Towards Environmental - Responsive Electronics Megastores:
A case study in Markopoulo, Greece

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ABSTRACT: The paper reports on a dissertation project undertaken in the course of the 2007-08 academic year as part of the AA School's Masters Programme in Sustainable Environmental Design. By using an electronics Megastore building as a learning tool in terms of its environmental performance, as well as of its energy consumption, the objective was to explore the abilities of this building type to reduce non-renewable energy consumption and hence to obtain environmental character. The paper puts forward the implementation of a new adaptive comfort range compatible with this building type and appropriate ventilation strategies as well as the use of roof ponds in order to reduce the annual loads of such buildings and hence the energy consumption.
Keywords: energy consumption, Electronics Megastore, adaptive comfort, natural ventilation, roof pond

INTRODUCTION

Electronics Megastores are commercial buildings, which sell electronic devices such as TVs, laptops and other domestic appliances that consume energy when people use them. Not only they sell energy consuming items, but also they utilize large amounts of energy in order to power the appliances on display for 12 hours a day, compared to other commercial buildings. However, items on display contribute to building's internal gains affecting its thermal behaviour. They help the temperature rise during the cold period of the year, while they contribute to the space overheating during the hot period. Therefore, they reduce the heating loads and they increase the cooling loads of the space.

In order to reduce Electronics Megastore's cooling and heating loads by environmental means, passive strategies are tested in Tas thermal simulation software. The strategies which were chosen are natural ventilation [1] and the implementation of a new adaptive comfort zone according to the new ASHARE Standard 55–2004 [2]. Finally an exploration with calculations incorporating literature review in order to further cool down the Megastore by using roof pond is served.

Architectural literature lacks of such type of buildings. This paper is based on a case study of an Electronics Megastore in Markopoulo, Greece (Electronet Beis). This building was chosen as a case study because the author of this report had full access to all the relevant data of the building, due to his involvement in the refurbishment design as well as the supervision of the construction. The aim of the project is to use this building as a learning tool in terms of the environmental performance and the energy consumption of the Megastore. By understanding how the internal gains affect the internal space and where the energy is consumed in such type of buildings; the conclusions intent to help this type of building to obtain an environmental character.

CONTEXT

Climate Weather data for Markopoulo city (37.52°N 23.55°E) were obtained using an appropriate internet weather database for various Greek cities [3]. Markopoulo has a typical Mediterranean climate, characterized by mild, wet winters and hot, dry summers. Figure 1, highlights three distinct periods: a six – month period of cold weather (November to April inclusive) characterized by daily mean temperatures below 15°C; a mild period (May, September and October) with mean temperatures of 19-22.9°C, and a warm - hot period (June to August inclusive) with mean temperatures of 26.4-28°C. However, during the warm period there are two months, July and August, which are extremely hot months with the maximum mean temperature around 33°C. Thus, the building is expected to have high cooling demands. Finally, throughout the year mean relative humidity varies from 47% in July to 70% in December.

Table 1: Adaptive comfort for the Electronics Megastore (PPD 20%)

Month	Tmean °C	relative humidity %	air velocity m/s	met	clo	Tmin °C	Tmax °C	1<PMV<1
jan	11.6	68.8	0.1	1.3	1.12	**15**	23.7	-0.84
feb	10.2	68	0.1	1.3	1.12	**15**	23.8	-0.85
mar	12.6	65.9	0.1	1.3	1.12	**15**	23.9	-0.85
apr	15.4	62.6	0.1	1.3	1.12	15.1	24	-0.85
may	20.7	59	0.25	1.3	0.42	23	28	0.84
jun	26.4	52.8	0.25	1.3	0.42	23.1	28.1	0.84
jul	28.7	47	0.25	1.3	0.42	23.2	**28.3**	0.84
aug	28	47.1	0.25	1.3	0.42	23.2	**28.3**	0.84
sep	22.9	53.4	0.25	1.3	0.42	23.1	28.1	0.84
oct	19	62.1	0.25	1.3	0.42	22.9	27.9	0.84
nov	14.2	68.7	0.1	1.3	1.12	**15**	23.7	-0.84
dec	9.9	70.2	0.1	1.3	1.12	**15**	23.8	-0.84

