Application of the European Directive for the Energy Performance of Buildings in Cyprus

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SUMMARY

It is a fact that today in Cyprus there are no building-regulations concerning thermal insulation of the building envelope and consequently no restriction exist regarding energy performance. After joining the EU in May 2004, Cyprus has to comply with various directives of the Union. One of them is the Directive on the Energy Performance of Buildings 2002/91/EC. In order to comply with this requirement, a special committee was formed for the development of the required methodology and software to be used for this purpose. The objective of this paper is to present the methodology and program developed and its characteristics together with the type of output the user is expected to get. Considering that Cyprus is fully dependant on imported energy, it is believed that this new directive will lead to energy efficient buildings, and in the long run it will benefit the economy of the island.

INTRODUCTION

Today there are no building-regulations concerning thermal insulation of the building envelope in Cyprus and consequently no restriction exist regarding energy performance. After joining the EU on 1st May 2004, Cyprus has to comply with various directives of the Union. One of them is the Directive on the energy performance of buildings 2002/91/EC [1]. In order to comply with this requirement, a special committee was formed under the Ministry of Commerce, Industry and Tourism for the development of the required methodology and software to be used for this purpose. These are mostly based on the CEN/TC 89 'Energy performance of buildings – Calculation of energy use for space heating and cooling' [2] and the Cyprus standard CYS 98: part 1 published in 1999 on thermal insulation and rational use of energy in domestic buildings [3]. After a short description of the methodology the program developed for this purpose is described.

METHODOLOGY

The field of application of the present methodology covers both new residential buildings and new buildings that are not used as residences with floor area less than 1000 m^2, without central system for air treatment. The objective of the methodology is to establish the way and the standards that should be followed for the calculation of the energy performance of buildings as it is determined in the field of application, aiming to:

- Achieve indoor comfort conditions and ventilation requirements that will ensure the quality of the air inside the building and the hot water production requirements with the minimum possible consumption of energy.

- Avoid or minimize any pathological situations in respect of structural elements, arising from internal condensation, having negative effect on the durability of the structural elements and the quality of the air inside the building.

Despite its small size Cyprus has variable and distinctive weather patterns. For the purpose of this methodology, four climatic zones are set in the island; seaside, inland, semi-mountainous and mountainous as shown in Fig. 1. These zones were set according to the climatic data available from the Cyprus Meteorological Service.

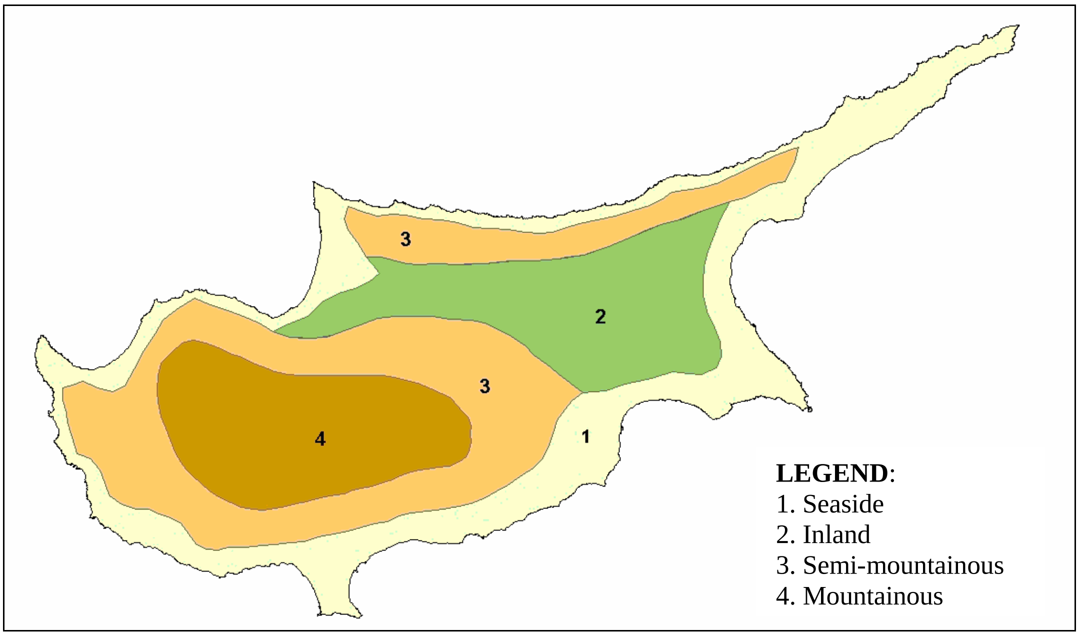

Fig. 1 Map of Cyprus showing the four climatic zones

Restrictions in the annual nominal useful energy needs and total annual consumption.

