Study of Night Ventilation Efficiency in Urban Environment: Technical and Legal Aspects

Konstantinos Maragogiannis, *Technical University of Crete,* Dionysia Kolokotsa, *Technical University of Crete, Environmental Engineering Department,* Efpraxia-Aithra Maria, *Technical University of Crete, Department of Sciences*

Abstract **– Night Ventilation is a critical technique of passive cooling, as it combines a significant decrease of cooling demand and improvement of thermal comfort and indoor air quality.**

The aim of the present paper is to study the technical and legal aspects of night ventilation in urban climatic conditions. The technical part examines the efficiency of night ventilation techniques for urban residential buildings. Moreover, the influence of urban heat island on the night ventilation effectiveness is studied. Urban heat provokes the degradation of urban air quality and causes changes in the urban area microclimate which reduce the night ventilation effectiveness as a passive cooling technique. Moreover, this paper studies the legal framework of energy efficiency in buildings and pinpoints the institutional deficiencies of the existing regulation regarding energy efficiency and passive cooling techniques

Keywords **– night ventilation, cooling demand, urban heat island, legal framework**

I. Introduction and State of Art

In Southern EU countries the necessity for cooling has been increased especially during the summer period. The urban microclimate and the geomorphological structure of an area have a strong impact on the application of the various passive cooling techniques for buildings. A very important method of passive cooling is night ventilation or nocturnal convective cooling. It consists of ventilating the building during the night in order to cool down its structural elements [1]. The use of the night ventilation method can also improve thermal comfort and indoor air quality. The process is related to the introduction of cool ambient air into the building, especially during the summer nights when ambient temperature is lower than indoors and the heat extraction to the outdoor environment. The energy impact of this technique can cause a reduction in the cooling load both in air-conditioned buildings and those naturally ventilated [2].

Various studies prove night ventilation effectiveness. Givoni [3-5] argues that the night ventilation technique is efficient, particularly for arid regions, where day time ventilation is insufficient to ensure thermal comfort. Kolokotroni and Aronis [6] introduce some variables for the building, such as building mass, glazing ratio, solar and internal gains, orientation, and demonstrate that the optimization of the building design for night ventilation according to these parameters can cause an abatement of about 20-25% of the air conditioning energy consumption. The effectiveness of night ventilation techniques is determined by the prevailing climatic conditions, the microclimate, the building characteristics and the location. The outdoor temperature, the relative humidity and the wind speed are the environmental parameters that influence the successful application of night ventilation techniques [7].

Santamouris et al [8] pointed out that the application of night ventilation techniques to residential buildings may lead to a decrease of cooling loads almost 40 $kWh/m^2/y$ with an average contribution of 12 $kWh/m^2/y$. In urban areas though, the Urban Heat Island (UHI) phenomenon deteriorates quality of life and has a direct impact on the energy demand, the environmental conditions and, consequently, on ventilation effectiveness. The increased urban temperatures [9, 10] exacerbate the cooling load of buildings, increase the peak electricity demand for cooling, decrease the efficiency of air conditioners, [11-13] and create an emerge necessity for passive cooling.

On the other hand, during the last decades there is substantial concern in promoting energy efficiency through international, regional and local policy and legal actions [14-18]. Through building energy regulations, also referred to as building energy codes, minimum requirements to achieve energy efficient design in new buildings are imposed. Moreover, passive techniques in the buildings' design are encouraged and promoted. The primary aim is saving final energy or any related parameter (primary energy, CO_2 emissions or energy costs) without compromising thermal comfort [19, 20].

To this end, the aim of the present paper is to examine the technical and legal aspects of night ventilation in the urban microclimate. The technical part examines the impact of night ventilation on the cooling demand and indoor comfort of the urban residential buildings by taking into account the different urban microclimatic conditions and the urban heat island phenomenon. The legal part analyses the EU and national legislative framework in Greece in order to reveal possible deficiencies related to the microclimatic conditions. The paper is structured in three more sections. Section 2 includes the technical aspects analysis and discussion, while section 3 examines the legal aspects. Finally section 4 summarizes the conclusions and discusses issues for future consideration and research.

