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Energy performance assessment of and advanced integrated façade through experimental data analysis

Francesco Goia[a,b,*], Lorenza Bianco[b], Marco Perino[b], Valentina Serra[b]

[a]*The Research Centre on Zero Emission Buildings, Faculty of Architecture and Fine Arts, Norwegian University of Science and Technology, Alfred Getz vei 3, Trondheim 7491, Norway*
[b] *TEBE Research Group, Department of Energy, Politecnico di Torino, Corso Duca degli Abruzzi 24, Torino10129, Italy*

Abstract

This paper deals with the experimental assessment of the energy performance of two Advanced Integrated Façade modules (AIF) characterized by two very similar configurations. The two AIF modules were installed on the south-exposed façade of an outdoor test cell facility (a real-scale mockup of an office building) and continuous measurements were carried out for more than one year. Data collected during the experimental campaign were analyzed to evaluate the energy performance and thermo-physical behaviour of the AIF modules. The performances of the two systems were assessed by comparison and by means of conventional and advanced synthetic metrics.
The results of the activity point out the different performances of the two configurations, which only differs on the inner-side glazing (a stratified single clear glass pane vs a stratified low-e double glazed unit). It was demonstrated that just a single additional glass layer can contribute to substantially improve the energy performance of a quite complex façade technology. On average, the façade configuration with the stratified low-e double glazed unit shows the abatement of heat loss and of solar gain of about 30% during the whole year. Moreover, the reliability of some conventional and less conventional metrics in assessing the performance of dynamic façade technologies was also investigated. The results confirm that conventional metrics are not fully reliable when they are used to assess advanced building envelope components with high level of dynamic.

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Keywords: Advanced Integrated Façade; experimental analysis; real scale mockup measurements; energy performance assessment.

*Corresponding author. Tel.: +47-73-550275; fax: +47-73-595094 / Tel.: +39-011-0904519; fax: +39-011-090-4499.
E-mail address: francesco.goia@ntnu.no / francesco.goia@polito.it

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1. Introduction

In 2010 the building sector covered 35% (the largest percentage) of energy consumption in Italy [1]. Buildings are great consumers of energy and an improvement of their performance is thus crucial in order to reach the European targets "20-20-20".

Energy saving in buildings can be reached by improving the performance of the building envelope and innovative approaches to envelope technologies can be explored. In this framework, the adoption of responsive building components can represent a promising strategy: in this concept, the elements of the construction (such as the façade) are characterized by a responsive behaviour and are rationally integrated with building services, such as heating, cooling, ventilation and lighting, in order to create a system capable of dynamically react to different boundary conditions and requirements [2].

In this paper the attention is focused on transparent vertical envelope and on a particular type of responsive façade technology. Present-day façade technologies are the result of a technological innovation process that has taken place mostly during the last four decades, and nowadays extensive use of glass in building façades is a common architectural feature in many commercial buildings. The glazed area of the building envelope plays an important role in controlling solar gain and heat loss, and it is often responsible of a large quota of energy demand (both for cooling and heating). Moreover, glazing systems have a huge impact on daylight conditions inside the building, which in turn affects both artificial light energy demand and visual comfort. Furthermore, the implications of large glazed areas on thermal comfort conditions cannot be neglected either.

Innovation in the field of the transparent building envelope has therefore focused on these two issues: environmental comfort implication and energy efficiency of the component. Considerable efforts have so far been made in R&D to improve the behaviour of transparent components, focusing both at system level (e.g. Double Skin Façade vs. Single Skin Façade) and at material level (e.g. innovative coatings, shading systems).

As far as the control and reduction of heat loss is concerned, the heat transmittance has been reduced by using double/triple glazing incorporating low emittance coatings. In relation to the optical/radiative properties of glazing, tinted glass panes (reflective, absorptive, selective) represent the state-of-the-art technology for controlling solar gains and light transmission. Furthermore, the incorporation of solar shading devices is becoming more and more common. Finally, with the development of the so-called dynamic fenestrations (e.g. Double Skin Façades, Advanced Integrated Façades, Smart Glazing), a responsive control over the behaviour of the façade has been introduced.