The annual nominal useful energy needs for heating a building, N_{ic}, examined with the present methodology, considering its form, thermal characteristics of the structural elements of its shell and the useful thermal gains from solar radiation entering the building, **should not exceed** the annual nominal useful energy needs for heating of the reference building, $N_{i.}$

Similarly, the annual nominal useful energy needs for cooling a building, N_{vc}, examined with the present methodology, considering its form, thermal characteristics of the structural elements of its shell and the thermal load from solar radiation entering the building, **should not exceed** the annual nominal useful energy needs for cooling of the reference building, N_v.

No restrictions are applied for the annual nominal useful energy needs for hot water production, N_{ac}.

The total annual consumption in primary energy of the building, N_{tc} in toe/m^2 per year, should not exceed the maximum allowed value of the total annual consumption in primary energy, N_t, as this is determined in the decree for the requirements of minimum energy efficiency, published by the Minister of Commerce, Industry and Tourism according to the law. This is calculated by adding the annual load for heating, cooling and hot water by multiplying each by its annual utilization factor (F_{pu}) and dividing by the equipment efficiency (η):

$$N_t = \frac{N_i F_{pui}}{\eta_i} + \frac{N_v F_{puv}}{\eta_v} + \frac{N_a F_{pua}}{\eta_a}, \qquad (1)$$

The annual nominal useful energy needs for heating and cooling the reference building should be achieved by using the following parameters:

1. Reference values of the thermal transmittance (U_{ref}) of the structural elements of the building that separate the building from the external environment or from areas not being air-conditioned or from other buildings attached to them.
2. Reference value for the solar factor ($g_{\perp ref}$).
3. 20% of the ratio of the area of the openings to the useful floor area.

The values presently applied are shown in Table 1.

Table 1 Reference values

Parameters	Value
Thermal Conductance of the roof, $U_{ref\text{-}roof}$	0.9 W/m^2 °C
Thermal Conductance of the walls, columns and beams, $U_{ref\text{-}walls}$	0.9 W/m^2 °C
Thermal Conductance of the exposed floor, $U_{ref\text{-}floor}$	0.9 W/m^2 °C
Thermal conductance of the openings, $U_{ref\text{-}openings}$	4.5 W/m^2 °C
Solar factor of the glazing, $g_{\perp ref}$	0.655
Note: The above values are subjected to periodical revision according to the decree for the requirements of minimum energy efficiency, published by the Minister of Commerce, Industry and Tourism according to the law.	

Each building should satisfy and not exceed the minimum requirements of the thermal characteristics of the building's shell as these are determined in the decree for the requirements of minimum energy efficiency, published by the Minister of Commerce, Industry and Tourism according to the law. The present values are shown in Table 2.

Table 2 Minimum requirements

Parameters	Value
Thermal Conductance of the roof, $U_{min\text{-}roof}$	1 W/m^2 °C
Thermal Conductance of the walls, columns and beams, $U_{min\text{-}walls}$	1 W/m^2 °C
Thermal Conductance of the roof, $U_{min\text{-}floor}$	1 W/m^2 °C
Thermal conductance of the openings, $U_{min\text{-}openings}$	5 W/m^2 °C
Note: The above values are subjected to periodical revision according to the decree for the requirements of minimum energy efficiency, published by the Minister of Commerce, Industry and Tourism according to the law.	

As this is the first implementation of this procedure, these factors are high enough compared with other Member States in order not to disturb the building industry. They will however be updated (possibly lowered) at least every 5 years.

Indoor comfort conditions are determined as follows:

1. The buildings should retain constant indoor temperature at 20°C for the heating period and 24°C for the cooling period.
2. The number of indoor air renewal, that will ensure its quality and comfort conditions, should not be less than 0.6 renewals per hour, which should be achieved naturally under usual conditions of operation (without mechanical ventilation).
3. For the consumption of hot water, 40 liters per person per day at the temperature of 37°C is considered (make-up water supply temperature of 15°C).

Calculation of annual nominal useful energy needs for heating, N_{ic}

The energy needs for heating of a building is the quantity of energy that is required in order to maintain the internal temperature constant during the period of heating. These needs do not represent the real consumption of energy because the tenants of the buildings do not maintain the same conditions and do not use the building the same way. In practice, the real consumption would be different depending on the habits of the owners.

