HYBRID VENTILATION AND COOLING TECHNICS FOR THE NEW NICOSIA TOWNHALL

Flourentzos Flourentzou[*1], Dickon Irwin [2], Margarita Kritioti [2], Tasos Stasis[3], and Nicholas Zachopoulos[3]

1 Estia SA
Par Scientifique EPFL
1015 Lausanne, Switzerland
Corresponding author: flou@estia.ch

2 irwinkritioti.architecture
10 Gregoriou Xenopoulou
1061 Lefkosia Cyprus

3 Eliofotou, Zinieris & Stasis Partners
77 Strovolos Ave.,
Strovolos Center 4th Floor,
2018 Strovolos, Cyprus

ABSTRACT

The new Nicosia Town-hall is a very particular building. On the site where it is built, important antiquities were discovered during the first day of construction and the whole design was completely modified to fit to the new situation. The archaeologists continued to excavate 2/3 of the entire site and created an archaeological park in the centre of the town. The building area was constraint to the remaining land, and co-exists with the uncovered findings.

As a consequence, the building was split into 5 smaller units, 4 office and public service buildings and a municipal hall. Foundations were changed to a combination of piling between findings and large raft slabs sitting above the level of undisturbed ground. The design of office buildings followed the rules of bioclimatic architecture to meet the passive standards and the building is on process for Minergie® (Swiss) labelling. Massive buildings, naturally ventilated and cooled, offer a natural comfort with minimum energy consumption.

The hall follows completely different design principles. Above a large slab, sits a light structure and glazed façades, allowing maximum view and contact between the interior- where the municipal council meet- and the surrounding archaeological park.

According to good practice design rules, this building would be a bad building, especially in a hot climate. A completely glazed cube would certainly overheat and consume a lot of energy. To avoid this, the design proposes a hybrid ventilation system using a sophisticated natural air path to cool naturally the building. Several distinct air streams using smart stack effect path ventilate the building differently according to the time, to the use of the building and to the external climate, in order to reduce mechanical ventilation and air conditioning hours of use to the strict minimum. Ventilation system shifts automatically from natural to mechanical offering maximum comfort with minimum cooling, heating and fan energy consumption.

This original hybrid ventilation and cooling system made possible the particular architectural expression of the building with low energy consumption. The whole building complex makes a harmonious eco-neighbourhood with low-energy-consumption, confortable interiors and friendly shaded, wind-protected public spaces, open to the town, where urban life meets cultural heritage.

The article explains the ventilation concept, bioclimatic principles and the simulated comfort and energy performances.

KEYWORDS

Potential for ventilative cooling strategies; design approaches for ventilative cooling and case studies; summer comfort and ventilation; nnovative ventilation.

INTRODUCTION

The new Nicosia town hall (Cyprus) is not a simply green building showing several bioclimatic architecture principles. It is the first contemporary building in the island applying all the bioclimatic principles, which are necessary to meet the passive building standards (primary energy consumption for heating, ventilation, air conditioning and hot water production less than 30 kWh/m^2y).

The “town hall” is not a single building. Archaeological findings restricted the available land to the 1/3 of the initial available surface and the unique initial building is split to smaller units in order to fit in the remaining complicated site. 4 office buildings and a municipal hall, able to receive the council meetings in presence of 250 people, form a neighbourhood in Nicosia old town, just 100 m from the green line, where the war divided the city several decades ago.

Bioclimatic and sustainable architecture starts from the site use. The buildings respect the old town scales and they are integrated in the archaeological site not only preserving cultural heritage, but also making it available to the population, through walk paths, squares, and shaded patios. They create a public space with a social environment, where urban life meets culture and municipal services, in a marginalised district of the city, where social life is stopped for many years now. Orientation and disposition of the buildings group similar uses, separate polluting and noisy activities from office spaces, create natural shading to public space and neighbouring buildings.