Advanced Integrated Façades (AIFs) are building envelope systems that show different degrees of integration with the HVAC and that are able to improve energy and comfort performance of glazed façades [2]. The main property of these systems is the dynamic behavior, which is achieved by means of the ventilated cavity that hosts a shading system. The combined effect of solar shading and of the airflow inside the façade cavity is able to reduce transmission heat loss, to lower solar heat gain, and to convert part of the solar short-wave radiation in thermal energy, which is removed from the cavity by the air flow – and may be later used for diverse purposes. Even though the advantage of AIFs over conventional systems was shown in some researches [3-4], its quantification and detailed assessment is still not an easy task. Since the thermo-physical properties and energy performance of these systems cannot be fully evaluated by means of conventional metrics (such as *U-value* and *g-value* [5]) and few regulations, standards or well established procedures are available to assess their performance, the spread of AIF technology is prevented. The energy performance of these systems is, in fact, not linearly correlated to the boundary conditions, and it cannot be easily described by means of simple parameters.

Real scale comparison experiments represent nowadays the best way to assess the performance of AIFs and to obtain a direct quantification of the advantages over a conventional system. Furthermore, different configurations of AIFs can also be tested in parallel to verify the influence of the subsystems on the behaviour of the AIF.

This paper deals with the experimental activity on two configurations of an AIF installed on a real scale mockup and with the evaluation of their energy performance.

Experimental data collected during more than one year are used to assess the energy and light performance of the two modules, by means of both conventional metrics and of dedicated synthetic parameters aimed at assessing the dynamic behavior of the systems. In this research, the AIFs are not compared against a conventional technology, but

the performance of the two systems is compared in order to highlight the influence of the multi-layered structure on the energy and light response.

Nomenclature

A	façade module A
B	façade module B
b_{tr}	transmission heat loss factor [-]
c	specific heat capacity [J g^{-1} K^{-1}]
E	illuminance [lux]
e_{24}	total daily energy transmitted through the façade [W h m^{-2}]
H_{24}	daily solar irradiation on the horizontal plane [W h m^{-2}]
I	solar irradiance on the vertical plane [W m^{-2}]
$\dot{m}$	mass flow rate [m^3 h^{-1}]
$\dot{q}$	indoor surface heat flux [W m^{-2}]
$\dot{Q}_R$	heat removed by the air in the cavity [W m^{-2}]
$\dot{Q}_{OUT}$	total heat flux entering the outside skin of the façade [W m^{-2}]
S	surface area of the façade module [m^2]
T	temperature [°C]
t	time [h]
U	thermal transmittance [W m^{-2} K^{-1}]
Greek symbols	
ε	dynamic insulation efficiency [-]
η_{PH}	pre-heating efficiency [-]
τ	transmittance [-]
Subscript	
cav	referred to the cavity
e	solar
exh	referred to the exhaust of the cavity
in	referred to the indoor
inlet	referred to the inlet of the cavity
l	light
out	referred to the outdoor

2. Methods

2.1. Advanced Integrated Façade configurations

The tested AIF modules are two configurations of the same technology and differ in the inner side glazing system. The AIFs are Climate Façades, i.e. a double skin fully glazed façade, with a mechanically ventilated cavity (depth: 0.24 m), that extracts the air from the room and releases it to the exhaust duct after it flows throughout the whole façade gap. In Figure 1 the two technologies are schematically represented, and the main features of the glazed layers summarized in Table 1. The inner-side glazing of Module A is made of a single extra-clear glass pane (10 mm) – a conventional solution for this technology – while Module B has a double glazed unit (10/16/10 mm, clear glass panes with low-e coating and Argon in the gap). Module A and B have the same shading system in the cavity (reflecting screen), the same outer-side glazing (double glazed unit with a selective external glass, 20/16/10 mm), airflow rate and control strategy. Through tracer gas technique, the mass flow rate through the cavity of the two modules was measured and the design flow rate $\dot{m}$ = 20 m^3/h confirmed. The dimensions of each AIF module are: 1.60 (w) x 4.40 (h) x 0.30 (d) m.