II. TECHNICAL ASPECTS

A. Methodology

In order to study night ventilation effectiveness an urban residential building is selected. The selected building is a typical Greek construction placed in the city of Chania, Crete, Greece [Fig. 1]. The specific area suffers from urban heat island based on previous studies [21]. The urban residential building, which is described in the next paragraph, is modelled using TRNSYS 16. Validation of the model is performed based on energy consumption data [22]. The building is then placed in different urban and suburban locations and different microclimatic conditions are considered. The cooling demand, thermal comfort and ventilation effectiveness are then evaluated for all urban and suburban locations.

B. Building Description

The building has two floors, each one with two flats of about a 110 m^2 living space [Fig. 2]. Each flat has a big living room, including the kitchen and three bedrooms. There is a big marquee on the south facade of each flat, covering almost the entire wall, and there are shutters on each window for shading. The house has a central oil fired heating system. This heating system powers seven radiators in each flat and is also responsible for the hot water supply in the winter. There are four solar thermal collectors on the roof, each one with approximately 2 m^2 surface area for hot water supply in the summer. On the roof terrace, there is a grapevine growing on a metal construction in about 2 meters height, which covers approximately 50% of the roof area. The building's characteristics are tabulated in Table I.

Fig. 2. The Building.

C. Urban microclimatic conditions

Data from eight different locations in both urban and rural areas are used [Fig. 1]. The collection of the weather data obtained by placing eight different loggers in the appropriate positions (Table II) and the measurements are elaborated to be presented on an hourly basis [21]. Urban areas are considered *1866 Square, A.Ioannis, Dikastiria, Gogoni, Nea Xora, Old Town, Sfakion* and suburban area is considered *TEI* position. Data collected by the 1st June until 31st August 2007 and include: wind speed and direction, outdoor temperature and outdoor relative humidity. Solar radiation is measured only in TEI site. The measurements system for each log site can be found in Kolokotsa et al [21].

Fig. 1. The City of Chania.

TABLE I

BUILDING DESCRIPTION

General Information	
Location	Chania, Crete
Building type	Residential building for family use
Surface area	220 m^2
Orientation	N-S
Building Envelope	
Walls	The walls consist of two layers of bricks with insulation in between and a layer of plaster on the surfaces
Roof	Two-layer (concrete, insulation) ceiling
Windows	The windows are double glazing windows with aluminium frame
Floor	One layer (concrete) floor
Shading	No external shading devices, window shutters
Building services	
Heating system	Same with cooling plus a heating appliance of 2000 W (Electricity)
Cooling system	Two split air conditioning systems of 12000 BTU each

TABLE II

THE LOCATION OF THE 8 CITY LOCATIONS

	Locations	Latitude	Longitude
1	1866	35^{0}30’48.00’’	24^{0}01’03.50’’
2	A.Ioannis	35^{0}30’28.00’’	24^{0}02’32.63’’
3	Dikastiria	35^{0}30’36.80’’	24^{0}01’43.30’’
4	Gogoni	35^{0}30’14.40’’	24^{0}00’48.80’’
5	Nea Xora	35^{0}30’44.00’’	24^{0}00’12.30’’
6	Old Town	35^{0}31’00.75’’	24^{0}01’08.98’’
7	Sfakion	35^{0}30’41.40’’	24^{0}01’23.17’’
8	TEI - suburban (reference)	35^{0}31’08.00’’	24^{0}02’32.63’’

III. Experimental results and discussion

The night ventilation effectiveness is studied using the building model developed in TRNSYS and the corresponding urban locations' data. Night ventilation is designed to start at 8.00 pm, continue all night and end at 8.00 am. In most cases, the application of an air change rate higher than 8 Air Changes per Hour (ACH) does not cause any further improvement in thermal comfort [23].

Four different strategies or scenarios are studied in order to investigate the night ventilation potential in urban microclimate:

- Scenario 1: No night ventilation is considered. The cooling demand is calculated for 25°C set point.
- Scenario 2: Night ventilation is considered with 1 ACH (air change per hour) from 8 pm to 8 am.
- Scenario 3: Free running conditions. No heating, cooling or ventilation is used. The building's thermal comfort conditions are studied in different locations.
- Scenario 4: Is similar to scenario 1, but the main difference is the parallel application of a night ventilation schedule which presence assists on cooling the building.

