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Night Ventilation Strategies

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1 The Increased Need for Cooling

A very important penetration of air conditioning is observed during the last years. This is mainly due to the increase of living standards in the developed world as well as to the adoption of architectural standards that are non climatic responsive. Latest industrial data, (IIR 2002), shows that actually there are more than 240 million of air conditioning units installed worldwide, while the annual sales of air conditioning equipment approach a level of $60 billions. In parallel, the market of air conditioning increases continuously. While in 1998 the total annual number of sales was close to 35188000 units, it has increased to 41874000 units in 2000 and to 44614000 units in 2002, (JARN and JRAIA, 2002), with a predicted level of 52287000 units in 2006, (Table 1).

As it concerns energy, the refrigeration and the air conditioning sectors consume about 15 % of all electricity consumed worldwide

Air Conditioning penetration in Europe is much lower in Europe than in Japan and USA. As shown in Table 2, (Adnot 1999), it has to be expected that during next years, the penetration of air conditioners will increase considerably.

Air conditioning is associated with many problems; the more important are the increase of the peak electricity load, ozone depletion and increase of indoor pollutants.

In Europe and in particular in Southern countries there is a very important increase of peak electricity load mainly because of the very rapid penetration of air conditioning. As an example, the actual load curves as well as the foreseen evolution of the peak electricity load in Spain, is given in Figure 1, (Adnot, 1999). In parallel, it is characteristic that Italy faced very important electricity problems during the summer of 2003 because of the high electricity demand of air conditioners.

Addressing successful solutions to counterbalance the energy and environmental effects of air conditioning is a strong requirement for the future. Possible solutions involve the use of passive cooling techniques and in particular of heat and solar protection techniques, heat amortisation and heat dissipation techniques. Recent research has shown that night ventilation techniques may contribute highly to improve thermal comfort in free floating and decrease the cooling energy consumption of air conditioned buildings.

Table 1: Actual and forecast total air conditioning sales in the world (JARN and JRAIA, 2002) (In thousands of units).

	1998 Actual	1999 Actual	2000 Actual	2001 Actual	2002 Projected	2003 Forecast	2004 Forecast	2005 Forecast	2006 Forecast
World total	35,188	38,500	41,874	44,834	44,614	46,243	47,975	50,111	52,287
Japan	7,270	7,121	7,791	8,367	7,546	7,479	7,344	7,459	7,450
Asia (excl. Japan)	11,392	11,873	13,897	16,637	16,313	17,705	19,227	20,890	22,705
Middle East	1,720	1,804	1,870	1,915	1,960	2,010	2,060	2,112	2,166
Europe	1,731	2,472	2,709	2,734	3,002	3,157	3,318	3,489	3,670
North America	10,437	12,408	12,322	11,894	12,521	12,522	12,524	12,525	12,525
Central & South America	1,588	1,665	2,109	1,939	1,866	1,906	1,973	2,043	2,114
Africa	511	670	664	758	781	806	833	861	887
Oceania	539	487	512	593	625	659	693	731	770

Table 2: Penetration of room air conditioners in the tertiary and residential sector in US, Japan and Europe for 1997, (Adnot, 1999).

COUNTRY	TERTIARY	RESIDENTIAL
Japan	100%	85%
USA	80%	65%
Europe	<27%	<5%

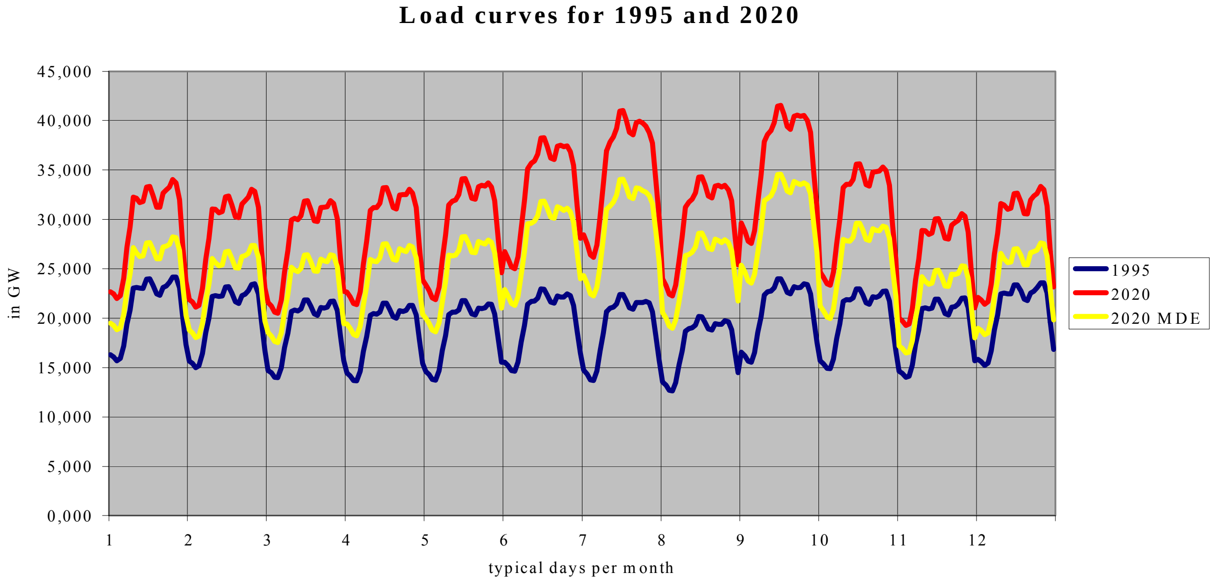

Figure 1: Load curves for 1995 and 2020 in Spain, (Adnot 1999).