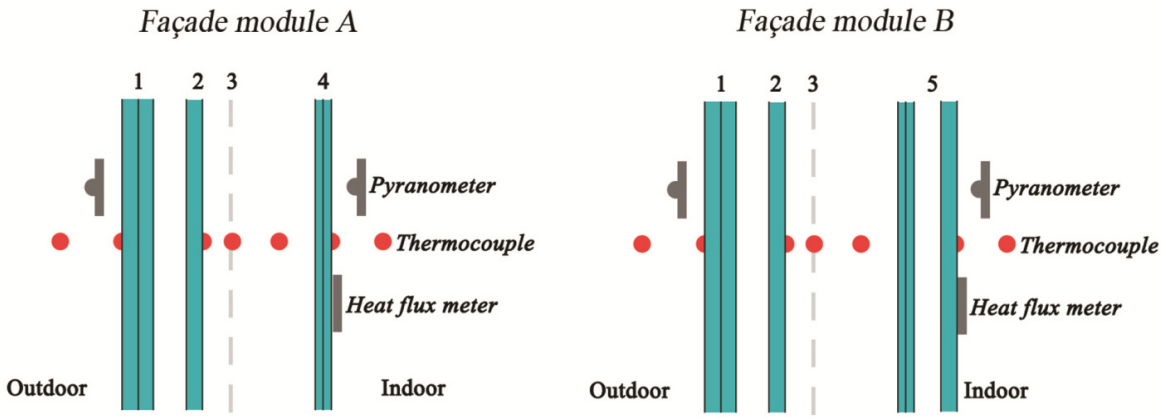

Figure1.Schematic section of the AIF and of the instrumentation on each façade module

Table 1.Multi-layer structure of façade module A and B

Module	Layer code (Fig.1)	Layers	Depth (*mm*)
A and B	1	Selective laminated glass 10 10.4	10 10.4
A and B		Air cavity	16
A and B	2	Clear glass	10
A and B		Mechanically ventilated cavity	240
A and B	3	Reflective roller screen	-
A	4	Laminated clear glass	5 5.2
B	5	Double glazed unit with low-e glass	5 5.2/16/10

2.2. Experimental set up and measurement campaign

The aim of the experimental campaign was to measure and quantify the difference between the two façade modules in terms of heat fluxes, indoor glass surface temperature and cavity air temperature. Thermal comfort measurements and direct energy consumption were not possible because the indoor environment of the test cell was influenced by both façade technologies. Hence, it was not possible to directly assess the influence of each module. However, the evaluation of the energy and light performance of each system was carried out by means of dedicated parameters – cf. section 2.3. At the same time, sharing the test cell was an advantage because the two modules were exposed to exactly the same boundary conditions.

The test rig is a real scale mockup of an office room, whose dimensions are: 3.20 m (w) x 5.90 m (l), 3.45 m (h, false ceiling). The mockup is located in a temperate sub-continental climate location in northern Italy. The two façade modules (A and B) are installed on the south/south-west exposed façade of the test cell, which is equipped with more than 70 sensors evenly distributed.

The indoor air temperature of the mockup is maintained at the desired set-point (usual set-points: 20 °C in winter, 23 °C in spring and autumn, 26°C in summer) by means of a combined air system and radiant panel (located in the false ceiling). The system can operate simultaneously in cooling and heating mode.

The façade modules were equipped with thermocouples and heat flux meter sensors at three different heights (+1,00, +2,00, +3,00 m), in order to analyze temperature stratification phenomena and correlated surface heat flux. Transmitted (on the vertical plane, I_{in}) and outdoor incident (on the horizontal and on the vertical plane) solar irradiance were measured by means of 4 pyranometers (2 outside, one horizontal and one vertical, and 2 inside, one at the rear of each façade module). The measurement accuracies of the sensors, previously calibrated/verified in the laboratory, were: ±0.3°C, ±5% and ±5%, for thermocouples, heat flux meters and pyranometers, respectively.

Thermocouples and heat flux meters which were directly exposed to solar radiation were suitably shielded with highly reflecting aluminum foils to reduce the influence of the solar irradiance on the measured physical quantity, - following established measures in literature [5]. Vertical illuminance values (both inside and outside the façade modules) were recorded (spot measurements) by means of an illuminance meter (Minolta LS100; accuracy ±5%).

2.3. Data analysis and performance parameters

Temperature, heat fluxes and irradiances were collected every 15 minutes and then average hourly values calculated. Data analysis is based on hourly values and the available data set covered one entire year.

The entire data base of the collected data were analyzed and data selected to characterize the typical standard parameters of the façade; solar transmittance (τ_e, [-]), light transmittance (τ_l, [-]), thermal transmittance (*U-value*, [W m^{-2} K^{-1}]). Additionally, another parameter, the total daily energy transmitted through the façade (e_{24}, [W h m^{-2}]) was assessed for typical days each season. Moreover, less conventional metrics (already established in the literature or dedicated developed during this investigation) aimed at assessing the dynamic features of the technology were calculated too.