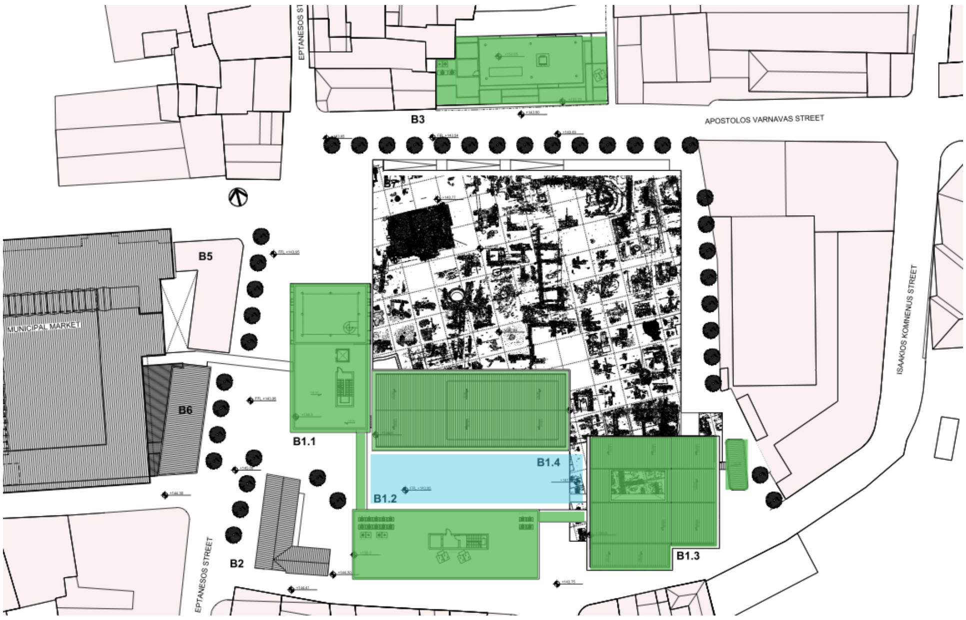

Figure 1. Instead of a single building occupying the whole land, a family of small buildings around the archaeological findings create interesting bioclimatic potential.

Figure 2. Panoramic virtual view of the building complex from the green roof of building 1.3; view of the municipal hall from the antiquities, view of the shaded patio between buildings B1.2 and B1.4. Only building B1.3 is finished. The other buildings are under construction.

Buildings B1.1, B1.2, B1.3 and B3 are massive and well-shaded office and public service buildings. Building B1.4 is the light structure, fully glazed 10 m height municipal hall. The square between buildings B1.2, B.3 and B 1.4 is shaded, providing solar protection to the three buildings and especially to the south glazed façade of the municipal hall. Building B1.3 is siting on 10 pillars over the archaeological site and it has an interior yard making available natural light and ventilation to the core of the building.

Regarding ventilation strategies, office buildings function with purely natural ventilation with specially designed vents. The municipal hall runs with a sophisticated hybrid system, with natural ventilation assuring air movement for free night cooling and mechanical ventilation distributing heat and mechanical cooling.

BIOCLIMATIC DESIGN, OF OFFICE BUILDINGS

The basic condition for a confortable thermal environment of offices is good insulation and solar protection. In south climatic conditions, with very hot summers and relatively cold winters, energy performance is necessary for both winter and summer seasons. A well-insulated building, with reasonable glazing orientation and solar protection, consumes 15-25% of the total thermal demand for heating and 75-85% for cooling. In the past, where buildings where not insulated, this ratio was inversed, with heating demand representing more than 75% of the total demand. This is illustrated on table 1 and figure 3.