2 Principles of Night Ventilation

Passive cooling techniques involve the use of heat and solar protection techniques, heat amortisation using the thermal mass of the building and heat dissipation to a lower temperature environmental sink.

Convective cooling is a very effective method to improve indoor comfort, air quality and reduce indoor temperatures. Higher indoor air speeds may enhance thermal comfort when do not exceed threshold values. Ventilation during daytime, contribute significantly when ambient temperature is lower the indoor one and is inside the comfort limits. Nightime ventilation is associated with the circulation of the low temperature ambient air in the building and the reduction of the temperature of a storage mass. Thus, indoor thermal conditions in the building are more positive during the next day. Night time ventilation is suitable for areas with high diurnal temperature range and where night time temperature is not so cold to create discomfort.

Night ventilation systems are classified as direct or indirect as a function of the procedure by which heat is transferred between the thermal storage mass and the conditioned space. In direct systems the cool air is circulated inside the building zones and heat is transferred in the exposed opaque elements of the building. The reduced temperature mass of the building contributes to reduce the indoor temperature of the next day through convective and radiative procedures. Circulation of the air can be achieved my natural or mechanical ventilation. In direct systems the mass of the building has to be exposed and the use of coverings or false floors or ceilings has to be avoided.

In indirect systems, the cool air is circulated, during night, through a thermal storage medium where heat is stored and is recovered during the day period. In general, the storage medium is a slab covered by a false ceiling or floor while the circulation of the air is always forced. It is evident that, during the day period, the temperature of the circulated air has to be higher than the corresponding temperature of the storage medium. Direct and indirect night ventilation systems are used many times in a combined way.

The performance of night cooling systems depends on three main parameters:

a) The temperature and the flux of the ambient air circulated in the building during the night period.
b) The quality of the heat transfer between the circulated air and the thermal mass
c) The thermal capacity of the storage medium.

Optimisation of the performance of night ventilation systems requires detailed simulation techniques where all the energy and environmental parameters are taken into account. Simplified simulation tools designed especially for night ventilation applications are also available and can provide very useful information.

3 Limitations of Night Ventilation Techniques

Night ventilation, although a very powerful technique, presents important limitations. Moisture and condensation control is necessary in particular in humid areas. Pollution and acoustic problems as well as problems of privacy are associated with the use of natural ventilation techniques.

Outdoor pollution is a serious limitation especially in urban areas. As reported, (Stanners and Bourdeau, 1996), it is estimated that in 70 to 80 percent of European cities with more than 500000 inhabitants, the levels of air pollution, regarding one or more pollutants exceeds the WHO standards at least once per year. Filtration and air cleaning is possible only when flow controlled natural ventilation components or mechanical ventilation systems are used. Noise is also a serious limitation especially when natural ventilation is used. As reported, (Stanners and Bourdeau, 1996), unacceptable noise levels of more than 65 dB(A), affect between 10 to 20 percent of urban inhabitants in most European cities. In parallel, OECD, (OECD, 1991), has estimated that 130 millions of people in OECD countries are exposed to noise levels that are unacceptable.

However, the more important limitation of night ventilation techniques is associated with the specific climatic conditions in cities. The increase of the ambient temperature because of the heat island effect as well as the serious decrease of the wind speed in urban canyons reduce considerably the cooling potential of night cooling techniques.

Experiments aiming to study the reduction of the air flow in single sided and cross naturally ventilated buildings in ten urban canyons in Athens, (Geros et al, 2001), have shown that air flow may reduce up to 90 %, (Figure 2), because of the reduced wind speed. Thus, efficient integration of natural and night ventilation techniques in dense urban areas requires full knowledge of the wind characteristics as well as adaptation of the ventilation components to the local conditions.

The same authors, (Geros, 1999), have compared the cooling load of a night ventilated building when located in an urban canyon or in a non obstructed site. It is found that the relative difference of the cooling load, between the two locations varies between –6 to 89%, for the single sided ventilation, and between –18 to 72% for the cross ventilated building depending on the characteristics of the canyon, (Figure 3)

In parallel, the same comparison has been performed for a free floating night ventilated building. It has been calculated the difference of maximum indoor temperatures in the building are between 0.0 to 2.6 °C for the cross ventilated buildings and between 0.2 to 3.5 °C for the single ventilated building, depending on the characteristics of canyon. Figure 4, illustrates the specific differences for the ten urban canyons.

Thus, a correct dimensioning and design of night cooled buildings using natural ventilation techniques has to be based on data appropriate for urban locations.

For cooler climates, stack ventilation might be used during the night. In these cases external temperature at night (when the urban heat island intensity is at its peak) might mitigate the effectiveness of the strategy.