Nevertheless, the energy needs for heating of a building is an objective criterion for the comparison of its thermal characteristics; the bigger they are the colder will be the building during the winter period or the more will be the consumption of energy required for maintaining internal comfort conditions.

The energy needs for heating are calculated by the method of calculation that is determined by European Standard EN ISO 13790. An important simplification is that the building is considered as one zone with the same temperature in all the spaces.

The annual nominal useful energy needs for heating, N_{ic} in kWh/m^2, is the algebraic sum of the heat losses by the shell of the building, Q_t; the heat losses due to infiltration and ventilation, Q_v; and the useful heat gains, Q_{gu}, as a result of the lighting, the tenants, the equipment and the rate of solar radiation that enters the building through the openings:

$$N_{ic} = \frac{(Q_t + Q_v - Q_{gu})}{A_p}, \qquad (2)$$

The heat losses by the shell of the building, Q_t concern the heat losses through the walls, columns, beams, openings, the roof and the floor, because of the temperature difference between internal and external temperature. These are given by the following equation in kWh:

$$Q_t = Q_{ext} + Q_{ina} + Q_{pe} + Q_{pt}, \qquad (3)$$

where Q_{ext} is the heat losses through the walls, columns, beams, openings, the roof and the floor in direct contact with the external environment; Q_{ina} is the heat losses through the walls, columns, beams, openings, the roof and the floor in contact with spaces that are not being heated; Q_{pe} is the heat losses through the structural elements in contact with the ground; and Q_{pt} is the heat losses through thermal bridges.

Heat losses through the walls, columns, beams, openings, the roof and the floor in direct contact with the external environment are given by the following equation in kWh:

$$Q_{ext} = \frac{U * A * DD * 24}{1000}, \qquad (4)$$

where U is the thermal transmittance (W/m^2 °C); A is the area of element, measured internally (m^2); and DD is the Degree Days.

Heat losses through the walls, columns, beams, openings, the roof and the floor in contact with spaces that are not being heated, are given by the following equation in kWh:

$$Q_{ina} = \frac{U * A * DD * 24 * \tau}{1000}, \qquad (5)$$

where $\tau = \frac{1-(\Theta_\alpha - \Theta_{atm})}{(\Theta_i - \Theta_{atm})}$; $\Theta_\alpha$is the temperature of the unheated space (°C); Θ_{atm} is the temperature of the external environment (°C); and Θ_i is the indoor temperature (°C).

The value of τ may be calculated with precision, using the method that is determined in the standard EN ISO 13789 or simply be considered as a conventional value taken by a table given.

Heat losses through the structural elements in direct contact with the ground, are given by the following equation in kWh:

$$Q_{pe} = \frac{\left(\psi_j B_j\right) * DD * 24}{1000}, \qquad (6)$$

where ψ_j is the linear factor of thermal conductivity of the structural element, j (W/m°C); and B_j is the internal perimeter of the floor and/or of the horizontal length of wall in contact with the ground j, internally (m).

Heat losses through thermal bridges, are given by the following equation in kWh:

$$Q_{pt} = \sum\left(\psi_j B_j\right) * \frac{DD * 24}{1000}, \qquad (7)$$

where ψ_j is the linear factor of thermal conductivity of the thermal bridge j (W/m°C); and B_j is the length of the thermal bridge j (m).

Heat losses due to infiltration and ventilation, are given by the following equation in kWh:

$$Q_v = \frac{\rho * Cp * R_{ph} * A_p * P_d * DD * 24 * (1 - \eta_v)}{1000}, \qquad (8)$$

where ρ is the density of air (kg/m^3); Cp is the specific heat of air (J/kg°C); R_{ph} is the number of air changes per hour (h^{-1}) depending on the position and the height of the building; A_p is the useful floor area (m^2); P_d is the mean internal height of the building (m); and η_v is the efficiency of heat recovery system.

Useful heat gains, Q_{gu} in kWh, as a result of lighting, occupants, equipment and the rate of solar radiation that enters the building through the openings are given by:

$$Q_{gu} = \eta * \left(Q_i + Q_s\right), \qquad (9)$$

where η is the utilisation factor of the heat gains (not all the heat gains are useful since a percentage can lead to internal overheat); Q_i is the internal heat gains; and Q_s is the heat gains due to solar radiation.

The utilization factor depends on the thermal inertia of the building and on the ratio between total heat gains and the total thermal losses of the building.

