INTEGRATED ENERGY USE ANALYSIS IN OFFICE SPACES

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ABSTRACT

Energy demand of different glazing materials and light control systems for office spaces are analyzed in this paper. The approach is based on an improvement of the hourly simulation program IENUS (Integrated ENergy Use Simulation), that was developed to assess building energy demand taking into account the integration between visual and thermal aspects. IENUS implements thermal aspects by the transfer function method, while daylighting is pre-processed by the package Superlite before entering in IENUS. Energy requirements are analyzed for different glazing systems and daylight control strategies.
Different strategies to control the artificial lighting systems are implemented, while automatic internal curtains modulate natural light incoming.
Occupants interactions are valued by occupants responses to the visual comfort (illuminance, local and window glare) that rules the probability both of operating internal shading devices and of switching on/off artificial light, overriding automatic control systems.

INTRODUCTION

This paper analyses the office space energy demand connected to the use of different glazing materials and light control systems for office spaces.
Industries in these last years have developed and produced several types of transparent materials and Lighting Control Systems (*LCS*) to improve the design and the building management in order to take full advantage of the energy saving potential coming from daylight. Electric light and daylight control systems capable of adjusting both the electric light output and the daylight incoming are recognized as very important in non-residential buildings. Artificial lighting systems are among the major energy consumers and can influence the HVAC size and the total peak electrical demand.
Automatic control systems could be overridden by all those occupants, who want to adjust indoor conditions to suit their own comfort requirements. Many applications of lighting control systems don't confirm the design predicted energy savings due to occupants interaction.
To assess energy demand it is necessary to use an integrated approach that takes into account the visual and the thermal environments realized both by control systems and by occupants interaction.
This study is based on an improvement of the hourly simulation program IENUS (Integrated ENergy Use Simulation, by Gugliermetti *et alt*. 1988, 2000/a, b, c) that was originally implemented to assess energy requirements for building innovative glazing material in Mediterranean climate.

BACKGROUND

IENUS is an advanced dynamic simulation program that integrates visual and thermal aspects connected to building energy demands and to global comfort aspects. IENUS uses algorithms that are inherently not CPU time consuming. IENUS characterizing feature, respect to other available packages (DOE 2.1 by Winkelmann and Selkowitz, 1988, ADELINE by Erhron et al., 1995, TSBI3 by Grau and Johnsen, 1994, DEROB-LTH by Hasse, 1995, WINSOM by Schultz, 1999) is its flexibility that permits to use different input data to characterize both indoor/outdoor environment and materials. This feature becomes particularly important for innovative materials, as experimental data are often incomplete, and when the available meteorological data for the considered locations are of different type (MTD, Monthly Typical Day, TMY, Typical Meteorological Year, DRY, Design Reference Year, or reduced set of data).
Comparative studies on advanced simulation programs can be found in Judkoff and Neymark (1995) and in Lomas *et al*. (1994).
The dynamic heat transfer algorithm of IENUS can incorporate different modules to simulate the interaction between the visual and the thermal environment. Thermal algorithm is based on the Mitalas (1982) transfer function method with different sets of coefficients: Conduction Transfer Coefficient CTF, Room Transfer functions RTF and Space Air Transfer Function SATF. CTFs can be constructed inside IENUS with the procedure and the software reported by McQuiston and Spitler (1992) or by direct input, as for RTFs and SATFs.
IENUS pre-calculates the indoor natural illuminance (Gugliermetti 2000/b) by a variation of the Solar

System Luminous Efficacy method (*SSLE*) (introduced by Place *et alt.* (1984)) to avoid the introduction of data which are different from those normally available in TMYs. *SSLE*s are the ratios of the illuminance on a prefixed internal point to the external horizontal solar radiation per m^2 of unobstructed surface. These are calculated for each hour of a month central day for a double-strength sheet glass (DSA) and for all the considered orientations by the package Superlite (Selkowitz, 1983). The efficacies required for the other days of the month are calculated by linear interpolation from central days *SSLE*s. Ratios of the actual glazing system visible angular transmittances to DSA ones are used to have efficacies for the considered glazing system. Direct and diffuse solar radiation are treated separately.