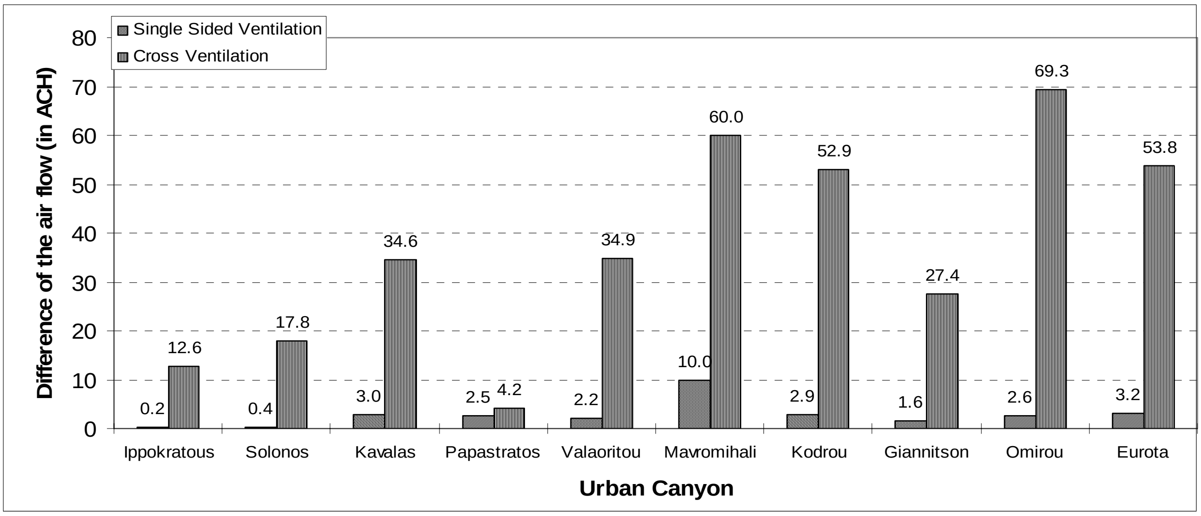

Figure 2: Reduction of air change rate for single sided and cross ventilated buildings in ten urban canyons, (Geros et al, 2001).

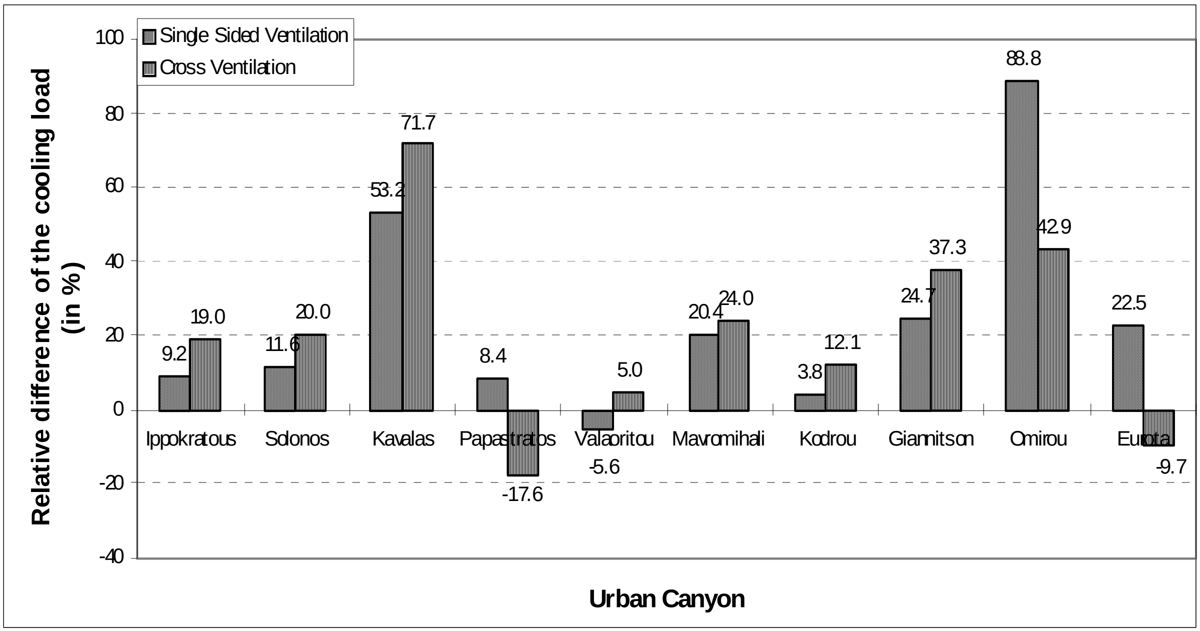

Figure 3: The difference of the cooling load calculated for a night ventilated building located in a canyon and in an non obstructed site. The analysis refers in ten urban canyons where experiments have been performed and results are given for the single sided and cross ventilated buildings