Insulation	Heating demand	Cooling demand	Total demand
A. 0 cm, single glazing	149 (78%)	43 (22%)	192
B. 4 cm, double glazing - 3.5 W/m^{2}k	21 (25%)	64 (75%)	85
C. 10 cm, double glazing - 1.3 W/m^{2}k	8 (19%)	34 (81%)	42

Table 1. Heat and cooling demand of 3 building scenarios (building B3) simulated dynamically with DIA+ software: A-construction as it was usual before the entry into force of the energy Low (without insulation and with single glazing), B-with insulation and glazing respecting the minimum requirements of the local energy Law, C-with optimised insulation depth, high energy performance windows and with static solar shading, meeting passive standards. For all scenarios, there is no special free cooling strategy.

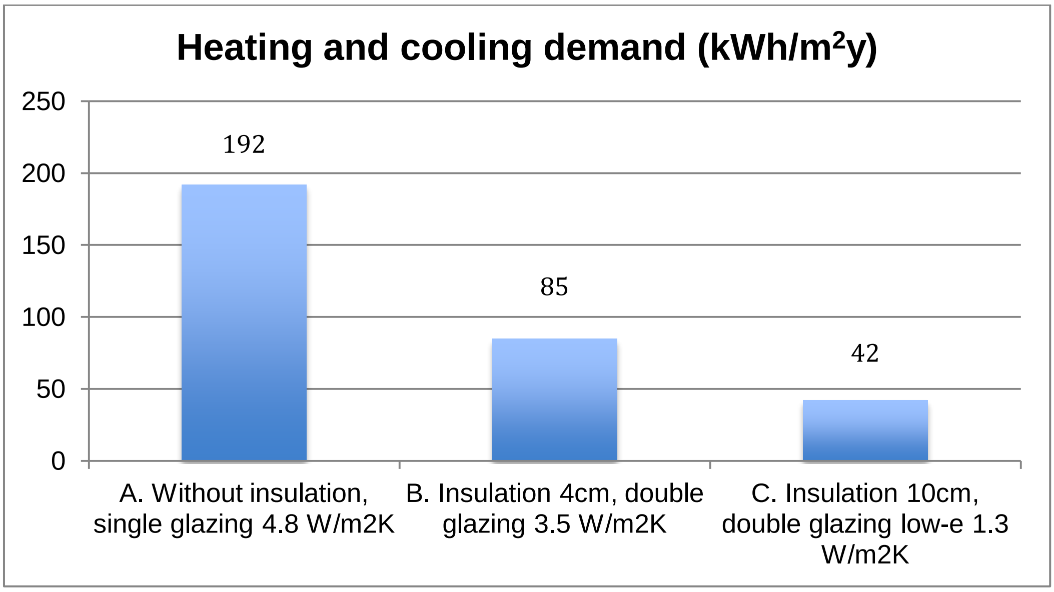

Figure 3. The graph shows heating and cooling demand, according to the 3 basic scenarios. Cyprus Energy Law reduces the energy needs to the 44% of those of a building, without any care for thermal insulation. Additional thermal insulation (10 cm instead of 4) and more insulated windows (U value 1.3 instead of 3.5), with 60 cm passive solar protection on the south façade, reduces the energy needs to the half of those of a building meeting the minimum legal insulation values. Passive buildings (C) have only 22% of the energy needs of non-insulated buildings (A).

Thermal insulation

After several optimisation dynamic simulations with DIAL+ software, we decided that the optimum insulation characteristics to meet the passive standards are 10 cm of rockwool for the roof and the facades, 5 cm for the periphery of the building and a U value of the windows of 1.3 W/m^{2}K. Thermal insulation on the ground does not change anything, as the mean ground temperature in Cyprus is high. A careful analysis and treatment of every joint between constructive elements minimises thermal bridges and heat losses in winter. External insulation gives the advantage of thermal mass inside the building.

Figure 4. Outside thermal insulation with minimised thermal bridges is composed mostly by 10 cm rockwool. Foundations are insulated with 5 cm xps. In some special cases it was necessary to use internal thermal insulation with 10 cm rockwool.