GLAZING AND LIGHT CONTROL SYSTEMS CHARACTERIZATION

Transparent spectrally selective coatings on glass or polymeric substrates are nowadays available. Low emittance (low-e) coatings can transmit either a large portion of solar radiation (high total solar energy transmittance τ_s and high visible light transmittance τ_v) or selectively a high proportion of visible radiation and reflect the near infrared component of the incident solar radiation (low τ_s and high τ_v). Coatings of pyrolytic heavily doped wide band-gap semiconductor coatings, such as flourine-doped tin oxide, are used in solar gain glazing systems, while coatings of sputtered multi-layer dielectric-metal-dielectric, such as silver-based film, are used in solar filter systems. The possibility of producing homogeneous thin films over large areas provides the solar filter low-e glazing systems are largely used in office building applications where cooling requirements are dominating.

This paper analyzes double glazed systems made of a clear glass towards indoor and an outer low-e coated absorbing glass, with different spectral behaviors. Central optical properties of the glazing materials assembled to form the considered double glazed systems are reported in Table 1.

All the glazing systems are realized with an air gap of 15.7 mm and their central optical properties are reported in Table 2. The parameters listed in Table 2, with the angular properties required to perform energy calculations by IENUS, are obtained from the program Window 4.1 (Arasteh et alt., 1994, 1989) on the base of the glazing material spectral and angular characteristics.

Several types of management strategies and equipment are used to control lamp light outputs and natural light. Natural lighting controls by automatic mini-internal blinds to large exterior rolling louvered shutter systems are available and popular in office building due to their adjustability and ability to reflect light. Artificial lighting systems are dimmed or switched following daylight variations to keep the Design Lighting Level (DLL) as constant as possible for all the lamps maintenance cycle. Commercial control systems can operate with algorithms that can realize either a closed-loop integral control (a photosensor detects the artificial light as well as the available daylight) or an open-loop proportional control (a photosensor detects only daylight and it is insensitive to the electric light). In day-light following approach closed-loop integral control tends to supply too little illumination, while open-loop control produce the best energy savings in office building with the currently available systems (CEC-EPRI, 1993).

Control modules can be easily implemented in IENUS. Particularly in this paper the following systems, that reflect the up-to-day available technology, are implemented and analyzed:

- A daylight control system can operate a motorized internal curtain, to avoid overheating and people glare, on the base of light photosensors signal. The controller Daylighting Set point (*DLS*) fixes the maximum tolerable solar irradiation inside the room. *DLS*, sensors position and type of response to the daylight can be changed at pleasure.
- An electric light control system verifies the natural illumination level in order to supply artificial light. The natural luminance level can be verified in different points inside the room and the artificial light, in response to an Artificial Light Set point (*ALS*), can be dimmed or turned on/off in one or more zones.

CALCULATION HYPOTHESES

The results are referred to a typical office room located in Rome (Ciampino, 42°- latitude North). The adjoining spaces are conditioned and the inside air temperatures are basically equal to the indoor temperature of the considered room. The room dimensions are: floor and ceiling 5x7 m^2, external front and rear walls 5x3 m^2, and lateral walls 7x3 m^2. The window systems are assembled with a 75 mm in width Al frame, having a thermal transmittance of 3.97 W/(m^2K). The considered window is 3.15 x 2.15 m, with 3.00 x 2.00 m glazed area. Window systems central and global thermal properties are reported in Table 3. The window center is displaced 1.80 m above the floor and in the axes respect to the external wall; the window is recessed 0.10 m with respect to the external wall surface. The window is externally unobstructed without external overhangs, while the office room is at the third level.