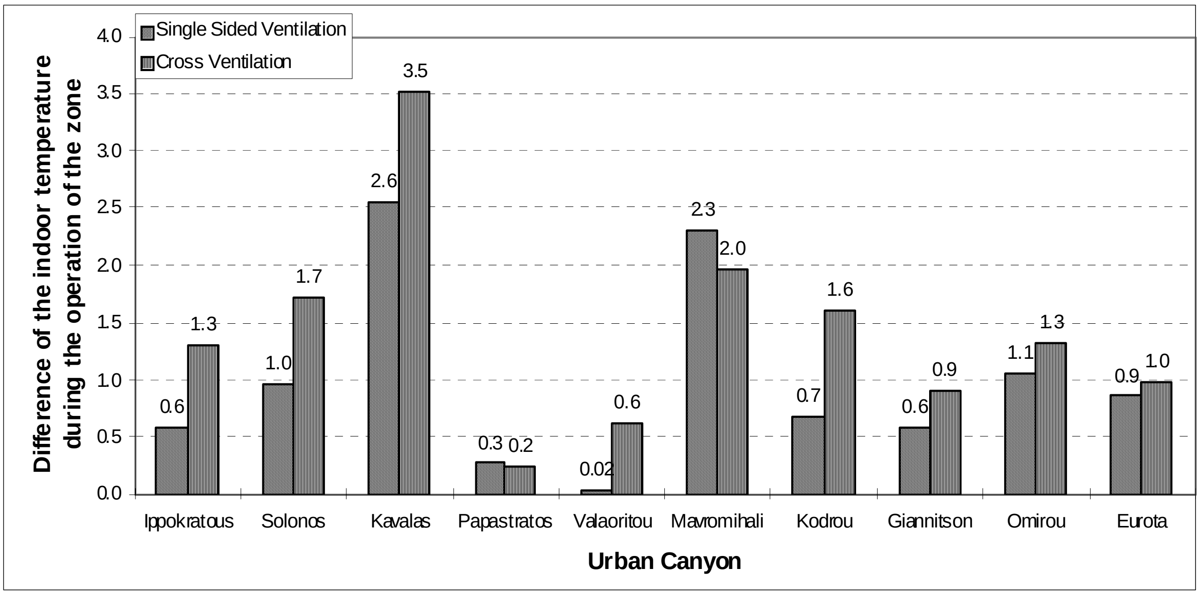

Figure 4: The difference of the maximum indoor air temperature calculated for a night ventilated building located in a canyon and in an non obstructed site. The analysis refers in ten urban canyons where experiments have been performed and results are given for the single sided and cross ventilated buildings

4 Expected Performance of Night Ventilation Techniques

Important theoretical and experimental research has been carried out to better understand the phenomena, to evaluate the cooling potential of night ventilation techniques and also to develop computational and design tools and codes.

Extended experimental work on night ventilation techniques are reported by Van der Maas and Roulet, (1991), Agas et al, (1991), Geurra et al, (1992), Barnard N (1994),), Van

der Maas et al, (1994), Hassid S, (1994), Santamouris and Assimakopoulos, (1996), Givoni, (1994, 1998), Blondeau et al, (1995, 2002), Ren (1995), Kolokotroni et (1996, 1997), Meierhans R A, (1996), Santamouris et al, (1996), Behne, (1997), Feustel, H.E.; Stetiu, C., (1997), Zimmerman and Anderson, (1998), Geros et al, (1998), Dascalaki and Santamouris, (1998), Aboul Naga and Abdrabboh , (1998), Burton, (1998), Demeester et al, (1998), Wouters et al, (1998), Roucoult et al, (1999), Nicol et al (1999), CEC, (2000), Liddament, (2000), Shaviv et al, (2000), Turpenny et al, (2000), Barnard et al, (2001), Blake Thomas, (2001), Axley J W, Emmerich S J, (2002), Herkel et al, (2002), Todorovich et al, (2002), Breesch et al, (2003)
Geros et al, (1999), performed measurements in free floating and A/C night ventilated office buildings in Athens, Greece. It is found that under free floating conditions, the use of this technique decreases the next day peak indoor temperature up to 3 ^{o}C. Results of sensitivity analysis shown that the expected reduction of the overheating hours, varies between 39% and 96% for air flow rates for 10 and 30 ACH respectively (Figure 5). Under A/C conditions the early morning indoor air temperature can be reduced by 0.8 to 2.5 ^{o}C depending of the considered set point temperature. Sensitivity analysis has shown that under A/C conditions, the expected energy conservation varies between 48% and 94% for air flow rates between10 and 30 ACH respectively (Figure 6).

Behne, (1996), has performed a detailed study to evaluate the potential of night ventilated buildings under various operational conditions. The study has been performed for Berlin, Locarno, Red Bluff and San Francisco. Natural and mechanical ventilated free floating and mechanically ventilated air conditioned buildings have been considered. As shown in Table 3, under natural ventilation conditions, peak power gains varies between 31 % fro San Francisco and 40 % for Berlin, while the peak power conservation in air conditioned buildings varies between 9 % for San Francisco to 30 % for Berlin

Kolokotroni and Aronis, (1999), found that in typical air-conditioned UK office buildings 30% cooling energy consumption reduction and a 40 % reduction of the installed cooling system's capacity are achievable by using natural ventilation during the night.

In conclusion, night ventilation techniques can contribute to decrease significantly the cooling load of A/C and improve the comfort levels of free floating buildings. The exact contribution of night ventilation for a specific building is as a function of the building structural and design characteristics, the climatic conditions and the building's site layout, the applied air flow rate, the efficient coupling of air flow with the thermal mass of the building, and the assumed operational conditions.

Table 3: Reduced electrical peak power demand of a building in percentage for the different night ventilation strategies, (From Behne, 1996).

Reduced electrical peak power demand of the building in % for the different night ventilation strategies investigated

		Berlin	Locarno	Red Bluff	San Francisco
no chiller	natural NV	-40 2)	-52 1)	--	-31
	mechanical NV	-38 2)	-51 1)	--	-29
with chiller	mechanical NV	-30	-28	0	-9

1) Room temperatures and humidity levels are frequently beyond the thermal comfort range.
2) Indoor air humidity might exceed 60 % RH at about 200 h/a.

