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Legislation driven scenarios based on recent construction advancements towards the achievement of nearly zero energy dwellings in the southern European country of Cyprus

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ABSTRACT

Europe has a significant target ahead to fulfill: to achieve the goal of nearly zero energy buildings from the year 2021. This paper presents viable scenarios to achieve the achievement of nearly zero energy dwellings in the southern European country of Cyprus. The analysis is based on the documentation of the developments in the building sector after the adoption of mandatory building insulation regulations. For this purpose, data concerning the building stock of Cyprus before the adoption of the regulation of thermal insulation, as well as the construction characteristics for sixty dwellings which were built from 2010 to 2012 are compared. The ability of adoption of renewable energy in the building sector is also analyzed. Several scenarios are examined and a matrix defining the possible ranges of primary consumption of dwellings in Cyprus considered as nearly zero energy are presented. Possible scenarios examined in relation to consumption of dwellings in Cyprus by 2020 showed that this would range from 65 to −40 kWh/m^2 year, depending on the degree of renewable energy technologies penetration. The outcomes of this work are particularly revealing with regard to the definition of feasible consumption targets for nearly zero energy dwellings in southern Europe by 2020.

1. Introduction

Today the policies on energy saving in buildings are of particular interest in Europe and the rest of the world. In Europe, a very strict policy is followed and Member States show special devotion in implementing such policy. Specifically, under Directive 2002/91 [1], Member States adopted common methodologies for determining the energy performance of buildings and accepted the system of energy certification of buildings through relevant certificates. The recast of the Directive on the energy performance of buildings 2010/31 [2], requires the adoption of an action plan for the significant decrease of the energy consumption of buildings by 2020, which is expected to be achieved with the contribution of renewable energy sources. While in countries with long tradition in the field of energy savings in buildings and with existing models of low energy buildings this objective seems attainable, things are more difficult for countries with little tradition in this area.

Cyprus, as a case study on energy efficiency in buildings has significant specific features which are as follows:

1. It is a country with hot summer prevailing conditions. The average maximum temperature for summer in Cyprus is 36 °C and the average number of hours of bright sunshine for the whole year is 75% of the time that the sun is above the horizon. Details of the weather conditions of Cyprus are shown in Table 1 [3].
2. In the past and until the adoption of the relevant regulation in 2007, there were no regulations on the energy performance of buildings.
3. Cyprus energy system is isolated, resulting to significant barriers for the upgrade of the system and this creates a high energy cost.
4. The dominant building is the dwelling, which has a relatively large area per inhabitant in relation to the rest of Europe.

Cyprus, as a member of the EU (European Union), was obliged in 2004 to implement the legislation on the energy performance of buildings, which was realized in 2007. By the end of 2012, Cyprus adopted a national legislation regarding the promotion of the nearly zero energy buildings into its building stock [4].

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Nomenclature

Symbols

B	day function [−]
E	energy carrier contribution to energy mix [%]
Q	quantity of heat [W/m^2]
PE	primary to end energy conversion factor [−]
t	time [s]
U Value	thermal transmittance [W/m^2 K]

Subscripts

H	heating
ht	heat transfer
gn	gains
int	internal
sol	solar
tr	transmittance
ve	ventilation

Abbreviations

AC	air condition
EPBD	energy performance of buildings directive
EPC	energy performance certificates
HVAC	heating ventilation and air conditioning
IAM	incidence angle modifier
LHV	lower heating value
PV	photovoltaics
RES	renewable energy sources
SBEM	simplified building energy model
ZEB	zero energy building

Greek letters

η	efficiency [%]
Θ	temperature [K]

This legislative framework is in full compliance with the EPBD (Energy Performance of Buildings Directive) [2] using identical definitions. However the nature of this document is rather general than specific, and no specific consumption ranges are defined regarding the expected performance of nearly zero energy buildings. The previous studies of Panagiotou et al. [5] and Fokaides et al. [6], recorded the behavior of the buildings stock in Cyprus at the time of implementation of the legislation with respect to the mandatory insulation of buildings, which was the first measure adopted in the history of the building regulations of Cyprus. According to the findings of these studies, the characteristics of the building stock in Cyprus are as follows:

1. The average building area per habitant in Cyprus is 52.3 m^2.
2. The primary energy consumption of dwellings per total area is 129 kWh/m^2 year. This consumption includes all the dwellings' energy needs and it was defined based on measurements of 500 dwellings in Cyprus.
3. The wall average overall heat transfer coefficient (U Value) is equal to 1.51 W/m^2 K.
4. The exposed roof average U Value is equal to 3.3 W/m^2 K.
5. The glazed surfaces average U Value is equal to 3.9 W/m^2 K.

The low primary energy consumption in Cyprus is mainly attributed to the fact that cooling loads prevail, whereas in cooling seasons not all spaces of the buildings are conditioned. According to Panayiotou et al. [5] the percentage of the conditioned space is nearly 20% of the dwellings.

Cyprus obligation is to initiate all necessary actions to establish the necessary framework that will enable the zeroing of the energy consumption of all new buildings by 2020. The nearly zero energy building is defined as the building which has a very high energy performance and produces or exploits energy from renewable sources in the same or similar rate it consumes energy on an annual basis [2]. It is hence understood that the forthcoming policies should move into two directions: the reduction of the energy consumption of the buildings by means of more strict rules and legislation and the promotion of the green energy for the building sector, either produced onsite or off site.

This study aims to provide useful insight with regard to the challenges that are faced in introducing principles of energy zeroing to the building stock of a country with insular energy system, summer dominant conditions and no previous experience on this task. The experience gained from this study, as well as the knowledge presented is for the benefit of the engineering communities and policy makers of the other 27 EU member states that currently implement similar policies, and most specifically to the other southern EU member states which have similar conditions. The climatic conditions of Cyprus are also similar to numerous countries outside Europe, which are currently in the process of adopting zero energy building principles (such as Oceania countries or large parts of the USA). Therefore this study offers significant added value to the international effort towards achieving zeroing of energy consumption of dwellings.

Table 1
Average air temperature and total solar irradiation in Cyprus [3].

Month	Global horizontal irradiation kWh/m^2	Daily average ambient temperature, °C
January	86.0	11.90
February	96.0	12.30
March	141.0	13.50
April	166.0	16.80
May	203.0	20.20
June	216.0	23.80
July	216.0	26.40
August	194.0	26.40
September	153.0	24.40
October	130.0	21.20
November	99.0	16.90
December	77.0	13.50
Year	**1777.0**	**18.98**

2. Literature review

The performance of a building towards achieving the 'zero' energy goal is influenced by a number of critical factors such as the system boundary and the metric which is used. The kind of energy considered, i.e., primary or final energy, the kind of loads included in the balance, the kind of data which are taken into account, i.e., design or monitoring, complicates the way a net ZEB (Zero Energy Building) is defined [7]. Despite sharing a similar definition net ZEBs differ from nearly ZEB in the fact that in the latter case the buildings may have a primary negative energy balance of few kWh which is technically reasonable and achievable. The zero energy

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