Room furnishing is ordinary and without carpet. The external wall thermal transmittance is U=0.50 W/(m^2K) while the envelope construction weight is about 200 Kg/m^2 of floor. The following usage aspects characterize the room:

- People occupancy: 3 office workers everyday from 8:00 AM to 20.00 PM;

- People sensible heat: 50 W/person (50% convective and 50% radiative);
- artificial light: flourescent lamps with recessed, not vented fixtures, from 8:00 AM to 20.00 PM when it is required by the system control. Lighting system utilization factor is about 0.83 lx/W
- HVAC running period: everyday from 6.00 AM to 21.00 PM;
- latent loads, ventilation, infiltration and equipments loads are not considered;
- thermostat throttling range: 1 °C;
- design indoor dry-bulb temperature is compensated with the outdoor temperature and it varies from 20 °C in winter to 26 °C in summer

The daylighting control system acts on a motorized internal curtain, that can assume only two position (completely closed or opened); photosensors are sided between the internal curtain and the window, while the system respond to the direct solar radiation by *DLS*.

Artificial light control provided the required amount of artificial light with an on/off action or with a dimming action. Light sensors, connected in an open-loop control system, can realize a one, two or three zone control with a daylight following approach illumination level. Zone *ALS*'s fix the minimum zone illuminance to operate the artificial light system.

The internal curtain has a shading coefficient SC= 0.4 and τ_{vnn}= 50%, while the direct light transmitted diffusely is τ_{vndiff} = 10%. The angular dependence of the curtain light transmission is not taken into account.

*SSLE*s coefficient are determined by a luminous efficacy of 115 lm/W for the direct component of the solar irradiance and 120 lm/W for the diffuse one. Five inter-reflections are considered to calculate the reflected component by Superlite, while the number of nodes are fixed in 15 for the window, the rear and the front wall, in 21 for the left and right walls and in 35 for the working plane, that is 0.8 m above the floor. The required indoor data are: internal walls visible reflectance 50%, floor reflectance 20%, ceiling reflectance 80%, outdoor ground reflectance 20%. All reflectances are assumed "lambertian".

De Giorgio (Mazzarella, 1997) TMY is used as hourly meteorological input data set. CTFs reported by CNR (1982), RTF and SAFT expressed by ASHRAE (1993:28.15) formulation are used in the thermal simulation.

All kinds of energy requirements are reported into petroleum equivalent ton (tep) to evaluate the total yearly energy demand. The following conversion factors are used:

- Cooling system with electric chiller: $2.17\text{x } 10^{-2}$ tep/GJ (performance COP=3.2);
- Heating system with gas boiler: $3.23\text{x}10^{-2}$ tep/GJ (efficiency η=0.8);
- Artificial light system: $8.68\text{x}10^{-2}$ tep/GJ (ballast factor BF=0.8);

RESULTS

Yearly energy requirements, both for room sensible cooling/heating and for the artificial lighting system, are analysed.

Yearly total energy demand for different *LCS's* is reported in Table 4. The daylight and the artificial set points are respectively fixed at *DLS*=30 W/m^2 and *ALS*=500 lx for each zone; the Design Lighting Level *DLL* is 500 lx for this example with lamps total power of 600 W. *DI* is the Daylight Illuminance.

The artificial lighting system on/off control is turned on at its full design power when the natural daylight illuminance *DI* falls below *ALS* set point , in the rear of the room.

The artificial lighting system dimming control keeps the illuminance constant at the *DLL* in each considered zone by reducing lamps light output. Equal floor strips parallel to the external wall represent dimming zones. Each zone is controlled by its local photosensors. Zonal *DLL's* and *ALS's* are the same for all the room assumed zones.

On/off control is the less energy efficient system, as it produces illuminance above the design lighting level, while in dimming control energy demand is less.