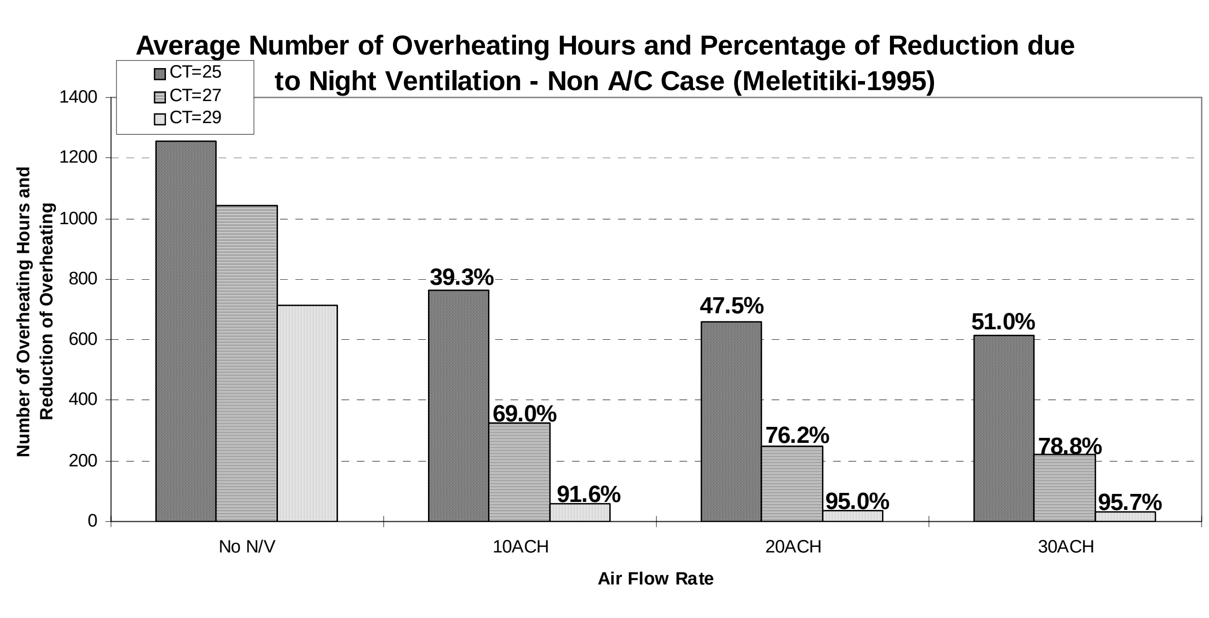

Figure 5: Average Overheating Hours and Reduction because of the use of night ventilation in Meletitiki Building in Athens. The building is considered to operate under free floating conditions, (Geros et al, 1999).

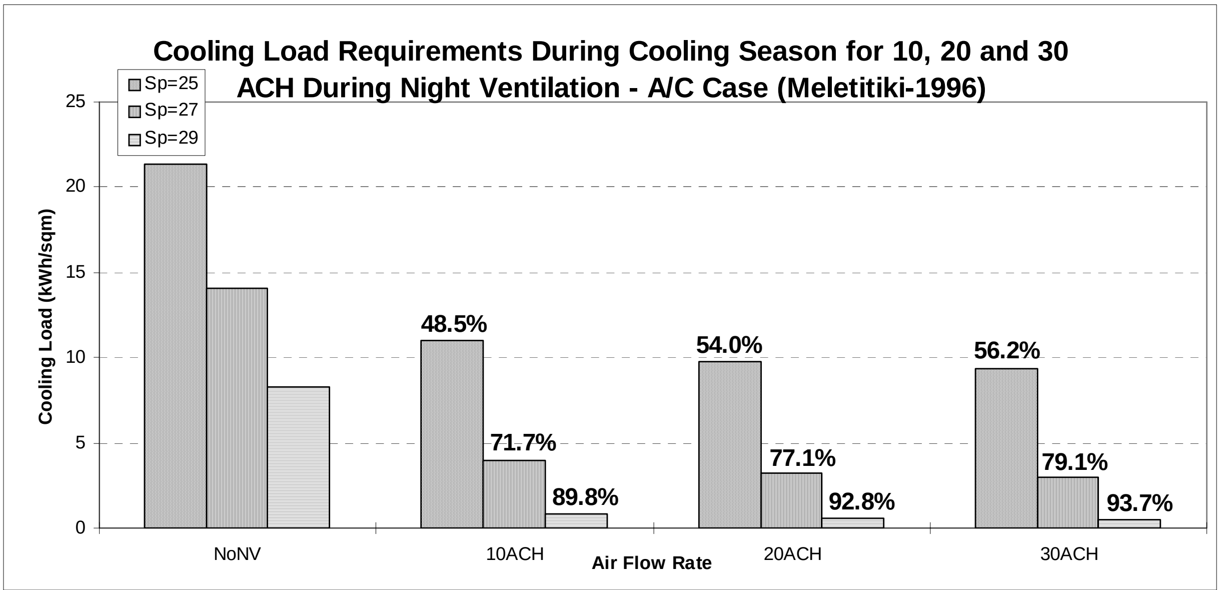

Figure 6: Cooling load reduction because of the use of night ventilation in Meletitiki Building in Athens. The building is considered to operate under air conditioning conditions, (Geros et al, 1999).

5 Computer Tools for Night Ventilation Techniques

Proper design of night ventilated buildings requires consideration of all parameters that define the energy performance of the building. Detailed simulation using well validated codes is the more appropriate method to achieve the best possible performance.

Several codes have been prepared to calculate the specific performance of night ventilation techniques. These tools are designed to help architects and engineers to consider in a more simplified but accurate way the sizing of night cooling techniques. In the following, information on some of the data is given.

NiteCool, (Tindale et, 1995), was developed under the Energy Related Environmental Issues in Buildings (EnREI) DOE Programme and is designed especially for the assessment of a range of night cooling ventilation strategies. The program is based on a single zone ventilation. This simplified design tool is developed to enable the design team to explore rapidly the effects of a number of key performance parameters, and thereby ensure that the basic design concept was workable in terms of the chosen strategy.

A simplified RC model has been developed by (Millet, 1997). The model takes into account the thermal inertia of the building and the impact of night ventilation. Attention is paid to the impact of the outdoor noise (related to the windows opening at night). This model was validated by comparing its results to a more detailed one (TRNSYS) and was used to produce guidance rules. Used primary for new buildings, these tools will also be a help for retrofitting.