The parameters extracted by the simulation for each site and scenarios are:

- Indoor/outdoor air temperature.
- Operative temperature.
- Cooling load.

In the first place, in scenario 1, there is only a mechanical cooling system in the building, due to the absence of a night ventilation technique. Clearly the loads are elevated and diversified, depending on the site. By setting TEI position as a reference point, we observe that the cooling load for Gogoni position is 47.83% higher than the referred and the cooling load at the 1866 site in the city centre is 175.5% higher than TEI site. The percentage changes are considerable and reveal the extent to which the microclimate and the urban heat island phenomenon affects the cooling load and consequently the operating costs of the building [Fig. 3].

In scenario 2, the only means of cooling the building is the application of night ventilation. Although this technique has great impact on the cooling load of the building, the indoor air temperature is significantly lower in suburban areas because of favourable climatic conditions. For instance, the rate of reduction in temperature due to ventilation for the position of TEI is 7.64%, while for the position of 1866 is 8.81%. Notwithstanding the above, however, the indoor temperature in the second position (1866) is about 3 °C higher than the reference point [Table III].

The difference in the thermal comfort of the building between urban and rural areas is examined better in scenario 3. Thermal comfort indices (operative and air temperature) are considerably more adverse for downtown sites [Fig. 3, Fig. 4]. It is obvious that the temperature inside the building acquires higher values for the case of urban areas where there is the effect of UHI phenomenon.

TABLE III

Average indoor Temperature (°C) in summer for each position.

Positions	Scenario 2	Scenario 4
1866	27.01	24.63
A.Ioannis	26.21	24.42
Dikastiria	25.95	24.31
Gogoni	25.36	24.14
Nea Xora	25.3	24.03
Old Town	25.73	24.24
Sfakion	26.04	24.35
TEI	24.16	23.55

TABLE IV

Cooling loads for each scenario in 8 different positions

	Scenario 1		Scenario 4	
Positions	Cooling load kWh/m^2	Indoor Temperature °C	Cooling load kWh/m^2	Indoor Temperature °C
1866	14650	24.84	9651	24.63
A.Ioannis	10600	24.61	8411	24.42
Dikastiria	10500	24.56	7731	24.31
Gogoni	7860	24.35	6048	24.14
Nea Xora	8908	24.34	6093	24.03
Old Town	8340	24.38	7509	24.24
Sfakion	10940	24.6	7666	24.35
TEI	5317	23.83	3898	23.55

The main difference between scenarios 1 and 4 is the presence of ventilation, which is beneficial for the cooling load of the building, despite the fact that the indoor temperatures in both scenarios are at the same level. As readily apparent in Fig. 5, the application of night ventilation in different positions inside and outside the urban environment can lead to similar deviations to the cooling load of the building. Therefore, there are reductions in cooling power of up to 5000 kWh and then there are percentages of reduction up to 34%.

Moreover, these percentages are differentiated depending on the distance of each position to the centre of the city. The technique of ventilation, which is affected by outdoor climatic conditions and the microclimate of each location, has a higher impact on suburban sites, like TEI, where conditions are milder.

Furthermore, significant deviations in values among the two scenarios (1, 4) influence the total cost for cooling the building, due to the increased consumed loads [Table IV]. In scenario 4, where the natural night ventilation is applied in combination with cooling system, loads are considerably lower than these in scenario 1, and, consequently, they affect the total cost required to ensure the desirable levels of thermal comfort for the occupants.

Moreover, when studying the application of two different ventilation strategies it is evident that the average temperature inside the building is lower in the case where there is a combination of natural ventilation during the night and cooling system [Table III] and according to the distance from densely urbanized areas [Fig. 6]. The position TEI is a suburban area with a different microclimate from the other two positions in the centre of the city. As a result, a hybrid cooling system is preferable [scenario 4], despite the fact that scenario 2 is the most cost effective. As expected, the levels of indoor temperature and energy consumption of the building are differentiated between areas, depending on both the distance from the urban environment and the microclimate of the area.