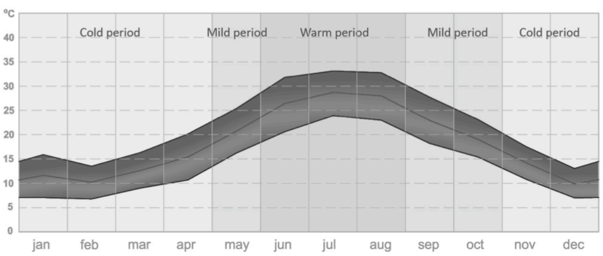

Figure 1: Monthly mean temperatures in Markopoulo, Greece.

Comfort In order to reduce the use of air – conditioning and hence the energy consumption, it is essential to narrow the temperature difference between indoors and outdoors. This will require the acceptance of adaptive standards of thermal comfort as now commonly understood by the international scientific and engineering communities [4].

In an Electronics Megastore there are two major categories of occupants; the employees (sellers) and the customers. Usually the customers have different clothing level (clo) than the sellers. During the cold months they enter the megastore wearing their jackets. Therefore, for the cold period a clothing level of 1.1 clo or even more has to be admitted for the customers. The clo value of 1.1 involves a jacket that very often the customers wear during the cold period; so they can keep on wearing their jackets indoors. As for the sellers they can be dressed accordingly; a similar clothing level around 1clo will offer them comfort. Metabolic rate for both customers and sellers is 1.3 met which means that they are stranded – walked [5]. On the other hand, during the hot period clothing level becomes 0.4 clo; while the metabolic rate remains the same. Also, in order to extend the comfort zone towards 28°C, air velocity has to be increased to 0.25m/s. The values which were calculated by Berkeley tool software are illustrated in the table 1. Those values satisfy the thermal comfort criteria as they are described by the international standard ISO 7730 and ASHARE Standard 55– 2004.

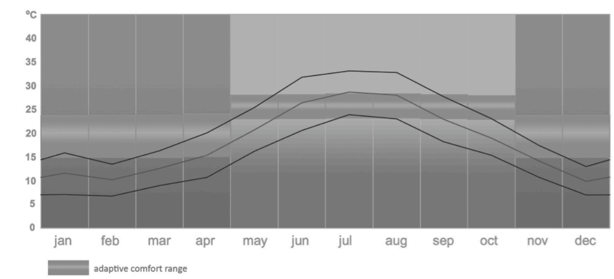

Figure 2: Thermal comfort range for the Megastore in Markopoulo according to the Berkeley tool software.

Figure 2 illustrates the new adaptive comfort range for each period during the year. During the cold period the accepted comfort range is 15 - 24°C; while, during the hot period the new comfort range is 23 - 28°C. Conclusively, it can be argued that the interior space of an Electronics Megastore can provide general comfort requirements to the most of the occupants, having at the same time the option of private – spot heating for some of the employees like the cashiers. As such, most of the area of the store can be heated and cooled according to the new extended comfort zone of 15 – 28 °C.

THE CASE STUDY OF ELECTRONET BEIS

The building Electronet Beis Electronics Megastore is a two-storey rectilinear building with a basement. The general dimensions of the basic building are approximately 38m x 8m with some 306m² of floor area for each floor above the ground and some 590m² of floor area for the basement. The construction of the building combines concrete structure and brick walls. , all the openings are double glazing with aluminium frames. After the renovation, the building obtained a second external layer as a second skin, which is made by perforated metal panels (fig. 3).

Figure 3: Electronet Beis, Electronics Megastore in Markopoulo, Greece.