LESOCOOL is a simple computer tool for the evaluation of the ventilative cooling potential. The small number of input data and the user friendliness of the program help the user to determine rapidly the influence of the main parameters, (Roulet et al, 1996). LESOCOOL calculates the cooling potential and the overheating risk in a naturally or mechanically ventilated building, showing the temperature evolution, the air flow rate and the ventilation heat transfer. It can also take into account convective or radiative heat gains.

A detailed methodology to calculate the performance of air conditioned as well as of free floating night ventilated buildings is presented by Santamouris et al, (1996). The method is based on the principle of Modified Cooling Degree Days and is extensively evaluated against theoretical and experimental data. The method is integrated into the simulation tool SUMMER, (Santamouris et al, 1995), and calculates the variation of the balance point temperature of a free floating or air conditioned night ventilated building, as well as the overheating hours and the cooling load. In parallel, it performs comparisons with a conventional free floating or air conditioned building.

6 Case Studies

Thousands of buildings are designed to use night ventilation techniques. In the following, some examples are presented in brief. The selected examples are real buildings that are not designed for experimental purposes and have achieved an exceptional performance.

6.1 The Meletitiki Building – Athens, Greece

This is the architectural office of Meletitiki Ltd, A.N. Tombazis and Associates, (Allard 1998). It was constructed in 1995. The building is a unique space, in terms of interior design and space layout. The total floor area of the building is 1000 m². The building consists of three floors and a basement. The envelope structure of the building is heavy, consisting of thick well insulated exterior walls. All external openings are very well shaded. Natural ventilation techniques are used in order to avoid overheating during summer. Ceiling fans are used to enhance thermal comfort. Mechanical assisted night cooling is used. The building is extensively monitored. It is found that under free floating conditions, night ventilation lowers the next day peak indoor temperature by 1-2 C. By taking advantage of the heavy mass of the building, this strategy contributes towards delaying the peak load hour by 4-5 C. Under thermostatically controlled conditions, the building presents a very low energy consumption for cooling and does not exceed 5 kWh/m²/year.

Figure 7: The Meletitiki Building. (Picture provided by A.N. Tombazis)

6.2 The SD Worx' in Kortrijk (Belgium).

The office building 'SD Worx' is situated in Kortrijk, Belgium and consists of two floors on top of the ground floor. At the southern side, the floors are connected with an open vertical circulation zone. An exposed concrete ceiling delivers a high thermal capacity, which reduces and postpones the cooling load. Secondly, passive cooling is applied. By day, an earth-to-air heat exchanger cools down the supply ventilation air flow. By night, outside air enters the office floors through grilles at the northern side, cools down the exposed ceiling and leaves the building at the top of the circulation zone (Figure 8).

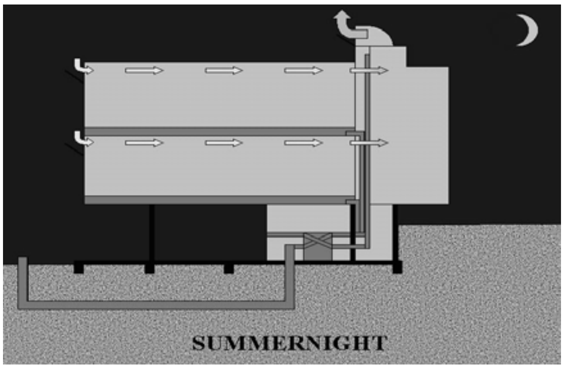

Figure 8: Night time Operation of the SD Worx' in Kortrijk building.

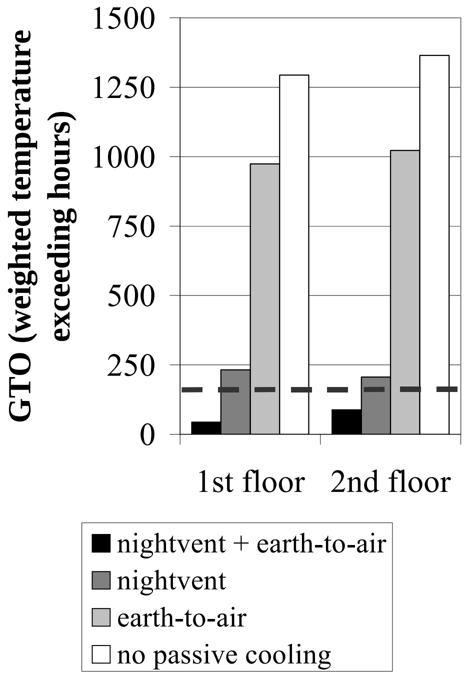

Figure 9: Weighted temperature exceeding hours (GTO) from May 15 to September 30, 2002 (TRY Ukkel) at present occupation, from (Breesch et al , 2003)

The performance of the system is given in Figure 9.

Monitoring of the building has shown that night ventilation alone or combined to an earth-to-air heat exchanger deliver an excellent thermal comfort.

6.3 Sofiendal School in Denmark

This is a naturally ventilated building near Copenhagen in Denmark. To induce ventilation to have airflow through the room, mechanically operated windows are located on the exterior wall of each classroom. Night ventilation is foreseen, since the opening size is controlled by the "BMS", which allows for increased security and controlled airflow. The cooling strategy of the building allows for Natural Ventilation to work alone for temperatures below 24 Celsius, while using it as night ventilation down to 19 Celsius. The use of fan assist only occurs in the late hours of the night if needed to get cooler if the natural ventilation does not cool down enough.