The energy consumption that corresponds to the increased loads increases the energy demands and peak demands for electricity. The cooling loads differentiated between the urban and suburban areas. Due to this fact, an appropriate legislative framework is required, in which there will be examined and taken into account significant terms like microclimate and UHI.

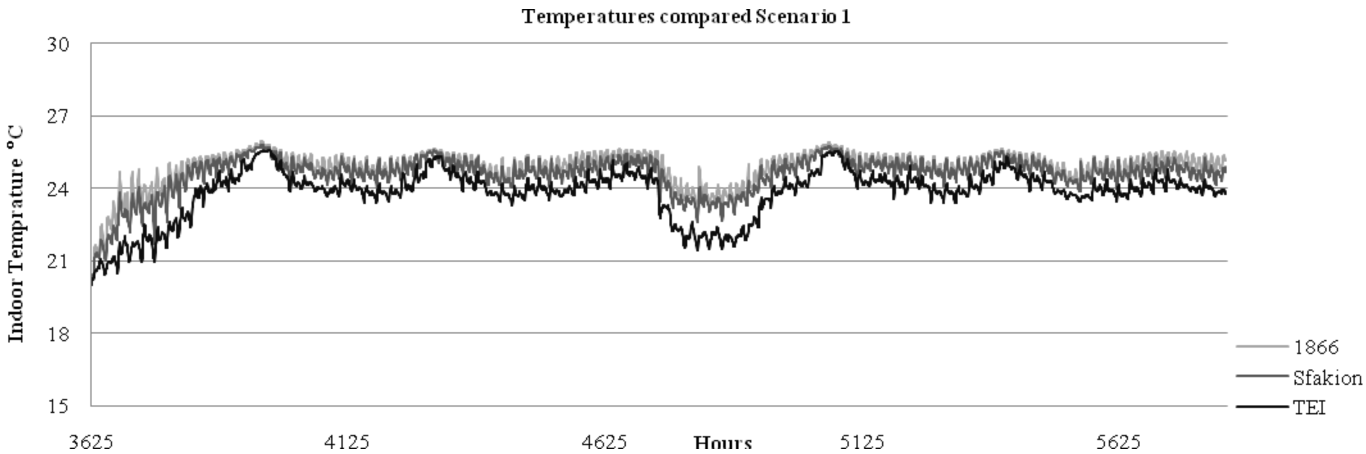

Fig. 3. Graph of temperature for all zones of the building in three different positions. In this case there is no ventilation during the night.