Solar transmittance was evaluated as the ratio of the vertical transmitted solar radiation (I_{in} [W h m^{-2}]) to vertical incident solar radiation (I_{out} [W h m^{-2}]). This parameter was calculated on an hourly basis for both summer and winter, with open and closed shading devices in the cavity.

Light transmittance (τ_l, [-]) was calculated as the ratio of the illluminance on the vertical plane at the rear of the façade modules E_{in} [lux] to the illuminance on the outdoor vertical plane E_{out} [lux]. This parameter was calculated by means of spot measurements in summer, with open and closed shading devices in the cavity. Although continuous measurements were not carried out, the resulting values of τ_l are representative of the behavior of the systems in that season.

An attempt to evaluate the thermal transmittance of the two modules by means of linear regression method was made [4], although such a conventional parameter, developed for steady state conditions, cannot fully describe the performance of building envelopes due to the dynamic behaviour of the ventilated cavity. This parameter was assessed, following the definition of *U-value* given by the international standard, using night-time readings only, when no solar radiation acted on the glazing. A linear regression technique (OLS method) was adopted to linearly correlate the (long-wave radiative plus convective) heat flux exchanged at the indoor surface of the façade modules $\dot{q}$ and the thermal gradient between the outdoor and the indoor ($T_{out} - T_{in}$). The first order coefficient of the linear correlation was interpreted as the *U-value* of the technology – the constant term of the linear regression was imposed equal to zero.

Evaluation of the total daily energy transmitted through the façade, e_{24}, were also performed in order to synthetically characterize and analyze the energy performance of the two modules (A and B) during the different seasons. For this purpose, a typical day was selected in each season, comparing the measured boundary conditions with those of an "average" day in the location of the experimental campaign – data on the average day were retrieved from the Italian standard UNI 10349 [6]. Among the measured physical quantities, the daily mean outdoor air temperature, T_{out} [°C], and incident solar radiation on the horizontal plane, H_{24} [Whm^{-2}],were used to select the typical days, which thus showed T_{out} and H_{24} very similar to those identified as "average" in UNI 10349.

For each season, the evaluation and analysis of the total daily transmitted energy was repeated for the two configurations of the shading system: in the first configuration the reflective roller screen in the cavity was not used (*screen OFF*) while in the second one the screen was displaced in the cavity (*screen ON*). The boundary conditions of the two days selected are very similar to each other, and similar to the values in UNI 10349; the plot of the boundary conditions for each day is reported in the upper part of the charts in Figure 3.

The total daily transmitted energy e_{24} [W h m^{-2}] during a typical day is defined as the energy that crosses the façade on a daily basis. The total daily energy (1) is given by the integral over the 24 h (from 00 am to 00 pm of the following day) of the transmitted solar radiation on the vertical plane I_{in} [W h m^{-2}] and the heat flux exchanged at the indoor surface of the façade $\dot{q}$ [W m^{-2}]. The indoor surface heat flux was calculated as the average of the values monitored by three heat flux meters positioned at three different heights of the façade.

$$e_{24} = \int_{00:00}^{+1day} (I_{in} + \dot{q})dt \ \ [\text{W h m}^{-2}] \tag{1}$$

Three dynamic metrics were also assessed to analyse the dynamic performance of the façade. Cumulated frequency analyses of such parameters were then carried out.

The pre-heating efficiency assesses the capability of the façade to pre-heat the ventilation air flow rate during the cold season (heating periods) [5]. It is defined as:

$$\eta = \frac{T_{exh} - T_{inlet}}{T_{in} - T_{out}} \ \ [\text{-}] \tag{2}$$

where the numerator is the difference between the air temperature at the exhaust of the façade cavity T_{exh}[°C] and the air temperature at the inlet of the façade cavity T_{inlet} [°C], and the denominator is given by the difference between the indoor air temperature T_{in} [°C] and the outdoor air temperature T_{out} [°C]. From a physical point of view, this index represents the ratio of the enthalpy flux related to the air in the ventilated cavity to the enthalpy flux necessary to heat the air for the ventilation. The pre-heating efficiency was calculated during winter season for days with T_{out} < 21 °C both for *screen ON* and *OFF* configurations.