Figure 10: Sofiendal school in Denmark

7 References

Aboul Naga M M, Abdrabboh S N : Improving night ventilation into low-rise buildings in hot-arid climates exploring a combined wall-roof solar chimney. Proceedings of "Renewable Energy: Energy Efficiency, Policy and the Environment", World Renewable Energy Congress V, 20-25 September 1998, Florence, Italy, edited by A A M Sayigh, Volume 3, pp 1469-1472, Pergamon, Elsevier Science Ltd, 1998

Adnot J. (Ed) : 'Energy Efficiency of Room Air-Conditioners", EERAC, study for the Directorate General for Energy (DGXVII) of the Commission of the European Communities, Co-ordinator : May 1999.

Agas G, Matsaggos T, Santamouris M, Argyriou A : On the use of the atmospheric heat sinks for heat dissipation. Energy and Buildings, No 17, 1991, pp 321-329,

Allard F. (Ed) : 'Natural Ventilation of Buildings', James and James Science Publishers, London, UK, 1998.

Axley J W, Emmerich S J : A method to assess the suitability of a climate for natural ventilation of commercial buildings. Proceedings of Indoor Air 2002 (9th International Conference on Indoor Air Quality and Climate) - June 30 - July 5, 2002 - Monterey, California - vol 2, pp 854-859.

Barnard N : Fabric energy storage of night cooling. Proceedings of CIBSE National Conference 1994, held Brighton Conference Centre, 2-4 October 1994, Volume 1,pp 88-100.

Barnard N, Concannon P and Jaunzens D, Modelling the performance of thermal mass, BRE Information Paper IP 6/01, Garston, Construction Research Communications Ltd, 2001

Behne M. : 'Alternatives to Compressing Cooling in Non Residential Buildings to Reduce Primary Energy Consumption, Deutsche Forschungsgemeinschaft (DFG) and the U.S. Department of Energy, May 1996

Blake Thomas G : Thermal mass storage and energy saving using underfloor air conditioning. Proceedings of the 7th REHVA World Congress and Clima 2000 Naples 2001 Conference, held Naples, Italy, 15-18 September 2001, Italy

Blondeau, M. Sperandio, F. Allard : "Night Accelerated Ventilation for Building Cooling in Summer". Proceedings of the International Conference on Passive Cooling of Buildings, M. Santamouris (Ed), Athens, 1995.

Blondeau P, Sperandio M, Allard F : Multicriteria analysis of ventilation in summer period. Building and Environment, No 37, 2002, pp 165-176.

Breesch H, A. Bossaer, A. Janssens : Passive Cooling in a Low Energy Office Building', Submitted for Publication, Solar Energy Journal, 2003

Burton S : Energy comfort 2000 - the application of low energy technologies to seven new non-domestic buildings. Proc of EPIC '98, Volume 2, pp 473-478, 1998.

California Energy Commission : 'Alternatives to Compressor Cooling', P600-00-003, January 2000.

Dascalaki and M. Santamouris : 'The Meletitiki Case Study Building', In 'Handbook on Natural Ventilation of Buildings', F. Allard, (Ed), James and James Science Publishers, London, UK, 1998.

Demeester J, Wouters P, Ducarme D. : Natural ventilation in office-type buildings - results and conclusions of monitoring activities. Proceedings of "Ventilation Technologies in Urban Areas", 19th Annual Conference, held Oslo, Norway, 28-30 September 1998, pp 407-413.

International Institute of Refrigeration, (IIR) : 'Industry as a Partner for Sustainable Development – Refrigeration', 2002.

Feustel, H.E.; Stetiu, C., : Thermal Performance of Phase Change Wallboard for Residential Cooling Application LBL-Report 38320, 1997, LBL, Berkeley, California

Geros V. 'Ventilation Nocturne. Contribution a la reponse thermique des batiments', Ph. D. Thesis, INSA Lyon, 1998.

Geros V., M. Santamouris, A. Tsangrassoulis and G. Guarracino :'Experimental Evaluation of Night Ventilation Phenomena'.J. Energy and Buildings, 29, 141-154, 1999

Geros V, Santamouris M, Papanikolaou N and Guarraccino G. : 'Night Ventilation in Urban Environments', Proc. AIVC Conference, Bath, UK, 2001.

Geurra J, Molina J L, Rodriguez E A, Velazquez R : Night ventilation in industrial buildings: a case study. Proc of the Conference 'Indoor air quality, ventilation and energy conservation, 5th International' Jacques Cartier Conference, Montreal, Canada, October 7-9, 1992, Publisher: Center for Building Studies, Concordia University, Montreal, Canada, pp 476-483.

Givoni B. : 'Passive and Low Energy Cooling of Buildings', Van Norstrand Reinhold, 1994

Givoni B : Effectiveness of mass and night ventilation in lowering the indoor daytime temperatures. Part 1: 1993 experimental periods. Energy and Buildings, No 28, 1998, pp 25-32.

Hassid S : Evaluation of passive cooling strategies for Israel. Proceedings of 11th PLEA International conference, "Architecture of the Extremes", held 3-8 July 1994, Dead Sea, Israel, 162-169. Israel, The Desert Architecture Unit, J Blaustein Institute for Desert Research, Ben-Gurion University of the Negev, 1994, edited by Y Etzion, E Erell, I A Meir and D Pearlmutter.

Herkel S., Pfafferott J., Wambsganí M. : Design, monitoring and evaluation of a low energy office building with passive cooling by night ventilation. Proceedings of EPIC 2002 AIVC (3rd European Conference on Energy Performance and Indoor Climate in Buildings and 23rd Conference of the Air Infiltration and Ventilation Centre) - 23-26 October 2002 - Lyon - France - vol 2, pp 487-492.