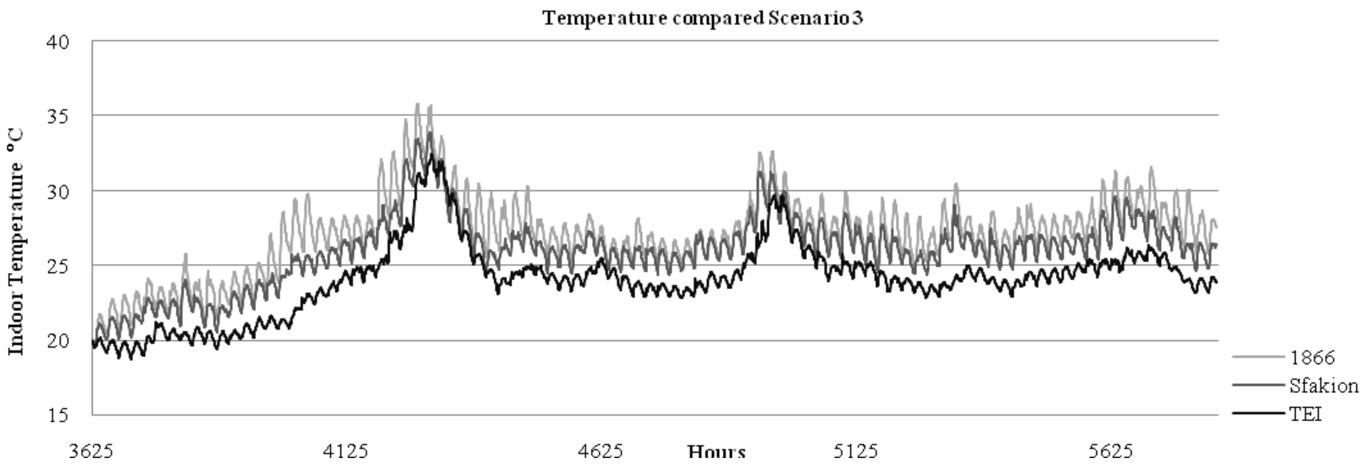

Fig. 4. Graph of temperature for all zones of the building in three different positions. In this case there is no ventilation, Cooling or Heating.

IV. Legal aspects

A. The EU and Hellenic regulatory framework on energy performance of buildings: a brief overview

At the European level, almost ten years ago, on 16th of December 2002, both the European Parliament and the Council adopted Directive 2002/91/EU on the energy performance of buildings. The objective of this Directive is to promote the improvement of the energy performance of buildings, depending on outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness. Member States enter into force laws, regulations and administrative provisions necessary to comply with the Directive by the 4th of January 2006 at the latest [24]. Following to this Directive, a recast is issued via the Directive 2010/31/EU, where Member States have to comply with

Articles 2 to 18, and Articles 20 to 27 by 9 July 2013 at the latest.

For the first time, this Directive introduces a completely new concept of "nearly zero-energy building" (article 2 par. 2). This constitutes a very drastic action that sets stricter criteria on energy behaviour/performance of buildings. Zero-energy building functions as a reference building, both for newly designed buildings, as well as those which are subject to transformation. Member States which have to be harmonized with the Directive should provide incentives and raise the number of nearly zero-energy buildings in a long term perspective [Article 9]. This action reinforces the national building sector and gives to the "zero-energy" term a significant role in the national energy balance. This is an important innovation in the field of Community law since the shift to zero buildings marks a new era in energy saving in buildings.

At the national level concerning domestic law, Hellenic Administration sets a priority on the management of energy resources in a manner which ensures the smooth, uninterrupted and reliable supply of the nation's energy needs and secures the access for all users to affordable, secures energy by setting legislative changes in energy policy. Via Law 3661/2008 [25] on "*Measures for the reduction of energy consumption in buildings*" (Official Government Gazette 89A/19.5.2008) and the Ministerial Decision D6/B/14826/17.6.2008 "*Measures for the improvement of energy performance and energy saving in public sector"* [25], the Hellenic legal system has been harmonized to Directive 2002/91/ EC in order to monitor the achievement of the objectives of the national energy policy on the energy efficiency of buildings, after a long delay [27]. Moreover, towards this direction the Joint Ministerial Decision "*Regulation on Energy Performance of the Building (JMD REPB)"* [28], as well as the Presidential Decree (PD) on energy inspectors are issued [29]. All the above legislative tools create the main regulatory framework of harmonization with Directive 2002/92/EC.

The aforementioned initiatives by the EU and the Hellenic State constitute, to a great extent, a significant effort to reduce the energy balance of the building sector. Nevertheless, an interdisciplinary approach of the above European and Hellenic legal framework highlights several points that deserve attention and clarification on some notions related to phenomenon and techniques like urban heat island, microclimate, ventilation and climatic zones. Therefore, from a critical point of view, a few deficiencies are revealed, which could be discussed.