Thermal mass

An apparent cladded concrete ceiling and a floor composed with 4 cm anhydride screed over the concrete slab and rough concrete screed, offer a high thermal mass, absorbing excess heat during the day and restoring it during night. This optimises the use of internal heat gains during winter and reduces the pick temperature during summer.

Figure 5. Floor and ceiling are composed by massive materials with high thermal mass.

Solar shading

As building B3 is north - south oriented, static solar protection of 60 cm is sufficient. As we see from table 1, comparing scenario B with scenario C, solar protection reduces cooling demand in summer by nearly 50% (additional wall and window insulation plays a small role for the cooling demand).

1st February	1st April	1st June	1st July
24 %	48 %	88 %	91 %

Figure 6. The south façade (15° South – West) at 14:00 is shaded with 60 cm static top and side solar protection. The choice of a glazing with g value of 0.4 is a good compromise between summer solar protection and winter useful solar gains. The façade white ceramics is a robust, inert, self-cleaning material with low sun absorption, offering low façade temperature rise to prevent overheating of incoming air during summer. The table shows the solar shading during the year. In winter solar shading is minimum and in summer maximum.

1st May	1st June	1st July	1st August
86 %	60 %	57 %	74 %

Figure 7. As the north façade is 15° oriented east, early in the morning during June and July, sun hits the façade during 2 hours – 05:00 – 06:00. Some solar shading is necessary to protect north offices early in the morning. The table shows the shading efficiency of a 60 cm vertical static solar protection at 6 h in the morning.

Natural and artificial lighting.

In a context where air conditioning represent ¾ of the total energy demand, internal gain control is capital. Lighting counts for around 50% of the installed electric power. The question is how many hours the users will need to turn it on. High natural lighting autonomy is easy to obtain in a climate with 300 days of sunshine per year. The designer should even pay attention so that there is not excessive light coming from windows. A delicate equilibrium should be found between daylight needs, winter solar gains for passive heating and summer solar gain control. A north office of 4 m large has 2 modules of glazing of 140 X 300 (70% glazing), while a south oriented one a single module of the same dimensions (35% glazing).

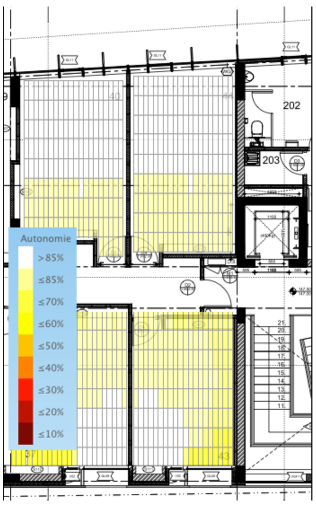

Figure 8. Natural light autonomy, simulated with DIAL+ software between 75 and 85% during working hours.

Several optimisation measures increase up to 30% the natural light autonomy: white colour walls and ceiling; reduction of glazing frames and rise of the window top, up to the ceiling; white colour external shading; glazing with high luminance transmission (g value 0.4, LT 0.7); light wash of the lateral white wall with the glazing moved to the side; These measures provide a natural light autonomy between 70 and 85% during working hours

In addition to natural light maximisation, artificial lighting uses high efficiency luminaires with installed power < 12 W/m^2. Light is automatically switched off when the office is empty.

Ecological materials and health.
The objective is not only a high-energy performance and confortable building but also a building using environmentally friendly materials, creating a healthy interior environment. Concrete for the structure, plain wood for the façade structure and the window framing (non treated larch), gypsum panels and rock wool for interior partitions, rock wool for the thermal insulation and ceramics for façade exterior facing, are the main materials used in the building. Joint synthetic substances are avoided. Instead of surface treatments and painting, the natural material colours create the chromatic synthesis and the aesthetical language. Wood is just oiled with linseed/turpentine/TiO mixture, avoiding varnishes and synthetic substances. The life cycle of the building elements is high, with low maintenance needs. Cyprus climate is very difficult for the exterior materials exposed to sun, dust and rain. The exterior façade facing with ceramics, white for façades with high sun exposure and coloured for other orientations, is a robust high life-span solution, adapted to the local environment.

