energy consumption per year for each air degree lowered in the room (Amunarriz, 2013).

In summer, when the heated layer is turned off, the low Solar Heat Gain Coefficient (SHGC) of a low-emissivity glass pane can reduce the heat gains from solar radiation thus decreasing the cooling demand, especially in hot regions where the solar radiation is high, and achieving more energy savings in the year balance of the building. The value of this effect depends on the orientation of the façade, and it is more important in the South.

The EHG can be considered as part of the building envelope as well as part of the service system (La Ferla et al., 2004). The main component of this technology is the low-emissivity glass, which is used in common reflective glazing for its high optical transmission at visible wavelengths and effective reflection near infrared and infrared (i.e., heat) wavelengths. It is also known as Transparent Conductive Oxide (TCO), and its properties are the result of a combination of an extremely thin primary metal and a second band-width oxide semiconductor material (Granqvist and Hultaker, 2002). There are several different types of TCO, one of the most common used in a variety of industrial application is the Indium-Tin Oxide (ITO). When electric power is inducted into the glass pane the TCO layer operates as semiconductor, producing heat radiations due to resistance according to Joule's law (Gerhardinger, 2003). The main material utilised in the EHG technology, the low-emissivity glass, can be de-metalised as typically happens with TCO and thin film solar cell materials during the recycling process using a very simple method. This minimises waste and produces other marketable products. (Palitzschl and Loser, 2012; Palitzschl et al., 2014).

As shown in Figure 1, EHG is composed of a low-e double pane glazing (filled with air, argon or krypton) with a TCO layer on the internal surface (face 3), which is electrified and radiates towards the opposite face (face 4), while a thermostat is used to regulate the temperature (La Ferla et al., 2014). To reduce heat losses to the outside environment, face 2 is also coated with low-e layer, thus the exterior glass pane acts as reflector for the radiation emitted by the interior glass pane. The equations of thermal balance between interior and exterior are given by Moreau et al. (2008). Kurnitski et al. (2004) have demonstrated that the efficiency of EHG is between 90 % and 70 %, with a U value oscillating from 0.5 to 2 W/mK, depending on exterior temperature (of +10 °C, 0 °C, -10 °C and -20 °C as illustrated in Figure 2.

The efficiency of the electrical energy use of heated windows is defined as the proportion of the electrical heat output which is used to cover the heat losses from the window and from the heating of the room, and it is inversely proportional to the U-value of an unheated window. Also it is practically independent of the inner surface temperature of windows, and can be expressed by a simple linear equation of U-value (Kurnitski, 2004).

According to IQ Glass (a commercial brand system) and tests by Laborelec in Belgium in 1990, EHG can produce energy savings of 25 %, compared to a convection heating system (IQ Glass, 2014). Another study by CEBTP in 1997 for IQ Glass asserts that in a room where the glazed area is more than 1/3 of the total floor area, EHG is recommended. This study confirms that with traditional heating, air has to be heated to 25°C for the occupant to experience a sensation of approximating 20 °C; with EHG, air temperatures of only 17.8 °C provide a sensation of warmth of 22 °C. The difference of 12.8 °C to have same sensation results in a considerable energy saving (IQ Glass, 2014).

Impact of the technology

The embodied environmental impact of EHG is equal to a low-e double glazing because it is using a standard product of building technology (low-e float glass), although glass as material has significant environmental impacts due to the high energy intensity of its production process.