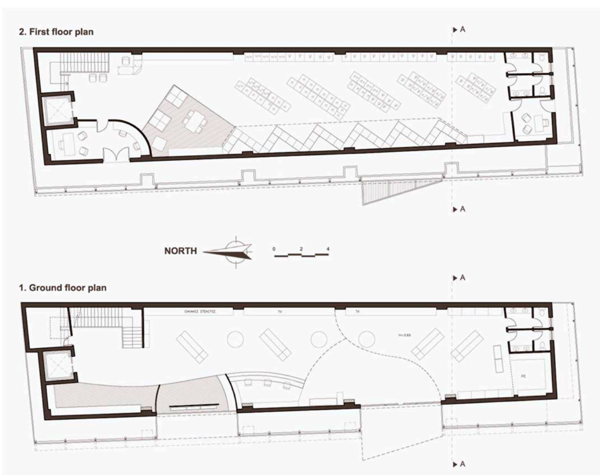

Figure 4: Ground floor and first floor's plans.

Electronet Beis sells electronic devices and other home appliances. Most of the merchandise is electrical appliances divided into departments over two floors. All the electronic devices such as televisions, laptops, cameras, gadgets etc. – the so called "**black goods**" – are situated on the ground floor, while the other domestic appliances such as cookers, dishwashers, fridges etc – the so called "**white goods**" – are situated on the first floor. The basement is used as a storage area.

Figure 5: "black goods" - "white goods"

As far the environmental design is concerned, the division into departments is not only a colour division and a way to group the merchandise, but it is also a division in terms of energy consumption. For that reason an energy consumption analysis is served.

Energy performance assessment The year 2007 was selected as representing a typical year of the Megastore's energy performance. According to the energy consumption bills for the year 2007, the average energy consumption for each month is about 9,500 kWh, and the total energy consumption for the year 2007 is some 114,520 kWh.

The building consumes energy for **artificial lighting**, for **heating** and **cooling** purposes and to **power the appliances it displays**. Also, a small amount of energy is consumed by the lift and by external lighting. Heating and cooling requirements are covered by a mechanical air-conditioning system. When the indoor temperature drops under 20°C mechanical heating is switched on and when it rises above 26°C mechanical cooling takes on; however, the air-conditioning system is operating only during the opening hours of the building. Finally, hot water is excluded from heating since the building does not have such requirements.

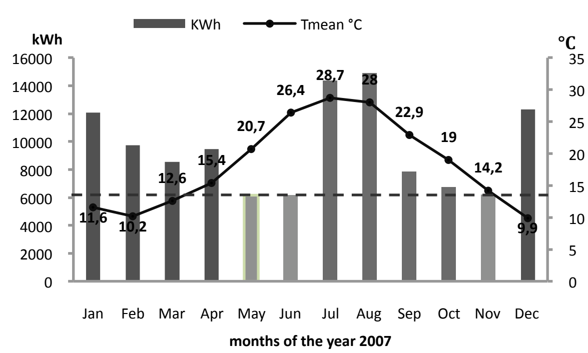

Figure 6: Energy consumption vs Temperature for the year 2007.

Figure 6 shows the comparison of monthly mean temperatures for the year 2007 and the Megastore's energy consumption. The building during May, June and November was behaving as free-running; so, the air-conditioning system was off. From December until April the building had heating demand. Assuming that the energy which was consumed during the neutral months is the consumed energy for the building's needs apart from air-conditioning, it can be argued that some **6,200** kWh/month is the energy consumption for the aforementioned demand. From July to October inclusive the building had cooling demand. It is remarkable that July and August were the months with the highest energy requirements in terms of cooling! The building's energy consumption for each of the peak summer months increased sharply to 231%, relatively to the neutral month's energy consumption.