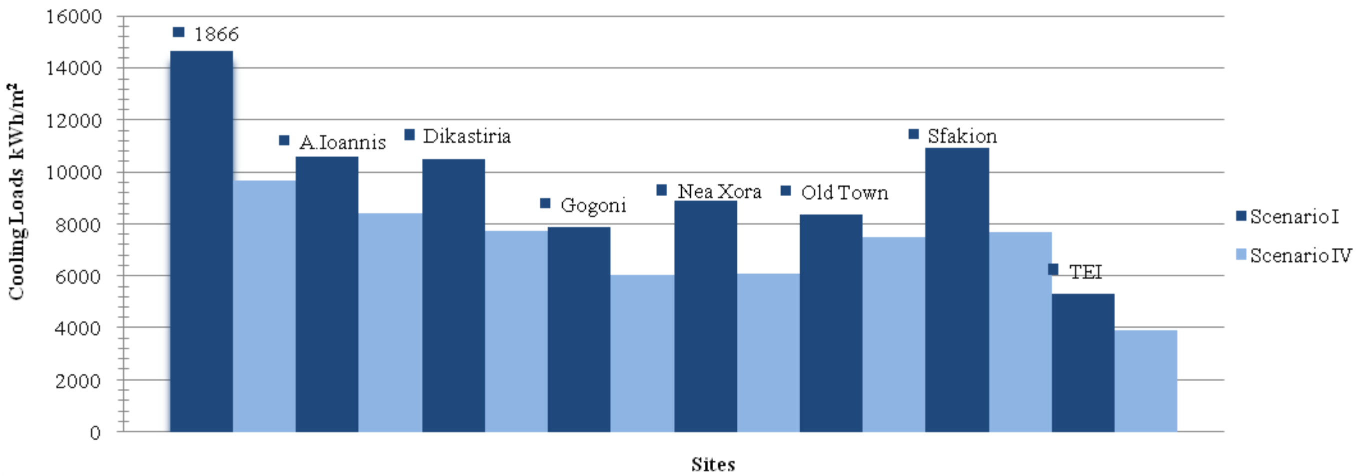

Fig. 5. The effect of night ventilation in urban and rural areas.

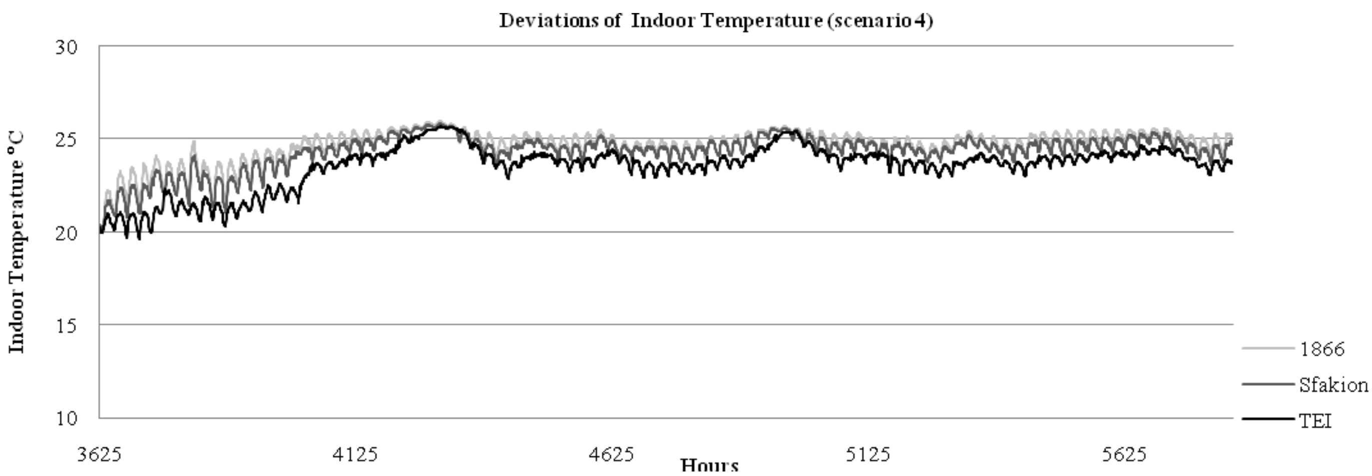

Fig. 6. Hourly temperature of three positions for the summer.

B. Some critical thoughts on regulatory framework

The incorporation of the EU Directive 2002/91/EC into national legislative framework through Law 3661/2008-"*Measures for the reduction of energy consumption in buildings*", the JMD REPB and the PDs, is a fundamental reform for the national regulatory framework. This framework has as a priority and top objective safeguarding and managing the energy balance of the building sector in Greece, and secures viable and sustainable development in accordance with the EU directives. Nevertheless, in the frame of an interdisciplinary point of view, such as in the present study, a few deficiencies, concerning the criteria of energy performance in buildings enacted both from EU and Hellenic regulatory framework, lead to some thoughts and proposals.