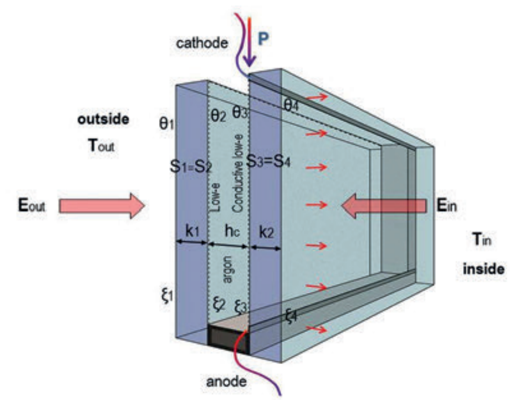

Figure 1 - EHG structure and variables used for the thermal balance equations

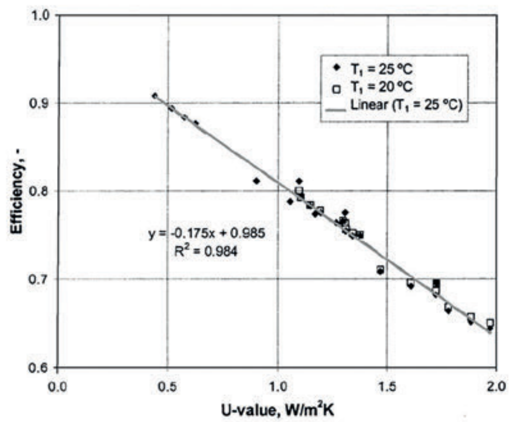

Figure 2 - Linear equation that expresses the efficiency of EHG, where U is the thermal transmittance of a referenced unheated window at specific outdoor temperature (Source: Kurnitski et al. 2004)

According to the International Energy Agency, in 2005 the global glass production was around 130 million tons, float glass production was about 43 million tons, and around 70 % of this production was for windows. About 0.5 – 0.8 exajoules of energy were used for the glass production worldwide, provided mostly by natural gas and fuel oil with an average energy use of 7 GJ/ton of product, giving an emission factor of 450 $kgCO_2$ per ton of product (International Energy Agency, 2007).

In the EU the total CO_2 emission for the float glass production was around 6,500 kton with average emissions of 697 $kgCO_2$ per ton of packed product (Standing Committee Of The European Glass Industries, 2010). According to the National Glass Association of Spain, in 2011 the domestic emission for the production of float glass was 520 $kgCO_2$/ton (Pejenaute, 2013).

The supply chain for the production and installation of EHG technology is very similar to conventional insulating glass for the building sector. The production of low-e coating float glass and installation of bas bar at the edge of the panes is undertaken by large companies such as AGC, Guardian, Pilkington and Saint-Gobain Glass. The assembly and electrification it is done by national manufacturers. Onsite installation of the glass curtain wall (for large scale glass façades) or in case of small scale buildings it is usually done by regional contractors.

Secondary industries are involved in the supply chain such as electrical manufacturers (for electric power transformer) and domestic home systems (for thermal regulation by thermostat or microprocessor equipment).Thus the economic impact of the EHG technology can be positive at a national and regional scale as several manufacturers and local companies are involved in the process of producing, assembling and installing the technology. Social impacts could be positive due to the potential for local employment, and the use of skilled workers. High qualified workers are needed in large companies for industrial production, as well as in the medium sized companies for the assembly. Low skilled workers are needed in local companies for the installation in the buildings.

Supply chain development

The adoption of EHG in the building sector will use existing industries and local contractors, therefore enhancing existing supply chains. The type of glass required is available in Spain because large companies can provide the main material (float glass), and local manufacturers can provide the coating layers, the electrode bus bars, and assemble the system.

Despite the fact that it could be generally available, the use of EHG is not yet widespread among stakeholders because of lack of demand. In 2008 there were four companies trying to introduce EHG in the building sector (Cytherm, Power-e, Termocristales and Eglass) but due to the economic crisis only one company (Control Glass) exists. These are collaborating with the Universidad Politècnica de Madrid to test the EHG performance in Madrid Region.

The Spanish national industry of float glass has 1,200 ktons capacity of production per year with 7 plants belonging to 3 companies (AGC, Guardians and Sant-Gobain), € 500 million of turnover per year and 3,500 employees (Ministerio de Medio Ambiente, 2007). These figures show the relevant impact on the glass industry in the building manufacture and construction sector, particularly in the Spanish economy which depends significantly on construction activity. The importance of this technology lies in the novel approach, using normal products in a different way to solve problems emerging with the increase use of glazed façade.