Glazing system solar and visible transparences influence energy demands in a quite complex way. When the glazing system transparence τ decreases, an increasing of the internal curtain closing time is manifested ; but solar energy amount flowing into the room, with the curtain closed, increases with τ. The resultant indoor daylight can be sufficient to guarantee the required illuminance or can cause the artificial lighting system turning on. Indoor daylighting is influenced by the optical properties of the room walls and curtains, by the outdoor sun irradiation and by the daylight set point *DLS*; beside lamp consumptions also depend on the artificial light set point *ALS* and on the design lighting level *DLL*.

The increasing in the number of dimming zones reduces both total energy demands and differences among windows. The first reduction is less evident in glazing systems with small visible transparences (Table 4), but becomes important with greater transparences, when the artificial lighting plays an important role due to the increasing of the internal curtain closing time. Table 5 reports yearly zone consumptions and the operating time of the artificial lighting systems for different light controls; internal curtain closing times, expressed as percent of the yearly working hours, can be seen in Table 6 for different *DLS*'s (30 or 80 W/m^2) .

For example, yearly total energy demands for an on/off control system is reduced with a three zones dimming of about 1% for the less transparent glazing system *ISF1* and of about 40% for the clearest *ISF4*. These two windows have respectively the internal curtain close for 43% and 53% of the yearly working hours (as shown in Table 6, South exposition).

The decrease of the design illuminance level *DLL* also mitigates the different behavior of windows and reduces yearly total energy demand. This effect can be seen by a comparison between Table 4 and Table 7, referred to *DLS*=30 W/m^2. Table 4 and Table 7 differ for their *DLL* value, respectively 500 lx and 250 lx, while *ALS=DLS*. *ISF1* and *ISF4* glazing systems for a three zones dimming and a window sided South demand respectively 0.250 tep and 0.350 tep for *DLL*=500 lx, (Table 4) , 0.164 tep and 0.205 tep for *DLL*=250 lx (Table 7). More transparent windows, as it is for *ISF4* respect to *ISF1*, increase the energy demand, ranging from 10%, when *DLL=ALS*=500 lx, to 5% when *DLL=ALS*=250 lx. An on/off control system on the other side increases the differences to 35% for the higher *DLL*.
The decreasing in *DLL* values minimizes also the difference among control light system types, because artificial lighting system energy consumptions assume less importance respect to cooling/heating thermal loads.
The effect of the outdoor solar irradiation is reported in Table 8, in which yearly total energy requirements are presented as a function of windows exposure. The *ISF1* glazing system is penalized by its low transmittance τ, which reduces availability of indoor natural light and increases the use of artificial light.
The effect of *DLS* can be seen in Table 4 and Table 9. A decreasing in *DLS* value tends to reduce energy demand for the more transparent glazing systems, due to the reduction of the curtain closing time (see Table 6) that produces smaller requirements of artificial light. In table 9 , *DLS* value is 80 W/m^2, while in Table 4 *DLS* value is 30 W/m^2, and the corresponding energy requirements are 0.362 and 0.350 tep (*ISF4* window, dimming 3 zone, window sided South, *DLL=ALS*=500 lx); if *DLL=ALS* is reduced to 250 lx, energy requirements become respectively 0.223 tep (Table 9) and 0.205 tep (Table 7) as the solar gain load becomes the room prevailing load in respect to the others. This effect is influenced by the outdoor solar irradiance, that means by the window orientation.