If $\eta < 0$ there is no heat recovery because the temperature exiting from the façade (T_{exh}) is lower than the indoor air temperature (T_{in}). In this condition, no heat recovery is possible and the ventilated cavity acts a conventional glazing system – with, in general, high thermal resistance. If $\eta > 1$, T_{exh} is higher than the indoor air temperature, and the façade is able to completely compensate the ventilation loss –while transmission heat loss may occur.

A new metric, b_{tr}, was also developed in order to evaluate the performance of the AIF in winter time as far as the reduction of the transmission loss is concerned. This metric is derived from a parameter (correction factor for an unconditioned adjacent space) used in the International Standard ISO 13790:2008 [7].

$$b_{tr} = \frac{T_{out} - T_{cav}}{T_{cav} - T_{in}} \ \ [\text{-}] \tag{3}$$

- When b_{tr} < 0, the temperature of the air inside the cavity of the AIF (T_{cav}) is lower than the outdoor air temperature (T_{out}), and therefore the heat loss through the cavity of the OSM is higher than the heat loss which would occur if there was no cavity inside the façade – an event very unlikely to occur with the type of façade technology under investigation.
- When b_{tr} = 0, the temperature of the air inside the cavity of the AIF (T_{cav}) is equal to the outdoor air temperature (T_{out}), and therefore the heat loss through the cavity of the OSM is equal to the heat loss which would occur if there were no cavity inside the AIF.
- When 0 < b_{tr} < 1, the temperature of the air inside the cavity of the AIF (T_{cav}) is higher than the outdoor air temperature (T_{out}), and therefore the heat loss through the cavity of the AIF is lower than the heat loss which would occur if there were no cavity inside the AIF; the thermal buffer has a certain effect in reducing the transmission heat loss.
- When b_{tr} = 1, the temperature of the air inside the cavity of the AIF (T_{cav}) is equal to the indoor air temperature (T_{in}), and therefore no heat loss occurs from the inside to the cavity of the AIF.
- When b_{tr} > 1, the temperature of the air inside the cavity of the AIF (T_{cav}) is higher than the indoor air temperature of the (T_{in}), and therefore heat gain occurs from the cavity of the AIF towards the indoor environment.

The temperature in the cavity T_{cav} was calculated as the average of the three thermocouples placed in the ventilated cavity of each module. The index was calculated during winter only for T_{out} < 21 °C both for screen *ON* and *OFF*.

During summer, the dynamic performance of the façade modules was analysed by means of the dynamic insulation efficiency ε [-]. The physical meaning of this metric (Eq. 4) is the amount of heat removed by the air in the cavity with respect to the total cooling load impinging on the façade [5]. It is expressed as the ratio of the heat

removed by the air in the cavity Q_R (W m^{-2}) to the total heat flux (shortwave plus long wave and convective) entering the outside skin of the façade Q_{OUT} (W m^{-2}) [5]. In order to calculate ε it is necessary to know the mass flow rate within the cavity. Continuous measurements of this physical quantity were not implemented in the experimental set-up, but representative spot measurement by means of tracer gas technique were carried out, confirming a flow rate $\dot{m}$ = 20 ± 1 m^3 h^{-1}.The dynamic insulation efficiency was calculated during summer season for days with T_{out} > 21 °C both for *screen ON* and *OFF*.

$$\varepsilon = \frac{\dot{Q}_R}{\dot{Q}_{OUT}} = \frac{\dot{m} \cdot c_p \cdot (T_{exh} - T_{inlet})}{S \cdot (\dot{q} + I_{in}) + \dot{m} \cdot c_p \cdot (T_{exh} - T_{inlet})} [-] \tag{4}$$

The values of ε are in the range 0 to 1, where 0 means that the façade module is not able to remove any heat through the ventilation layer, and 1 means that the façade module is able to completely remove the impinging energy thanks to the ventilation flow – the greater ε, the better the summer performance.

3. Results

3.1. AIF properties

The first step in the experimental data analysis focused on light and energy properties of the AIF modules (Table 2). Solar and light transmittance of module B (with low emittance coating in the inner side double glazing) is always lower than those of module A. When the screen is not displaced in the cavity (i.e. *screen OFF*) and the solar irradiance that impinges on the inner side is higher, the difference in performance between the two technologies becomes even more evident.