There is no material in the building emitting VOC particles. The floor is done with anhydrite liquid screed, which is mineral and inert, offering high thermal mass and avoiding VOC emissions.

VENTILATION AND COOLING STRATEGIES OF OFFICE BUILDINGS
Before we adopt a ventilation strategy, we put on the balance 4 aspects: air flow necessary to assure air quality and occupant's health, energy consumption by fans or by thermal losses or gains because of excess ventilation, occupant's wishes / well-being. Some people, influenced by good practice in the North and Central Europe countries, concentrate on the possibility of heat recovery. They a priori consider that mechanical ventilation with heat recovery is a good practice for every climate and for every building use, extrapolating intuitively this conclusion from what happens in the cold climates.

Without excluding any solution, before adopting a ventilation strategy, we answered to 3 questions:

1. what are the wishes of the users and how do they feel in regards to the control of their environment;
2. what is the real impact of different ventilation strategies on heating, cooling and electricity demand;
3. what is the real risk of wrong use and bad ventilation control by the users ?

Question 2 and 3 may have a different answer according to climatic conditions, building function, physical characteristics of construction elements.

Users wishes and feelings in regard to ventilation systems.
The objective was not only a high-energy performance and a confortable building. A municipal building is a professional tool for public service. Well-being of the users is a key factor on productivity and service quality. Before the building design, the great majority of

the municipality personnel answered to a questionnaire about their current indoor environment quality and their expectations from their new place of work. The personnel showed a high degree of environmental consciousness with low CO2 emissions being their second concern. 63 people imagine an exemplary building of natural comfort and only 23 an exemplary fully air-conditioned building. 30% of the people consider mechanical ventilation as problematic. Less than 5% considered natural ventilation from the window as problematic. These results confirm the results of European research, showing higher acceptance and lower building sick syndrome index in naturally ventilated buildings.

Impact of ventilation strategy and heat recovery on energy demand.

In order to quantify the impact of different ventilation strategies, we have simulated a typical section of the building with two offices of 4 m large, and 10 m deep representing the total depth of the building from north to south. One office faces south and the other north with an interior buffer corridor zone in the middle. The thermal model considers the whole space as a single zone with dimensions, building thermal characteristics and shading as explained in the previous paragraphs. It considers also standard use conditions and occupation schedules according to the Swiss regulations SIA 2024. DIAL+ software simulates dynamically the solar gains, internal temperature, and natural ventilation airflow, cooling or heating load and energy consumption.

For the electricity consumption we used an optimistic hypothesis of a high efficiency fan, consuming 0.16 W/m^3.h for simple extraction and 0.32 W/m^3.h for a system with heat recovery. We used a high-COP energy system of 4 to calculate electricity consumption.

Column Title	Heating need kWh/m^2	Cooling need kWh/m^2	Total thermal demand kWh/m^2	Fan electricity demand kWh/m^2	Total electricity demand kWh/m^2
1. Mechanical, 36 m^3/h.pers	6.7	35.5	42.2	1.5	12.1
2. Mechanical + heat recovery 80%	3.4	33.1	36.5	3	12.1
3. Natural with 10 cm tilted window	6.0	31.8	37.8	0	9.5
4. Natural with 10 cm standard window	9.6	35.2	44.8	0	11.2
5. Excessive ventilation - 50 m3/h.pers	7.5	36.2	43.7	0	10.9
6. Natural with night ventilation	9.6	16.5	26.1	0	6.5

Table 2. Heating and cooling and ventilation thermal and electricity demand.

From this table we can learn several not very well known truths.