Kolokotroni M, Webb B C, Hayes S D : Summer cooling for office-type buildings by night ventilation. Proc of the 17th AIVC Conference, "Optimum Ventilation and Air Flow Control in Buildings", Volume 2, held 17-20 September 1996, Gothenburg, Sweden, pp 591-599.

Kolokotroni, A. Tindale and S.J. Irving : "NiteCool: Office Night Ventilation Pre-Design Tool". 18th AIVC Conference - Ventilation and Cooling. 23rd-26th September 1997, Athens, Greece.

Kolokotroni M and Aronis A, Cooling-energy reduction in air-conditioned offices using night ventilation, Applied Energy 63 (1999), 241-253

JARN and JRAIA, Japan Air Conditioning and Refrigeration News and Japan Refrigeration and Air Conditioning Industry Association : 'Air Conditioning Market', 2002

Liddament M W : Making ventilation work for cooling. Proceedings of "Renewable Energy. : The Energy for the 21st Century. World Renewable Energy Congress VI", edited by A A M Sayigh, held 1-7 July 2000, Brighton, UK, Part 1, pp 420-425, Pergamon, 2000.

Meierhans R A : Room air conditioning by means of overnight cooling of the concrete ceiling. USA, Ashrae Transactions, Vol 102, Pt 1, 1996.

Millet J R : Summer comfort in residential buildings without mechanical cooling. Proceedings of the Second International Conference on Buildings and the Environment, held Paris, June 9-12 1997, Volume 1, pp 307-315.

Nicol F, Robinson P, Kessler M R : Using night cooling in a temperate climate. proceedings of "Environmentally friendly cities", PLEA 98 (Passive and Low Energy Architecture) conference, held Lisbon, Portugal, June 1998, pp 467-470, James and James Science Publishers, London, UK.

OECD : Fighting Noise in the 1990's. OECD, Paris, 1991.

Ren J. : Night Ventilation for Cooling Purposes Part I : Reference Building and Simulation Model IBPSA, 4. International Conference in Madison, Wisconsin, 1995

Roucoult J M, Douzane O, Langlet T : Incorporation of thermal inertia in the aim of installing a natural nighttime ventilation system in buildings. Energy and Buildings, No 29, 1999, pp 129-133.

Roulet C A, van der Maas, Flourentzos F : A planning tool for passive cooling of buildings. Proceedings 7th International Conference on Indoor Air Quality and Climate, Nagoya, Japan, July 21-26 1996,

Santamouris, V. Geros, N. Klitsikas and A. Argiriou : "Summer : A Computer Tool For Passive Cooling Applications". Proceedings of the International Symposium : Passive Cooling of Buildings. M. Santamouris (Ed), 19th-20th June 1995, Athens, Greece.

Santamouris M and Assimakopoulos D. (Eds) : 'Passive Cooling of Buildings', James and James Science Publishers, London, UK, 1996.

Santamouris M, Mihalakakou G, Argiriou A, Asimakopoulos D : The efficiency of night ventilation techniques for thermostatically controlled buildings. Solar Energy, Vol 56, No 6, 1996, pp 479-483.

Shaviv E, Capeluto I G, Yezioro A : A simple design tool for determining the effectiveness of thermal mass and night ventilation as passive cooling design strategy. proceedings of Roomvent 2000, "Air Distribution in Rooms: Ventilation for Health and Sustainable Environment", held 9-12 July 2000, Reading, UK, Volume 2, pp 881-886, Elsevier, 2000.

Stanners D. and Bourdeau P. (Editors) : 'Europe's Environment - The Dobris Assessment'. European Environmental Agency, Denmark, 1995.

Tindale A W, Irving S J, Concannon P J, Kolokotroni M : Simplified method for night cooling. CIBSE, 1995, National Conference '95, Eastbourne, 1-3 October 1995, Volume 1, pp 8-13.

Todorovic B., Randjelovic I., Krstic A. : Air pressure - A potential force for night cooling of atrium buildings. Proceedings of EPIC 2002 AIVC (3rd European Conference on Energy Performance and Indoor Climate in Buildings and 23rd Conference of the Air Infiltration and Ventilation Centre) - 23-26 October 2002 - Lyon - France - vol 2, pp 393-398.

Turpenny J R, Etheridge D W, Reay D A: Novel ventilation cooling system for reducing air conditioning use in buildings. Proceedings of Roomvent 2000, "Air Distribution in Rooms: Ventilation for Health and Sustainable Environment", held 9-12 July 2000, Reading, UK, Volume 2, pp 875-880, Elsevier, 2000.

Van der Maas J., Roulet C.-A : "Night time ventilation by stack effect". ASHRAE Technical Data Bulletin Vol 7, Number 1, Ventilation and Infiltration, p.p.32-40, NY January 1991

Van der Maas J, Florentzos F, Rodriguez J-A, Jaboyedoff P.: Passive cooling by night ventilation. Proc. European Conference on Energy Performance and Indoor Climate, Lyon, 24-26 November 1994.

Wouters P, Demeester J, Ducarme D, Kofoed P, Zaccheddu E : Overview and synthesis of the monitoring activities carried out in the framework of the NatVent EC Joule Project. Proc of EPIC '98, Volume 3, pp 958-963, 1998

Zimmerman M., and J. Andersson : 'Low Energy Cooling – Case Study Buildings', International Energy Agency, Energy Conservation in Buildings and Community Systems Programme, Annex 28 Final Report, 1998.

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The Air Infiltration and Ventilation Centre provides technical support in air infiltration and ventilation research and application. The aim is to promote the understanding of the complex behaviour of the air flow in buildings and to advance the effective application of associated energy saving measures in the design of new buildings and the improvement of the existing building stock.