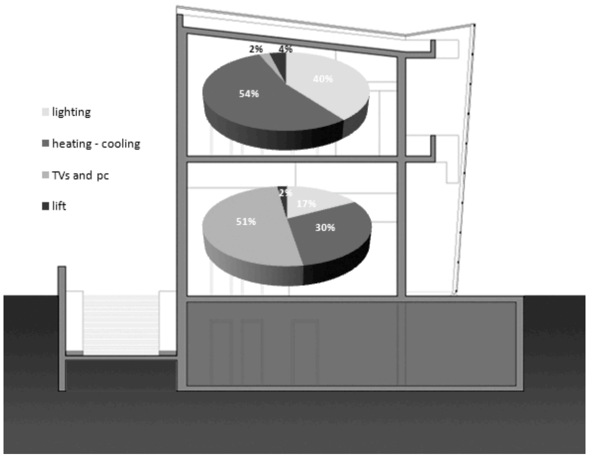

Figure 7: Energy breakdown for the ground floor and the first floor.

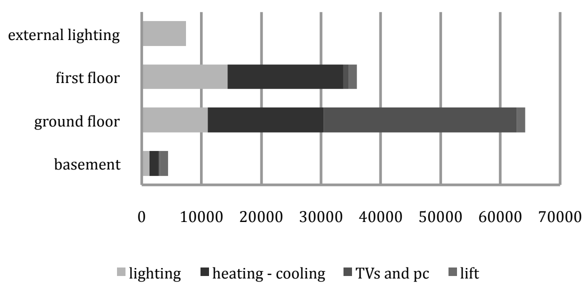

Figure 8: "Electronet Beis" Electronics Megastore – energy breakdown for the year 2007 (in kWh).

Building's energy breakdown (Figs 7 – 8) show that some 51% of the ground floor's energy was used to operate appliances on display, with the balance of 49% accounting for artificial lighting, mechanical air – conditioning and energy for the lift. On the other hand 54% of the first floor's energy was consumed for mechanical air – conditioning with the balance of 46% spent for artificial lighting, office equipment and energy for the lift. It is also noticeable (fig. 8) that the energy which was used in the ground floor is almost double the energy which was spent in the first floor because of the displays. Ground floor's annual energy consumption was calculated to be **210** kWh/m² and **118** kWh/m² for the first floor respectively.

It was indicated that within the same building there was different energy consumption between the two floors. Ground floor consumed almost double the energy which was used in the first floor. Commercial buildings in Greece consume some 152 kWh/m² per year [6]. Ground floor as a separate building type consumes 1.4 times more energy than the amount of energy a common commercial building consumes.

THERMAL PERFORMANCE

Methodology Dynamic thermal simulation software EDSL TAS (version 9.0.9d) was used to build a geometrically precise model of the Electronet Beis Electronics Megastore. Thermal properties of the materials were assigned according to reality to all construction elements. Internal conditions and the building schedule were allocated as well as the weather file of the climate of Markopoulo. Finally, the software was run to simulate passive heating and cooling strategies' impact to the model.

The model of the Megastore is a box shaped configuration. It consists of three floors; the basement the ground floor and the first floor. Six zones were set for the simulation; two in the ground floor and four in the first floor. Focus will be in the basic zone of the ground floor, which is named ground floor zone and in the major zone of the first floor, which is called first floor zone. Those are the zones which accommodate the merchandise of the Electronics Megastore.

Base case evolution The first task was to calibrate the performance of the base case comparing to the real data. The only unknown variable was the ventilation rate of the building. After a series of parametric studies in terms of ventilation rate it was proven that the value for the base case is 5.4 ach (infiltration and ventilation). Assuming that the value for infiltration rate is 1ach and it remains steady the whole day, the rest 4.4ach is ventilation and follows the building's schedule. Finally, thermostat's setpoints were allocated according to the reality; 20°C for heating and 26°C for cooling.

The implementation of adaptive thermal comfort Since the base case is set, the model is simulating again with the new set points of 15°C and 28°C for heating and cooling respectively. Thus, adaptive thermal comfort is applied to the Electronics Megastore.