The impact of transportation could be significant because the supply of main material and the localisation of glass industries are established by international large companies. This part of the supply chain cannot be modified because it depends on other industrial factors. However the impact of transportation could be reduced in the others stages as several regional manufacturers are producing glass for industry components and applications in the building sector.

Lessons learned

This case study shows that EHG is an innovative technology of the building sector even though the components can be found in conventional products. The technologies can be employed in a different way, with a small change, to increase energy savings in buildings. Regarding the supply chain, it can be considered established as necessary glass factories and local manufacturers of the technological components are present within the Spanish building sector.

Despite this, further research is needed to demonstrate the efficiency of the EHG for commercial buildings in the Mediterranean climate, and more dissemination in order to improve the market acceptance.

A barrier for the large scale adoption of EHG may be the initial higher cost for the installation in comparison to a conventional windows. Another barrier could be the commercial building market itself, because this sector is usually seeking low cost technology. At the moment there is no research or publication that shows if the energy savings in Mediterranean Regions can provide pay off the initial higher cost of implementation. Other barriers include mistrust due the limited knowledge of the new products among the stakeholders, especially when they are small local companies which lack experimentation on a large scale for different buildings. This barrier could be overcome with close collaborations between the glass industry and the research sector, evaluating the energy saving of EHG in different climate areas and considering the side effects and real impact on the energy demand of commercial buildings.

References

Amunarriz Ollokiegi, E. 2013. Electric Heated Windows. Thermal comfort and energy use aspects. Master's Thesis in Energy Systems. Faculty of Engineering and Sustainable Development. University of Gävle.

Anderson, T., Luther, M., Brain, T. 2011. Assessment of thermal comfort near a glazed exterior wall. 45th Annual Conference of the Architectural Science Association, ANZAScA 2011. University of Sydney.

ASHRAE Handbook 2001. Fundamentals SI edition. American Society of Heating, Refrigerating and Air-Conditioning Engineers. Atlanta.

Chazarra, A., Mestre B., A., Pires, V, Cunha, S., Mendes, M., Nieto, J. 2011. Atlas Climático Ibérico. Agencia Estatal de Meteorología, Ministerio de Medio Ambiente y Medio Rural y Marino, Instituto de Meteorología de Portugal, Closas-Orcoyen.

Duska, M., Lukes, J., Bartak, M., Drkal, F. & Hensen, J.L.M. 2007. Trend in heat gains from office equipment. Proceedings of the 6th international conference on Indoor Climate of Buildings, Štrbské Pleso, Bratislava: SSTP.

Ferguson S., Siddiqi A , Lewis K., De Weck O. 2007. Flexible and reconfigurable systems: nomenclature and review. In: Proceedings of ASME 2007— International design engineering technical conferences & computers and information in engineering conference.

Fox M.A., Yeh B.P. 1999. Intelligent kinetic systems in architecture. In: Proceedings of managing interactions in smart environments (MANSE).

Gerhardinger P. 2003. Engineering Heated Glass. Next generation heated glass products. Online Appliance Magazine.com Accessed on May 2013: http://www.appliancemagazine.com

Gerhardinger, P. F. 2011. Wireless inductive coupling assembly for a heated glass panel. US 2011/0220639 A1. Maumee. Ohio. EEUU.

Granqvist C.G., Hultaker A. 2002. Transparent and conducting ITO films: new developments and applications. Thin Solid Films. 411, pp. 1– 5.

International Energy Agency 2007. Tracking Industrial Energy Efficiency and CO_2 Emissions. Accessed on September 2014: http://www.iea.org/publications/freepublications/publication/tracking_emissions.pdf

IQ Glass 2014. Heating Glass, General Insights. Accessed on July 2014: http://www.iqglass.com/images/downloads/IQG_Insights.pdf

La Ferla G., Acha C., Roset J. 2014. El vidrio calentado eléctricamente y su eficiencia energética como sistema de calefacción en una envolvente acristalada. 1st International Congress on research in Construction and Architectural Technologies. ETSAM. Madrid. Spain.