1. Heat recovery in south climates is not always energy effective.

As we can see from the results in the second line of table 2, heat recovery may reduce thermal demand by 13% (5.7 kWh/m^{2}y), but it consumes 3 kWh/m^{2}y of electricity instead of 1.5 of a simple extraction system and 0 of a natural ventilation system. If we measure electricity to produce 5.7 kWh of heat or coolness with a system of COP = 4, the heat recovery system does not recover even the energy that it needs to run. It could be energy effective for cases with direct heating or very low COP cooling, or for cases of non-insulated buildings with very high demand for heating as it was the case before the Energy Law.

2. Controlled natural ventilation is the most energy effective strategy for office buildings.

We can see this, if we analyse the results of the 3rd line. Controlled natural ventilation with a well-designed window, allowing small openings during hot or cold hours, does not spend more energy than mechanical ventilation. If we take into account saved electricity to run fans, the total balance is positive for natural ventilation, with 9 kWh/m^{2}y of energy consumption instead of 12.1 of a mechanical one. Dynamic simulations of the airflow showed that a vent of

40 cm large by 140 cm high, in tilted position, provides almost always the necessary airflow for pollutant evacuation without excessive ventilation.

3. Excess ventilation, if it is reasonable, does not destroy the energy balance of the building.
Minergie® standard counts for natural ventilation an overestimated 50 m^3/h airflow rate (simulation of line 5), but if we take a pessimistic hypothesis considering that the window is kept open all the time at 10 X 300 cm, independently of how cold or hot is the outside temperature, we can see that heat demand is not excessive. It creates extra 6% losses (44.8 kWh/m^{2}y of thermal demand instead of 42.2). This is because extreme temperatures (38 to 42°C in summer end -2 to 5°C in winter) take place very few hours during the office working hours. Most of the time, temperature difference is moderate, not creating excessive thermal losses.

4. The most interesting energy saving potential lies in night ventilation free cooling.
As we can see from the results of line 6, a night cooling strategy reduces cooling demand by 56% (16.5 kWh/m^{2}y instead of 35.5) and the total energy demand by 38%. **This is the key energy potential for south climates.** It is equivalent of the passive heating for cold climates.

As a result of these findings, we concentrated the efforts to design a smart, simple and user-convenient window. This window should provide easy and intuitive control for limited ventilation during office hours and high airflow rate ventilation during night in summer. In addition, users should not thing how to ventilate; they have just to open a window. The opening should be protected, in order to control the risk of intrusion by undesirable people, animals, insects rain and dust. People should feel safe to leave the vents open during night without any concern.

Natural ventilation design and ventilation strategies.
Vents are vertical, opening on the whole room height, in order to maximise stack effect. With 5°C temperature difference between inside and outside, a 40 by 300 cm vertical vent creates a stack effect of 611 m^3/h, while the same vent in horizontal position 300 by 40 cm creates only 223 m^3/h. The right disposition of the vent opening may boost ventilation airflow by 275%! High airflow rates are necessary only during night. During the day only 36 m^3/h per person are necessary. An opening of 40 by 140 cm height may provide 75m^3/h at a $\Delta T = 5°C$ and 47m^3/h at $\Delta T = 2°C$. These dimensioning calculations leaded us to divide the high vent in two parts and to make it open right or tilted. The user instructions become simple and easy to understand: “tilt the top vent during working hours winter or summer. During winter, you close it when leave the office and during summer, you open completely one or both vents, according to your cooling needs; you put it back to the tilted position in the morning.”