OCCUPANTS INTERACTION

Evaluation of occupants interaction with the light environment is quite complex in Mediterranean climate as there are not enough studies devoted to the people behavior in working place. The use of field study results developed in other countries (for example in UK by BRE, Building Research Estabilishment (Hunt 1980), in Germany by Fraunhofer Institute for Building Physics (Szerman, 1994) seems to be not suitable for different climate conditions and life habits.
Direct sun light penetration into the room and window glare are assumed as conditions for which occupants close the internal curtain. The first condition takes into account the uncomfortable being due to glare (both direct and indirect on horizontal working surfaces) and to local overheating. Sun penetration is considered acceptable if it does not hit the space occupied by people, that it is supposed to begin about 1.0 m from the external wall. Window daylight glare, following the study by Chauvel *et alt.* (1982) is critically dependent on the sky luminance, so we use the relationship between Daylight Glare Index DGI and sky luminance reported by Petherbridge and Longmore (1962) for the considered window size; DGI is considered acceptable when minor than 22.
With the internal curtain closed or with low external solar radiation the internal illuminance can become uncomfortable; in this situation occupants turn on the artificial light. The probability of someone switching on the lights is related to the daylight illuminance at the darkest point on the working plane. As probability indexes are not available for Mediterranean climate, calculations were carried out by fixing two different values of the minimum daylight illuminance at 1.0 m from the rear wall of the room (200 and 500 lx).
For manually controlled office space the artificial light and the internal curtain are usually either on or off (open or closed) and the most activity in changing their status is confined to the extremes of the occupation period. To take into account this behavior in the simulation, when the artificial light is turned on, it remains in the same status for all the working hours of the considered day. The same criterion is used for the internal curtain. At the beginning of each day the artificial light is off and the curtain opened.
Yearly total energy demand is reported in Table 10 for different orientations.
The effective yearly total energy demand is sided between the two values reported in Table 10 (respectively for a manual operation of the artificial lighting system at 200 and 500 lx at the rear of the room) and its exact value can be determined only on a base of statistic study.
Besides occupants interaction increases artificial lighting system working time is on and it produces an increase in yearly total energy demand.

CONCLUSIONS

The lighting control system design and management appears more important than the glazing systems optical properties, as the best systems tend to reduce yearly total energy demand differences among different low-e coated glazing materials.
Glazing system solar and visible transparences influence energy demand in a quite complex way. High visible transmittance glazing systems increase natural lighting and glare, that can not always be compensated by the solar heat gain reduction due to low solar transmittance. Besides glare requires to close internal curtain, that change both distribution

and flow rate of indoor natural light. The balancing of the aforementioned phenomena with the light controls conditioned the energy performance of used systems.
The energy performance is also greatly influenced by the window size and room geometry that are not analyzed in this paper. Glazing systems with high transparence are more suitable for small size windows and rooms with a small ratio between window and floor surface.
Occupant interactions influence negatively the realizable benefits of daylight control systems in a way that can be assessed only by statistical studies and analyses.

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NOMENCLATURE

τ	: transparence
ε	: infrared emittance
ALS	: artificial lighting system
ALS	: artificial lighting system
DLL	: design lighting level
DLS	: daylighting set point
LSC	: lighting control system
r	: reflectance

U	: total heat transfer coefficient		*h*	: hemispherical
			dif	: diffuse
Indices			*dir*	: direct
c	: center of glazing materials or systems		*s*	: solar
v	: visible			
n	: normal			

Table 1: Glazing material central optical properties

Cod.	*Type*	τ_{vn} *[%]*	τ_{sn} *[%]*	ε_1 *[%]*	ε_2 *[%]*	r_{vn1} *[%]*	r_{vn2} *[%]*	r_{sn1} *[%]*	r_{sn2} *[%]*
CL1m	Clear 6 mm	88.1	77.5	84.0	84.0	8.0	8.0	7.1	7.1
SF1m	Colored 6mm Low-e	40.3	24.3	84.0	11.0	12.2	14.5	19.5	23.8
SF2m	Colored 6mm Low-e	53.6	34.6	84.0	10.0	7.3	9.8	15.5	21.2
SF3m	Colored 6mm Low-e	72.8	35.8	84.0	9.0	5.2	4.3	6.6	22.7
SF4m	Clear 6mm Low-e	85.0	56.4	84.0	9.0	5.4	5.2	14.4	23.7