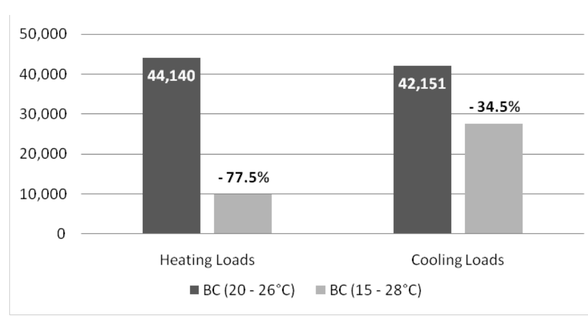

Figure 9: Annual Heating and Cooling Loads in kWh.

Figure 9 illustrates how the annual heating and cooling loads are reduced with the implementation of the new adaptive thermal comfort in the building. Annual heating loads are reduced by 77.5%; while the annual cooling loads are reduced by some 34.5%.

Ventilation Ventilation has a principal role in maintaining good indoor air quality. Ventilation air transfers efficiently the indoor pollutants from a building [7]. Therefore, ventilation rate can be calculated upon to fresh air requirements for the users. According to building's schedule, the mean occupancy in the Megastore will be thirty five people, twenty five in the ground floor and ten in the first floor. Fresh air requirements per each person are approximately 30 m^3/h of air, which means that the total required air supply is 30x35 = 1,050 m^3/h. The total volume of the building is 2,601 m^3. Consequently, the needed air supply will be 1,050:2,601 = 0.40 ach. This is the minimum amount of air exchanges the building needs in order to get rid of the CO_2 concentration from the occupants. Consequently, this value of ventilation will be the lowest value that will be accepted in the building of the case study.

Table 2: The effect of ventilation rate in the Electronet Beis Electronics Megastore.

total operational hours	3809	frequency (hours)					
temperature band (°C)		**<15**		**15<θ<28**		**28>**	
ground floor	1ach	89	2.3%	1926	50.6%	1794	47.1%
	B.C. (5.4ach)	578	15.2%	2064	54.2%	1167	30.6%
	9ach	857	22.5%	1924	50.5%	1028	27.0%
first floor	1ach	196	5.1%	2065	54.2%	1548	40.6%
	B.C. (5.4ach)	915	24.0%	1855	48.7%	1039	27.3%
	9ach	1138	29.9%	1775	46.6%	896	23.5%

In order to look into the exact effects of ventilation two simulations are run; one with ventilation 1 ach and one with ventilation 9 ach during the operational hours of the building. In particular, when ventilation rate is 1 ach the number of hours below 15°C is reduced dramatically from 578 to 89 hours on the ground floor and from 915 to 196 hours on the first floor. Also, the number of hours above 28°C is increased from 1167 to 1794 on the ground floor and from 1039 to 1548 hours on the first floor. Since ventilation rate has been reduced considerably the building became less coupled with the outside. Thus, it decreases the internal gains' dissipation and keeps them indoors. On the other hand, during the hot period the excess heat gains remain within the building and they increase the number of hours above 28°C in both floors, contributing to the space overheating. Furthermore, when ventilation rate is 9 ach the opposite results are occurring. The cold hours are increased and the hot hours are moderated.

Looking at the percentages of the total operational hours under, over and in between the comfort range (table 2), it is noticeable that in the ground floor the percentage of the hours which are in between the comfort range is remaining almost the same in all the cases. As far as ground floor is concerned, ventilation is affecting the extremes. At this point is important to mention that after a series of simulations, it was noticed that beyond a certain value of ventilation about 5 – 6 ach, the effect in both limits of the comfort zone are minimized.

To conclude with the above simulations, controlling the ventilation rate during the year will help the thermal performance of the Electronics Megastore. Keeping it in a value close to 1ach per hour during cold period will help significantly the building's thermal behaviour. On the other hand, during the hot period the building needs higher ventilation rate in order to dissipate the excess heat gains. In the final simulation the model is the same as the Base Case apart from ventilation rate which is set according to a specific schedule. Therefore, the above strategies are added to the building in a suitable way. Infiltration rate is set 1 ach for the whole year and the ventilation rate is set 0 ach during the cold period (November – April), and 5 ach during the hot period (May – October).