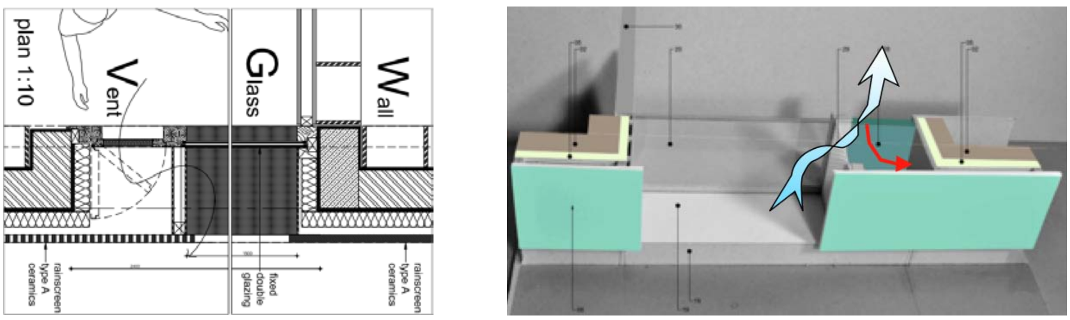

Figure 9. South façade vent. Air enters from the side of the glazing through a perforated protection sheet metal protection.

As we can see from the photos of figure 10, lighting openings are dissociated from air vents. This makes it possible to treat correctly the glazed part, hiding frames or any obstacles and divide, protect or hide the vent part. In the south façade, air comes from the side after passing through a perforated sheet metal. On the north light and façade air comes directly after the protection.

Figure 10. Tilted north façade vent, north façade open right, south window from outside, south vent from inside.

As we can see on the second picture of figure 10, all offices are equipped with a ceiling fan. This offers the possibility to the users not to use air conditioning up to 28-29°C of internal temperature and use the roof fan instead, reducing drastically the hours of use of air conditioning. It avoids also a wrong use of the window completely open when external temperature is around 30°C and users like wind breeze. If the user wishes an air movement, he may use the ceiling fan, avoiding excessive heat and dust entering in the office.

VENTILATION AND COOLING STRATEGIES FOR THE MINICIPAL HALL

The municipal hall is a light structure fully glazed building. According to what preceded in this article, bioclimatic architecture should exclude this design. However, the social needs constrained the design team to find special solutions for this building.

The constraints: light structure without thermal mass; high glazed-façades, difficult to equip with movable solar protection.
The advantages: rare and limited use during the day; a country yard in the south, possible to be shaded, creating a social place to meet and shading the exposed south façade; complete shading from the west building, a free massive technical space, under the bleachers, a high building offering high stack effect for ventilation and allowing a hot buffer zone outside the living zone.
The strategy: create a double skin façade using the acoustic element at the top part of the interior space; use a selective glazing with g value 0.4 to reduce sun thermal load; complete solar shading with an interior movable awing at the lower part of the façade and shade the south external yard; allow openings on to top and on the bottom of the façade canal, able to evacuate solar gains; allow a big opening behind the building for air inlet under the bleachers. We ventilate the building during night to cool the concrete slabs of the technical spaces under the building. Air may also come in the canal on the bottom of the double skin façade, when outside air is cooler than the interior air, in order to evacuate accumulated heat from solar gains locally very early in the morning in the north façade and during the morning in the east façade. When outside air becomes hotter than the interior, it comes in only from the back of the building. It is cooled by the coolness accumulated during night in the thermal mass. An automatic control system opens and closes the bottom and top openings of the space according to the desired strategy.

Simulations of interior temperature and stratification showed that with this strategy the interior climate is never worse than the exterior. The occupied space has the best climatic conditions, profiting from the precooled air under the building. By controlling stratification, we localise hot air in non-occupied spaces (within the double skin canal and on the top of the building behind the false ceiling).

Under these conditions, mechanical ventilation with cooled or heated air follows the same path with a part of natural ventilation. It comes to complete heating and cooling, when passive technics are not able to meet the demand. Mechanical ventilation recirculates air and recovers heat when this is beneficial (when stratification is low) but it may function as a hybrid system blowing only cooled air in cases where thermal gains are extreme and returning air is too hot.

By limiting mechanical cooling during some hours of the year, when the building is occupied and when bioclimatic technics cannot meat the demand, we limit energy consumption drastically and allow passive comfort without air conditioning for a large period of the year.