Table 2: Glazing systems central optical properties:Air gap 15.7 mm

Cod.	*Type*	τ_{vn} *[%]*	τ_{sn} *[%]*	τ_{vh} *[%]*	τ_{sh} *[%]*	r_{vn1} *[%]*	r_{vn4} *[%]*	r_{sn1} *[%]*	r_{sn4} *[%]*
ISF1	*SF1m+Air+CL1m*	35.9	19.2	30.0	15.7	13.5	19.4	20.0	21.6
ISF2	*SF2m+Air+CL1m*	47.6	27.2	39.7	22.4	9.6	15.7	16.4	20.0
ISF3	*SF3m+Air+CL1m*	64.4	28.2	53.6	23.2	9.5	11.3	7.5	21.0
ISF4	*SF4m+Air+CL1m*	75.2	44.5	62.6	36.5	11.2	12.1	16.7	21.6

Table 3: Glazing systems central thermal properties and window thermal transmittance

Cod.	U_c *[W/m²K]*	SC_{cn} *[-]*	$SHGC_{cn}$ *[-]*	$SHGC_{ch}$ *[-]*	*U* *[W/m²K]*
ISF1	1.80	0.31	0.27	0.23	2.03
ISF2	1.78	0.41	0.36	0.31	2.02
ISF3	1.76	0.43	0.37	0.32	2.00
ISF4	1.76	0.62	0.54	0.46	2.00

Table 4: Yearly sensible energy required for room cooling / heating and artificial lighting system electric consumption (South, *DLS*=30 W/m^2, *ALS*= 500 lx, *DLL*=500 lx)

--	On/off			Dimming 1 zone			Dimming 2 zones			Dimming 3 zones		
Cod	*Hvac [GJ]*	*Light [GJ]*	*Tot. [tep]*	*Hvac [GJ]*	*Light [GJ]*	*Tot. [tep]*	*Hvac [GJ]*	*Light [GJ]*	*Tot. [tep]*	*Hvac [GJ]*	*Light [GJ]*	*Tot. [tep]*
ISF1	3.09	2.03	0.253	3.08	2.01	0.252	3.08	2.01	0.251	3.08	2.00	0.250
ISF2	7.81	7.31	0.807	4.94	4.03	0.462	4.51	3.46	0.400	4.39	3.30	0.388
ISF3	6.32	5.66	0.631	4.38	3.25	0.383	4.12	2.87	0.344	4.05	2.76	0.330
ISF4	7.66	4.88	0.594	6.06	2.95	0.392	5.83	2.63	0.360	5.77	2.55	0.350

Table 5: Yearly zone consumption and operating time (as percent of the yearly working hours) of the artificial lighting system (South, *DLS*= 30 W/m^2,*ALS*=500 lx, *DLL*= 500 lx)

--	On/off		Dimming 1 zone		Dimming 2 zones				Dimming 3 zones					
	---		---		1st zone		2nd zone		1st zone		2nd zone		3rd zone	
	[GJ]	*[%]*	*[GJ]*	*[%]*	*[GJ]*	*[%]*	*[GJ]*	*[%]*	*[GJ]*	*[%]*	*[GJ]*	*[%]*	*[GJ]*	*[%]*
ISF1	2.03	21	2.01	21	1.01	21	1.00	21	0.67	21	0.67	21	0.66	21
ISF2	7.31	77	4.03	77	2.01	77	1.45	50	1.34	77	1.11	62	0.85	41
ISF3	5.66	60	3.25	60	1.63	60	1.24	40	1.08	60	0.93	47	0.75	32
ISF4	4.88	51	2.95	51	1.47	51	1.16	34	0.98	51	0.85	42	0.72	29

Table 6: Internal curtain closing time (as percent of the yearly working hours; *DLS*=30 W/m^2 and 80 W/m^2)