Internal heat gains, Q_i in kWh are given by:

$$Q_i = \frac{q_i * A_p * M * days * hours}{1000}, \qquad (10)$$

where q_i is the internal loads (W/m^2); A_p is the floor area (m^2); and M is the duration of the heating period in months.

Heat gains due to solar radiation, Q_s in kWh are given by:

$$Q_s = G_{sul} * \sum_j \left[X_j * \sum_n A_{snj} \right] * M, \qquad (11)$$

where G_{sul} is the mean monthly solar radiation on a 1 m^2 vertical surface of south orientation for the heating period (=108 kWh/m^2); X_j is the orientation factor of openings j; A_{snj} is the area of surface n, in orientation j, (m^2); j is the orientation; n is the number of surfaces in orientation j; and M is the duration of heating period in months.

It should be noted that angles of inclination of 60^o are considered vertical, otherwise they are considered horizontal.

The area A_s is calculated for each opening or group of similar openings, as far as glazing factor, solar protection and shading, are of the same orientation:

$$A_s = A * F_s * F_g * F_w * g_\perp , \qquad (12)$$

where A is the total area of openings (m^2); F_s is the solar obstruction factor due to shading caused by obstacles as other buildings, hills, trees, etc., other parts of the building, overhangs, verandas, and vertical obstacles and fins; F_g is the ratio of glazing area to the area of the opening; F_w is the correction factor for the glazing inclination; and $g_\perp$ is the solar factor of the glass at the vertical direction and indicates the percentage of solar radiation that passes through it.

The factor F_s has a range of values between 0 and 1, but in practice it cannot ever be less than 0.27 (characteristic percentage of diffuse radiation).

Calculation of the annual nominal useful energy needs for cooling, N_{vc}

As in the heating case, for cooling the real consumption would be different than the one estimated from this methodology, depending on the habits of the owners. Nevertheless, the cooling needs of a building is an objective criterion for the comparison of its thermal characteristics; the higher the cooling needs the hotter will be the building during the cooling period or the more will be the consumption of energy needed in order to maintain comfortable conditions. The cooling needs are calculated by the method of calculation determined by European standard EN ISO 13790. An important simplification is that the building is considered as one zone with the same temperature, like it happened for heating.

This methodology is the same with the methodology for the calculation of the heating needs. While for the heating period the non useful heat gains are responsible for overheating, for the cooling period are the ones causing cooling load and need to be removed.

The cooling needs of a building, N_{vc} in kWh/m^2, are calculated by the equation:

$$N_{vc} = \frac{Q_g (1-\eta)}{A_p} , \qquad (13)$$

where Q_g is the total cooling loads of the building, (kWh), given by Eq. (14); η is the utilisation factor of cooling loads; and A_p is the useful floor area (m^2).

$$Q_g = Q_1 + Q_2 + Q_3 + Q_4 , \qquad (14)$$

where Q_1 is the cooling loads because of the exposure of each individual building element to the external environment (effects of temperature difference and incident solar radiation); Q_2 is the cooling loads due to the solar radiation entering the building through the openings; Q_3 is the loads due to infiltration and ventilation; and Q_4 is the internal loads due to the equipment, occupants and artificial lighting.

Cooling loads because of the exposure of each individual building element to the external environment (effects of temperature difference and incident solar radiation) in kWh are:

$$Q_1 = M * U * A * (\Theta_m - \Theta_i) + U * A\left(\frac{\alpha * I_r}{h_e}\right), \qquad (15)$$

where U is the thermal transmittance of each building element of the shell, (W/m^2 °C); A is the area of element, (m^2); Θ_m is the mean external temperature of the cooling period, (°C); Θ_i is the indoor temperature, (°C); α is the solar absorption factor of the external surface; I_r is the mean monthly solar radiation on each orientation, (kWh/m^2); h_e is the exterior factor of transport of heat (e.g. 25 W/m^2 K); and M is the duration of the cooling period in hours.

Cooling loads due to solar radiation entering the building through the openings in kWh are:

$$Q_2 = \sum_j \left[I_{rj} \sum A_{snj} \right], \qquad (16)$$

For the calculation of solar factor $g\perp$ of the openings, the solar protection factor, $g\perp$', is taken into consideration as well. During the heating period this factor was ignored, which means that during winter, no solar protection is considered, e.g. shutters are assumed to be open allowing the building to benefit from the solar radiation entering through the openings (solar gain). On the contrary, because during the cooling period this is considered as load, solar protection is applied.