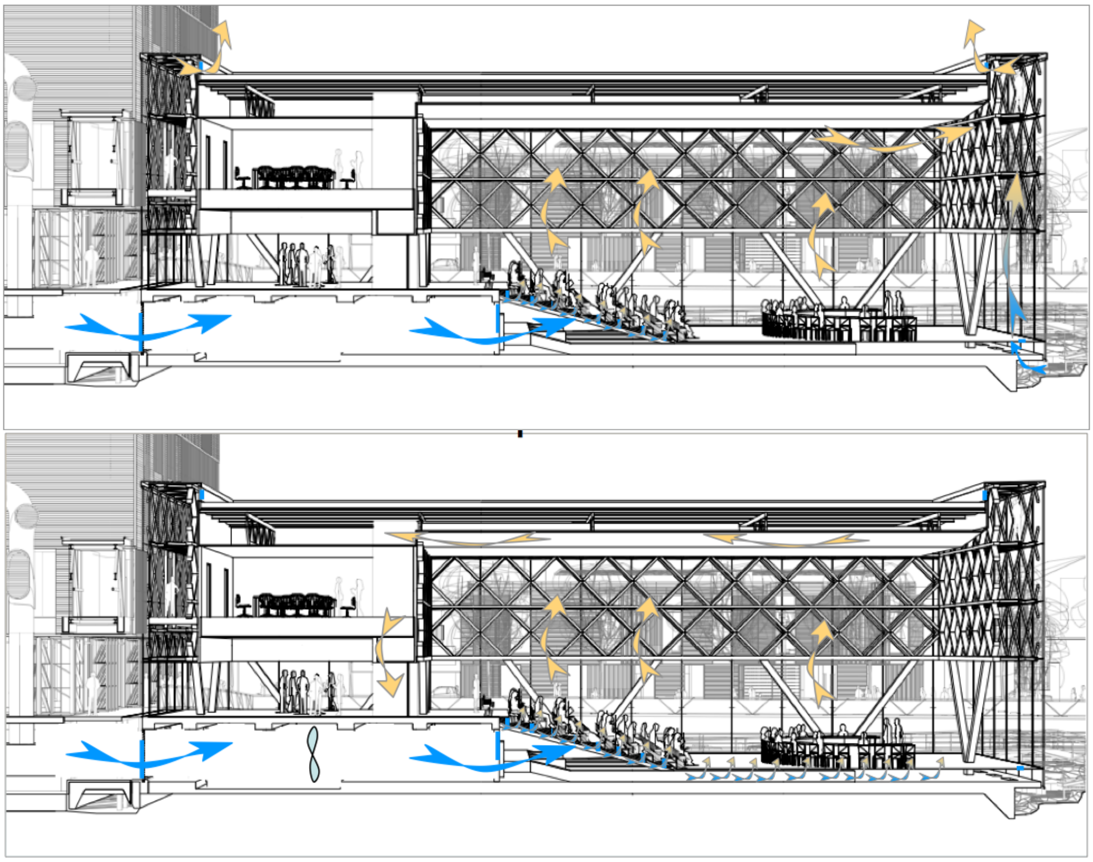

Figure 11. top natural ventilation patterns, bottom, mechanical ventilation patterns.

CONCLUSION

After thermal insulation and solar shading, free cooling is the key issue for low energy passive buildings in Mediterranean climate. Issues like high air-tightness and heat-recovery, which are important for North and Central Europe, have minor importance for southern Europe, simply because in the mild climates, most of the time the building should be open to benefit from the outside air, which is within or near the comfort zone.

Free cooling by natural night-ventilation is the simplest strategy, but it needs special design attention. Standard windows are not always the best way for natural ventilation. When ventilation strategy depends from the occupant's behaviour, simple smart windows with many opening possibilities, equipped with protections from insects, dust and vandalism, ensure the users and encourage a correct use. For common spaces and large halls, smart automation with the minimum number of openings and sensors is necessary, to achieve a sure result. Nicosia town hall is a good example illustrating both natural ventilation design principles on a very low energy consumption building.