Table 3:The effect of ventilation in the final proposal the Electronet Beis.

total operational hours	3809	frequency (hours)					
temperature band (°C)		**<15**		**15<θ<28**		**28>**	
ground floor	B.C.	578	15.2%	2064	54.2%	1167	30.6%
	final proposal	88	**2.3%**	2592	**68.%**	1129	**29.7%**
first floor	B.C.	915	24.0%	1855	48.7%	1039	27.3%
	final proposal	196	**5.2%**	2679	**70.3%**	934	**24.5%**

In the final proposal, the percentage of the total operational hours below 15°C is 2.3% for the ground floor and 5.2% for the first floor. Also, the percentage of hours spent within the comfort zone has been significantly increased reaching 70% of the total operational hours. The percentage of hours above 28°C has been slightly reduced.

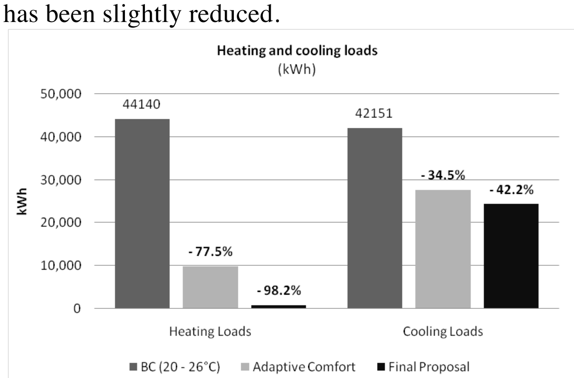

Figure 10: Annual Heating and Cooling loads in the final proposal.

Figure 10 illustrates the final annual heating and cooling loads for the Electronet Beis Electronics Megastore compared with similar loads of the Base Case and the Case with the implementation of adaptive comfort. A significant decrease of 98.2% to the heating loads of the building is followed by a meaningful drop of 42.2% in the cooling loads.

Roof Pond Despite the annual cooling loads have reduced some 42.2%, it is important to explore the possibility of further cooling the building. Roof ponds as a passive strategy affect the thermal behaviour of single storey buildings or the thermal performance of the building's last floor. Assuming that we can switch the Megastores' departments and hence first floors' internal gains will be replaced by ground floor's internal gains.

According to Yannas S. (2006) [8], there is a potential to further reduce the cooling loads by 41.6%, when the building obtain a roof pond with depth 0.3 m. By using roof pond cooling load will be reduced by **6554.56** kWh (0.41 x 15986.74 kWh). Therefore, after the introduction of roof pond the total output of cooling loads will be reduced some 27% (Fig. 11).

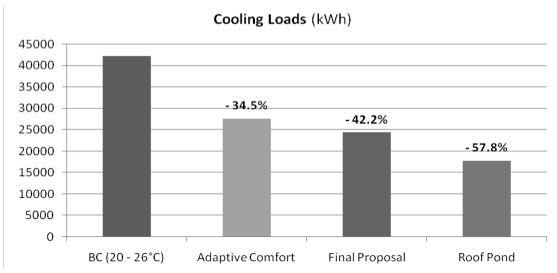

Figure 11: Final comparison of cooling loads.

CONCLUSION

Dealing with the energy performance of Electronics Megastores, through the case study in Markopoulo, Greece this paper illustrated where the energy is consumed in such buildings.

Through thermal performance simulations and with the incorporation of literature review, it has been indicated that Electronics Megastores have the potential to reduce non-renewable energy consumption by applying a new adaptive comfort zone, the strategy of natural ventilation as well as roof ponds. The above strategies are compatible with the climate of Markopoulo. In a similar way Electronics Megastores can obtain an environmental character by using environmental means to other parts of Europe.

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