In Fig. 2a) the attempt to calculate the thermal transmittance of the two modules is shown. As already stated and demonstrated in literature, the thermal transmittance is not able to characterize the properties of an AIF. The attempt was done trying to remove the dynamism of the façade and evaluating the thermal transmittance of the glass layers and air cavity with air flow activated. The *U-value* for module A is 0.62 W m^{-2} K^{-1} while for module B it is 0.33 W m^{-2} K^{-1}. For both façades modules the coefficient of determination R^2 is quite unsatisfactory – 0.71 and 0.46, for module A and B, respectively. Although the exact difference between the two technologies cannot be assessed due to the high uncertainty of the correlation, it is possible to hypothesize that the thermal resistance of module B is significantly higher than that of module A. The very low coefficient of correlation of module B can be due to the very low heat flux values that characterize this façade module (between -9 and -2 W m^{-2}) and that makes the linear correlation less reliable.

As far as the pre-heating efficiency is concerned, (Fig. 2 b), when the screen in not displaced (*screen OFF*) it is hard to see any substantial difference between the two façade modules. When the screen is *ON*, both the façade modules improve their performance, thanks to a better management and control of the solar gain, and two slightly different values of the pre-heating efficiency are found. *Screen ON* configuration shows a higher cumulative frequency when the efficiency is greater than 100% (i.e. ventilation heat losses completely compensated by the façade). The small difference between the two modules does not permit to remark an improvement in term of façade performance. In general, façade module A shows a slightly better performance, which can be correlated to the higher heat loss towards the façade cavity in module A, due to the lower thermal resistance of the inner side glass pane. In fact, during winter, the air gap temperature of module B was always lower than that of module A, confirming that higher heat loss takes place in module A than in module B – this results is in line with the assessed *U-values*.

The cumulated frequency analysis of b_{tr} (Fig. 2 c) shows that the air temperature in the cavity is always higher than the outside air temperature and thus the value of this parameter is always greater than 0. Screen ON configuration showed a slightly better performance than screen OFF. For approximately 70% of the time the value of b_{tr} is in the range 0.6-0.8 and there is not a substantial difference between the two modules. This means that, for approximately 70% of the time, the heat loss through the façade is reduced by 60-70% compared to a conventional, single skin technology that only adopts the outer skin of the façade modules under investigation. Once more, the performance of the two façade modules is very similar and it is not possible to identify the best configuration.

Table 2. Solar transmittance and light transmittance of the two modules, for different seasons and shading position

Module	τ_S *Summer screen ON*	τ_S *Summer screen OFF*	τ_S *Winter screen ON*	τ_S *Winter screen OFF*	τ_l *Summer screen ON*	τ_l *Summer screen OFF*
A	0,03	0,19	0,03	0,21	0,06	0,50
B	0,02	0,12	0,02	0,14	0,05	0,42