Kurnitski J., Jokisalo J., Palonen J., Jokiranta K., Seppänen O. 2004. Efficiency of electrically heated windows. Energy and Buildings. 36, pp. 1003 – 1010.

Lee E., Selkowitz S., Bazjanac V., T Inkarojrit V., Kohler C. 2002. High-Performance Commercial Building Façade. Building Technologies Program, Environmental Energy Technologies Division, Ernest Orlando Lawrence Berkeley National Laboratory. University of California. Accessed on December 2014: http://gaia.lbl.gov/hpbf/main.html

Lyons, P., Arasteh, D. 2000. Window Performance for Human Thermal Comfort. Proceedings of the 2000 ASHRAE Winter Meeting. Dallas. TX. February 5 – 9, 2000.

Loonen R.C.G.M. 2010. Overview of 100 climate adaptive building shells. MSc thesis report. Eindhoven University of Technology.

Loonen R.C.G.M., Trčka M., Cóstola D., Hensen J.L.M. 2013. Climate adaptive building shells: State-of-the-art and future challenges. Renewable and Sustainable Energy Reviews. 25, pp. 483 – 493.

Loonen R.C.G.M., Favoino F., Rico-Martinez J.M., Brzezicki M., Menezo C., La Ferla G., Aelenei L., 2015. Design for façade adaptability towards unified and systematic characterisation. 10th Conference on Advanced Building Skins. 3 – 4 November 2015, Bern, Switzerland. Accepted still unpublished.

Anon (nd). Transparent Conductive Oxide Thin Films. Technical paper. Materion. Accessed on Sptember 2014: http://materion.com/~/media/Files/PDFs/Advanced%20Materials%20Group/ME/TechnicalPapers/Transparent%20Conductive_All.pdf

Ministerio De Medio Ambiente 2007. Guía de Mejores Técnicas Disponibles en España del Sector de la Fabricación del Vidrio. Accessed on September 2014: http://www.prtr-es.es/data/images/Gu%C3%ADa-MTD-en-Espa%C3%B1a-Sector-Vidrio.pdf.

Moreau A., Sansregret S., Fournier F. 2008. Modelling and Study of the Impacts of Electrically Heated Windows on the Energy Needs of Buildings. 6th IASME / WSEAS International Conference on Heat Transfer, Thermal, Engineering and Environment (IHTE'08). Rhodes. Greece.

Olesen, B. W., Parsons, K., C., 2002. Introduction to thermal comfort standards and to the proposed new version of EN ISO 7730. Energy and Buildings. 34, pp. 537 – 548.

Palitzsch, W. , Schönherr, P. ; Loser, U. 2014. Integrated approach for economic PV waste recycling. 40th Photovoltaic Specialist Conference (PVSC), 2014 IEEE . 8 – 13 June 2014, pp. 2709 – 2711. Denver. Colorado.

Palitzsch, W. Y Loser, U. 2012. Economic PV waste recycling solutions-results from R&D and practice. 38th IEEE Photovoltaic Specialist Conference (PVSC), June 2012, Austin, Texas.

Pejenaute, J. M., 2013. FAVIPLA: Vidrio plano, en medio ambiente e industria del vidrio. Análisis del BREF 2012. Seminary organised by CSIC. 23th of May 2013. Madrid. Spain Accessed on June 2014: http://www.anfevi.com/archivos/medio-ambiente-e-industria-del-vidrio-analisis.pdf

Pilkington 2012. Global glass handbook. NSG Group.

Silver M.R., De Weck O.L. 2007. Time-expanded decision networks: a framework for designing evolvable complex systems. Systems Engineering. 10(2), pp. 167– 186.

Standing Committee of The European Glass Industries 2010. CPIV position paper on the design of CO_2 benchmarks and fall back options under the ETS for the glass sector. Bruxelles.

Wigginton M. 1996. Glass in architecture. London, Phaidon.