Initially, a significant parameter not studied extensively either in the European Directive nor in Hellenic harmonization is the Urban Heat Island (UHI) phenomenon. This phenomenon occurs as a result of microclimate changes brought about by man-made alterations of the urban surface and particularly is the maximum difference between urban and background rural temperatures as mentioned in the previous sections [31]. The Urban Heat Island has a great impact on the increase of temperatures and cooling loads, especially in urban agglomerations during the summer season, where air mass movements are restricted and the level of temperature differentiated between urban and rural areas.

Another subject that deserves further definition is the term "microclimate". Despite the fact that the initial European Directive 2002/91/EU "*on the energy performance of buildings*" mentions this term, even by promoting passive cooling techniques as a means of its improvement [Preamble point 18], the recast Directive 2010/31/EU does not include this term *expressis verbis*. Regarding the Hellenic harmonization, the JMD REPB indicates that microclimate should be taken into consideration for the progress of the energy performance study optionally. The documentation for the selection of vegetation included in the above JMD REPB is one parameter which improves the microclimate, while the explanatory Technical Directive [31] examines the vegetation and green areas close to the building, only as parameters which have to be considered for the design of the building and have a great impact on the microclimate. All the above constitute an indirect reference for microclimate which is an essential factor, as shown in the previous sections.

To this end, microclimate is a very substantial phenomenon from the technical perspective and, as a consequence, should be included in more detail in a subsequent revision of the European Directive, as a more specific criterion for the study of the energy performance of buildings. Similarly, all member States have to be oriented. Regarding the Greek reality, it should be underlined that the Draft of the aforementioned PD on energy inspectors (Chapter 5.6 "Training for energy inspections") suggested a training program that integrated subjects, like outdoor environment, vegetation and microclimate, which, unfortunately, at the end were not included in the final PD.

Referring to natural ventilation, to carry out the study for energy efficiency in buildings following the REPB, only a general description of the natural ventilation techniques applied in the existing building are required. Therefore, only the heating and cooling loads losses by the application of ventilation are considered without taking into account several critical parameters such as the type of ventilation, the schedule, the ventilation effectiveness, etc. Moreover, in both EU Directives, there is no reference to the selection of the most optimal ventilation technique, depending on the environmental conditions, as well as the directives do not distinguish day-time from night ventilation, a matter that has been examined from the technical perspective in several relevant studies. In the same direction, the Hellenic Technical Directive TOTEE [31] reports that natural ventilation, which is calculated for 18 hours/day, has great impact on cooling loads of buildings and differentiates mechanical from natural ventilation.

Despite the fact that both the initial Directive EPBD and its recast were enacted as legislative tools of environmental policies, the European Union stipulates that the objective is the investigation of the energy performance of buildings, mainly in the light of cost effectiveness and in the general concept of cost-benefit (for the 2002/91, points 9, 12, 14 of the preamble, as well as Article 1-Objective and Article 7; for the recast 2010/31, points 8, 10, 14, 15, 16, 32 of the preamble, as well as in Articles 1, 2, 4, 5, 9, 10, 11 and Annex III). Thus a significant omission of a clarified reference for the terms "microclimate, "climatic zone" and "UHI" is observed.

In this respect, the Hellenic harmonization and in accordance with Article 3 of the Directive 2002/91/EU, has chosen to introduce a classification method and a categorization of regions according to climate zones (JMD REPB Article 6). Consequently, the classification of a building as efficient or inefficient is governed by the climatic region, without taking into account substantially separate conditions prevailing because of the microclimate and its parameters. Thus it could be recommended that the Hellenic legislature should examine additional parameters for the determination of the microclimate, such as the ones mentioned above.