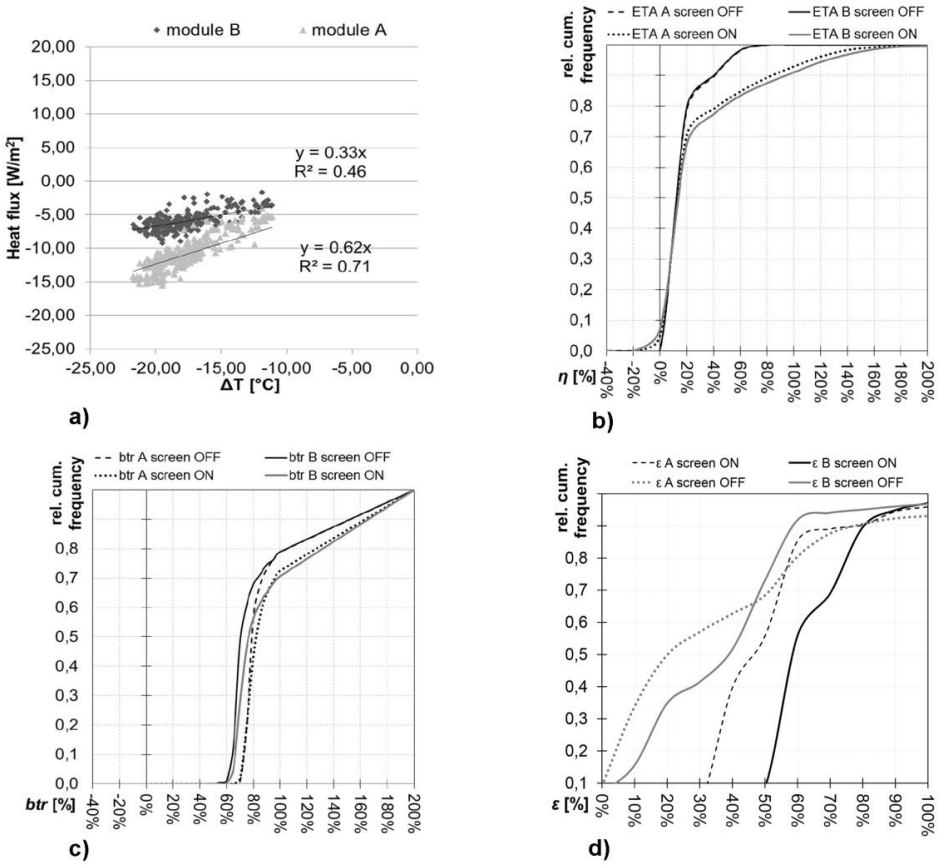

Figure 2. a) Linear correlation and determination of the *U-value* [W/m^{-2}K^{-1}]; b) pre-heating efficiency η [-]; c) transmission heat loss factor b_{tr} [-]; d) dynamic insulation efficiency ε [-]

Screen OFF configuration shows much lower dynamic insulation efficiency than when the screen is *ON* (Fig. 2 d), regardless of the façade module. This result is in line with the expectation, since the reduction of cooling load (the physical meaning of ε) can be greatly enhanced due to the action of the roller screen (*screen ON* configuration). The value of ε is higher for module B than for module A except when the screen is *OFF* and the value of ε is higher than 0.48. When the screen is *ON* for most of 50% of the time the dynamic insulation efficiency is higher than 50% for module A, while for module B it is slightly lower than 60%. *Screen OFF* configuration shows the same trend of screen *ON* but ε starting values are close to zero for both the modules. When the screen is not displaced for most of 50% of the time the ε is higher than 20 % and slightly lower than 40 % for module A and B respectively. The analysis of this parameter shows the better performance of module B compared to module A, reaffirming the robustness of this metric.

Table 3. Total daily transmitted energy through the façade modules – e_{24} [Wh m^{-2}]

Module	*Winter*		*Spring*		*Summer*		*Autumn*	
	Screen ON	*Screen OFF*	*Screen ON*	*Screen OFF*	*Screen ON*	*Screen OFF*	*Screen ON*	*Screen OFF*
A	180,5	1062,7	307,7	830,2	389,2	1015,7	319,7	1305,5
B	106,8	752,2	215,2	558,8	271,6	689,6	213,0	873,2