Loads due to infiltration and ventilation in kWh are:

$$Q_3 = Q_v, \qquad (17)$$

Internal loads due to the equipment, the occupants and artificial lighting in kWh are:

$$Q_4 = q_i * M * A_p, \qquad (18)$$

where q_i is the internal load in W/m^2.

Annual nominal useful energy needs for hot water production, N_{ac}

The annual nominal useful energy needs for hot water production in kWh are calculated by:

$$N_{ac} = \frac{M_{aqs} * Cp_{water} * \Delta T * \eta_d}{A_p * 3600 * 1000}, \qquad (19)$$

where M_{aqs} is the mean daily hot water consumption (lt); Cp_{water} is the specific heat of water (J/kg°C); ΔT is the temperature difference between cold and hot water, (°C); n_d is the number of days the building is occupied; and A_p is the useful floor area, (m^2).

Contribution of Renewable Energy Sources (RES).

The contribution of RES should be calculated and justified. For this purpose the contribution of RES systems can only be used if the systems or the equipment are certified according to the rules and existing legislation.

SOFTWARE

The software developed, which is currently in version 1.0, can be used for the estimation of the energy requirements of residential buildings and buildings up to 1000m^2 without centralized air conditioning system, for heating, cooling and domestic hot water. From the results obtained by using the software it can be decided whether a building fulfils the minimum energy requirements specified. According to the directive no building should be built without fulfilling the minimum energy requirements. Additionally, the results can be used for the issue of the energy performance certificate of the building.

The software estimates the energy requirements based on the envelope and orientation of the building. The software cannot be used for design purposes or system sizing. The building is considered as one zone. The software is user friendly and it is provided free to all engineers. The software has libraries of readymade structures and materials (walls, openings, slabs, roofs, floors, etc.) that can be found in buildings erected in Cyprus for the last 20 years, whereas the user has the capability to add a new structure not included in the libraries, under some circumstances. By choosing a city, a municipality or a village from a database the climatic conditions are automatically obtained based on the altitude of the area. Additionally the user can use U-value for walls, slabs, roof and openings up to the values specified in Table 2 (the program does not allow higher values).

The output of the program for a case investigated is shown in Fig. 2. As can be seen the building satisfies the criterion for the heating but not the cooling one. In this case the engineer should take various measures in order to reduce the cooling load such as, use better type of fenestration or improved wall insulation and if these are not enough, in cooperation with the architect, should try to reduce the glazing area, add overhangs, etc.

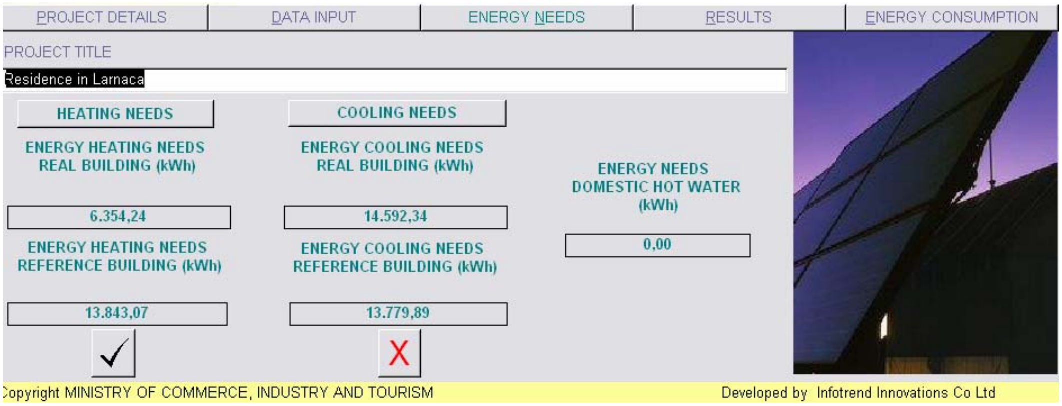

Fig. 2 Output of the software developed for the energy performance analysis of buildings

CONCLUSIONS

The methodology and program developed in Cyprus to satisfy the Directive on the energy performance of buildings is presented in this paper. It is believed by the authors that this methodology will improve the thermal performance of buildings in Cyprus as at the moment there are no building-regulations concerning thermal insulation of the building envelope. Considering that Cyprus is fully dependant on imported energy, it is believed that this new directive will lead to energy efficient buildings, and in the long run it will benefit the economy of the island. This will be more significant in a few years time as more strict minimum requirement will be imposed, not considered now in order not to upset the industry and the methodology will expand in new areas not covered at present (e.g. ventilation).

REFERENCES:

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