Another indicative but important issue arising from both the Hellenic and the EU legal framework regarding the optimization of the building's performance, is the fact that the replacement of frames made of materials, such as aluminium and plastic composite, is promoted. These materials possess high production costs and require high amounts of energy for mining and for their formation, a fact which makes them non-environmentally friendly. At first sight, there is a need to reduce the energy loads of the buildings in order to control the energy balance countrywide, while, on the other hand, some of the most energy-demanding materials are selected for this purpose. Therefore, a life cycle energy analysis of buildings and building materials should be promoted.

V. Conclusions

As it is apparent from the technical context of the study, the optimal strategy to cool the building is the combination of night ventilation supported by air conditioning during the daytime. Moreover, Hellenic legislation does not take into consideration the term of urban microclimate which affects the energy behaviour of the building following the EC directives.

Nowadays, the primary challenge is to achieve nearly zero energy buildings. The majority of buildings globally are located in big cities. In order to fulfil the goal of a nearly zero energy building, integrative approaches, along with passive techniques and innovative strategies, are essential.

From the legal perspective at the European level, there has been major progress in the regulative field concerning the energy efficiency of buildings, primarily via European directives. Due to the interdisciplinary nature of the topic which is under continuous development, there is a need for permanent revision of the EPBD Directives in order to follow the technical developments as, for instance, adding further parameters, such as microclimate and UHI, within their legal scope. The same procedure should be followed by the member states.

Therefore, legislative and political promotion of energy saving strategies in buildings with simultaneous improvements of the microclimatic conditions in an urban environment would assist achieving the initial target.

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Konstantinos Maragogiannis, Undergraduate Student, Technical University of Crete, Environmental Engineering Department. Research interests – Environmental Management, Energy Efficiency
Address: GR 73100, Crete, Greece
Phone: +302821037765, Fax: +302821037858
E-mail:k.maragogiannis@gmail.com

Dionysia Kolokotsa, PhD, Assistant Professor, Technical University of Crete, Environmental Engineering Department. Research interests – Energy Management Systems, Urban microclimate, Environmental Management, Energy Efficiency
E-mail:dkolokotsa@enveng.tuc.gr

Efpraxia-Aithra Maria, PhD, Associate Professor, Technical University of Crete, Department of Sciences. Research interests Environmental Law, Landscape Law
E-mail:efmaria@science.tuc.gr

Konstantinos Maragogiannis, Dionysia Kolokotsa, Efpraxia-Aithra Maria. Nakts ventilācijas efektivitātes izpēte pilsētas vidē: tehniskie un likumdošanas aspekti.
Eiropas Dienvidu valstīs arvien pieaug nepieciešamība pēc telpu dzesēšanas, īpaši vasaras periodā. Liela nozīme, izvēloties ēkām piemērotas pasīvās dzesēšanas metodes, ir pilsētas mikroklimatam un ģeomorfoloģiskajai struktūrai. Nozīmīga pasīvās dzesēšanas metode ir nakts ventilācija jeb nakts konvektīvā dzesēšana. Nakts ventilācija ievērojami samazina nepieciešamību pēc dzesēšanas, kā arī uzlabo termisko labsajūtu un iekštelpu gaisa kvalitāti.
Šī pētījuma mērķis ir analizēt nakts ventilācijas tehniskos un likumdošanas aspektus pilsētas klimata apstākļos. Tehniskajā daļā tiek pētīta nakts ventilācijas tehnoloģiju efektivitāte reālās dzīvojamajās ēkās. Tiek analizēta arī pilsētas „siltuma salas“ ietekme uz nakts ventilācijas efektivitāti. Pilsētā esošais siltums veicina gaisa kvalitātes pasliktināšanos un rada izmaiņas pilsētas mikroklimatā, līdz ar to samazinot nakts ventilācijas kā pasīvās dzesēšanas tehnoloģijas efektivitāti. Pilsētas klimata mērījumi tika veikti 8 reģionos Chania pilsētā, Grieķijā. Katrā reģionā tika mērīts vēja ātrums un virziens, āra gaisa temperatūra un relatīvais mitrums. Darbā analizēti arī likumdošanas akti, kas attiecas uz ēku energoefektivitāti, kā arī sniegtas precīzas norādes par trūkumiem esošajās regulās attiecībā tieši uz pasīvās dzesēšanas metodēm.