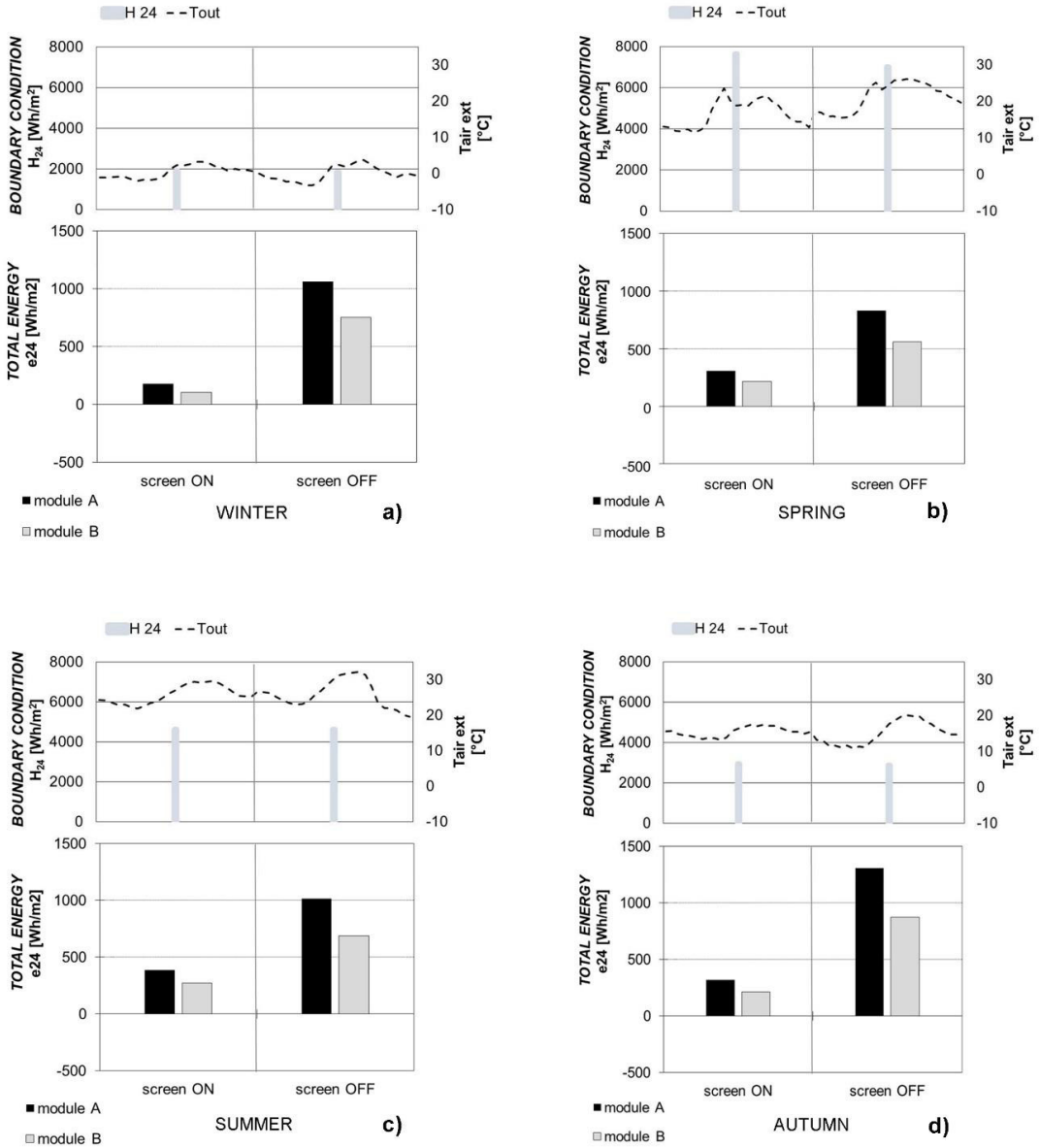

Figure 3. Daily boundary condition H_{24}, T_{out} and total daily transmitted energy e_{24} for SCREEN ON and SCREEN OFF configurations, module A and B a) winter season, b) spring season, c) summer season, d) autumn season.

The outcome of the frequency analysis of ε – i.e. the better energy performance of module B – is confirmed by the analysis of the total daily energy transmitted through the façade e_{24}. In Fig. 3 and in Table 3 the results for winter, spring, summer and autumn seasons are reported. During all the seasons and for both configurations (*screen ON* and *OFF*), the energy transmitted through the module B is always lower than module A.

For summer, spring and autumn the difference between the two modules was assessed between 29%- 33%. During winter season, for *screen ON* configuration, the highest difference between the two modules is found: under these circumstances the total daily energy transmitted through module B was 41% lower than module A. This is mainly due the negative surface heat fluxes (heat loss) which are nearly balanced from transmitted solar radiation, while in absence of screen the transmitted solar radiation through both modules reaches higher values than the ones during summer season.

4. Conclusion

The analysis of the experimental data collected during a one-year long campaign on two Advanced Integrated Façade (AIF) module shows that the properties of the inner glazing of an AIF can modify the energy performance of the façades. Two different AIFs façade technologies were investigated: the AIF module B with low-e coating on the inner skin showed a better performance than module A (without low-e coating). During all the seasons module B always showed lower value of total energy transmitted through the façade. The difference between the two modules is found to be around 30%. Total energy calculated for the two modules are representative of the technologies behaviour in the weather conditions of Torino.

The analysis of synthetic performance parameter (both conventional, such as U-value, and less conventional, such as η_{PH}, b_{tr} and ε) does not allow the same considerations to be drawn. The pre-heating efficiency and the b_{tr} metric do not show relevant differences between modules A and B. For what concerns the dynamic insulation and the thermal transmittance a better performance of façade module B is highlighted. The significance of the calculated U-value is jeopardized by the low coefficient of correlation (especially for module B), due to the fact that this parameter can difficulty asses the behaviour of an advanced façade system, where dynamic features play a very relevant role, and that the general good performance of the two configurations (very low heat transmission loss) prevents a reliable assessment of this parameter. It is important to point out that the better performance provided by module B with a low-e double glazing has to be evaluated in a wider perspective taking into account the higher cost of module B façade due to the presence of an extra layer. Furthermore the effects on thermal and visual comfort have to be deeply considered.

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