Cod	South		West		North		East	
	30 W/m^2 [%]	*80 W/m^2 [%]*	*30 W/m^2 [%]*	*80 W/m^2 [%]*	*30 W/m^2 [%]*	*80 W/m^2 [%]*	*30 W/m^2 [%]*	*80 W/m^2 [%]*
ISF1	43	20	29	21	2	0	19	12
ISF2	47	26	33	24	2	1	23	15
ISF3	51	34	36	26	3	1	25	17
ISF4	53	38	37	27	3	1	26	18

Table 7: Yearly sensible energy required for room cooling / heating and artificial lighting system electric consumption (South, *DLS*= 30 W/m^2, *ALS*=250 lx, *DLL*=250 lx)

--	On/off			Dimming 1 zone			Dimming 2 zones			Dimming 3 zones		
Cod	*Hvac [GJ]*	*Light [GJ]*	*Tot. [tep]*	*Hvac [GJ]*	*Light [GJ]*	*Tot. [tep]*	*Hvac [GJ]*	*Light [GJ]*	*Tot. [tep]*	*Hvac [GJ]*	*Light [GJ]*	*Tot. [tep]*
ISF1	2.95	1.01	0.166	2.95	1.00	0.165	2.95	0.99	0.164	2.95	0.99	0.164
ISF2	3.69	1.91	0.255	3.42	1.26	0.194	3.41	1.16	0.186	3.40	1.13	0.184
ISF3	3.48	1.46	0.212	3.41	1.11	0.182	3.41	1.06	0.178	3.41	1.05	0.177
ISF4	5.11	1.32	0.233	5.00	1.07	0.210	4.99	1.03	0.206	4.98	1.02	0.205

Table 8 : Yearly sensible energy required for room cooling / heating and artificial lighting system electric consumption (*DLS*=30 W/m^2, control type: dimming 3 zone)

Cod.	*ALS*= 500 ÷ *DLL*= 500 lx			*ALS*=500 lx ÷ *DLL*=250 lx		
	West [tep]	*North [tep]*	*East [tep]*	*West [tep]*	*North [tep]*	*East [tep]*
ISF1	0.259	0.295	0.298	0.184	0.197	0.196
ISF2	0.601	0.509	0.611	0.252	0.218	0.251
ISF3	0.515	0.420	0.524	0.227	0.206	0.230
ISF4	0.511	0.410	0.532	0.245	0.216	0.259

Table 9 : Yearly sensible energy required for room cooling / heating and artificial lighting system electric consumption (*DLS*= 80 W/m^2, control type: dimming 3 zone)

Cod.	*ALS*= 500 ÷ *DLL*= 500 lx				*ALS*= 250 lx ÷ *DLL*= 250 lx			
	South [tep]	*West [tep]*	*North [tep]*	*East [tep]*	*South [tep]*	*West [tep]*	*North [tep]*	*East [tep]*
ISF1	0.263	0.262	0.294	0.301	0.174	0.183	0.197	0.197
ISF2	0.378	0.587	0.509	0.599	0.196	0.250	0.218	0.249
ISF3	0.333	0.497	0.420	0.508	0.180	0.228	0.205	0.231
ISF4	0.362	0.499	0.410	0.522	0.223	0.251	0.291	0.267

Table 10 : Yearly sensible energy required for room cooling / heating and artificial lighting system electric consumption with occupants interaction

Cod.	Electric light manually turned on below 200 [lx]				Electric light manually turned on below 500 [lx]			
	South [tep]	*West [tep]*	*North [tep]*	*East [tep]*	*South [tep]*	*West [tep]*	*North [tep]*	*East [tep]*
ISF1	0.314	0.436	0.440	0.326	0.314	0.436	0.440	0.326
ISF2	0.561	0.867	0.779	1.022	1.001	1.030	1.000	1.022
ISF3	0.414	0.686	0.568	1.018	0.937	1.032	1.000	1.026
ISF4	0.495	0.644	0.545	0.927	0.886	1.077	1.038	1.071