PV Assisted Heat Recovery Ventilation System for nZEB at Mediterranean Climate

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Abstract

Recently, across the world, indoor air quality has become one of the most spoken issue in consequence of COVID 19. People spend time at houses, offices, schools and the other indoor environments for social activities and personal necessities. Indoor ventilation by opening windows and doors does not always meet the requirements as air pollution increases outside. However, building related illnesses are inevitable for people who are frequently exposed to indoor pollutant such as biological (viruses, bacteria etc.). Therefore, the determined precautions should be taken without any delay and excuse.

Energy consumption because of the mechanical ventilation could be problem for the most buildings. In this direction, by the end of 2020, all new buildings in Europe must be proper to achieve the target of the nearly net zero energy building (Directive 2010/31/EU). As a solution, an off-grid solar assisted system was designed to supply the electrical load of heat recovery ventilation system with the intention of an example of nZEB concept. In detail, this paper presents some sample residential heat recovery ventilation designs for different types of dwellings in Mediterranean countries such as Portugal, Spain, France, Italy, Greece, Turkey. The solar PV system was simulated by PVsyst which is known as one of the most widely used software.

Introduction

The building sector has a considerable influence on global warming and is responsible for around 40% of the energy consumption in the member states of the European Union [1]. Therefore, building strategies have gained speed by reason of increasing CO_2 emissions. nZEB concept includes renewable energy sources and innovative applications which meet the zero energy targets as it becomes compulsory by the end of 2020 [2]. Especially, designing efficiency and heat insulated structures is as significant as using renewable energy powered domestic appliances. The other remarkable points such as climate conditions and building facades play a significant role on energy efficiency.

Therefore, housing strategies have been become more of an issue as building caused environmental pollution has been increasing. Moreover, people are intensively exposed polluted air in closed spaces unless there is no mechanical or natural ventilation [3]. In some cases, natural ventilation does not supply sufficiently fresh air and mechanical ventilation remains as the only solution in highly polluted cities [4]. At this point, polluted air must be taken seriously as well as any kind of pollutants otherwise, long term and short term affects, called sick building syndrome symptoms might be eventually inevitable [5]. Considering fresh air needs, the utilization of renewable sources and ventilation systems can reduce global warming potential and its effects.

In this paper, residential ventilation requirements from the standards and CO_2 calculations were examined for the comparative assessment of ventilation designs in Mediterranean countries. In EN 16798-1:2019 (Revision of EN 15251), CO_2 concentration rate should be under 800 ppm in the case of CO_2 controlled ventilation. On the other hand, 1000 ppm CO_2 concentration limit (published by Pettenkofer) is well accepted and used at present as a reference value (Recknagel and et al.,1996) [6]. Besides, housing regulations were researched for each country to specify room areas of the sample dwellings and determine the correlation between the minimum floor area and the number of occupants. The system was designed based on a daily usage scenario with a PV system and a heat recovery mechanical ventilation unit.

Housing regulations

Cultural and social differences influence building designs and comfort levels. In almost every country, modern and innovative architectures become prominent as well as traditional architecture. Thus, the dwelling types are important for the space area to assess indoor air quality and efficiency conditions for residential buildings. In a statistic including the Mediterranean countries (except Turkey), the preferred housing types in the countries are given in the **Figure 1**.

According to the HC (House Corporation) funding system, dwelling area is determined through the number of occupants (**Table 1**).

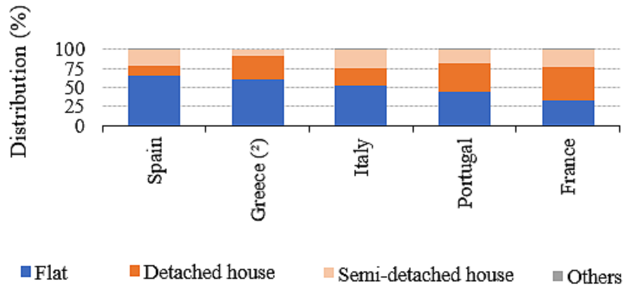

Figure 1. Dwelling types in Mediterranean Countries. [7]

Table 1. *Minimum Space Requirements [8] and Dwelling Area [9].*

Room (#of bdr/ocp.)	2/4	3/6	4/8
Dining Area	5	6	8
Living room	13	16	18
Kitchen	7	8	8
Bedroom (parents)	14	14	14
Bedroom 2	12	12	12
Bedroom 3	-	12	12
Bedroom 4	-	-	12
Bathroom with WC	4	-	4
Bathroom, no WC		4	-
Separate WC		1.2	1.2
Total	**56.5**	**76.2**	**93.7**

Occupancy	Dwelling Area (m²)
1	25-40
2	30-60
3	50-80
4	60-90
5	70-100
6	80-120
7	100-120
8	110-120

In 1988, World Health Organization published guidelines for healthy housing which explains the minimum comfort boundaries by taking into consideration of relation between the number of bedrooms and occupants [8].

Ventilation standards/regulations

One of the most widely used standard, EN 16798 is to contain four different indoor environmental factors such as thermal comfort, air quality, lighting, and acoustics. The approach of the standard in determining indoor air quality is to calculation a ventilation level depending on the number of occupants and the floor area. There are 3 categories in EN standard that are determined according to comfort needs. Minimum air flow rates per square meter given by category are 1.4 ℓ/s, 1 ℓ/s and 0.6 ℓ/s, respectively [10].

Although the ASHRAE Standard is published considering to North America, it is used all around the world as a source to calculation ventilation requirements. The minimum flow rates of ASHRAE for dwellings are 2.5 ℓ/s per occupant and 0.3 ℓ/s per square meter. In the ASHRAE 62.2, the exhaust flow rate for the kitchen and the bathroom is 50 ℓ/s. For the rooms, the recommended minimum ventilation rate is 3.5 ℓ/s per occupant and 0.15 ℓ/s per square meter [11].

National standards published in each Mediterranean country have been examined:

- In the Greek regulation, the air flow rate per capita is 4.72 ℓ/s [12].
- In Italian regulation, the air flow rate per person for the hall is 4.16 ℓ/s [12].
- In the Portuguese regulation, it is stated that ventilation is required once every hour [12].
- In the Spanish national standard (DB HS3), the air flow rate per person is given 5 ℓ/s for the bedroom and 3 ℓ/s for the living room [13]
- In the French national standard (Arrêté du 24 Mars 1982), the total amount of airflow is given per room. Flow rate is 35 m³/h for 1 room, 60 m³/h for 2 rooms, 75 m³/h for 3 rooms, 90 m³/h for 4 rooms [14]
- Turkey does not have a national ventilation standard and uses EN 16798 standard.

System design

Within the scope of the study, minimum and average space requirements per occupant were taken into consideration and 4 different dwelling types were determined. It is assumed that the dwelling types, whose number of bedrooms increase from 1 to 4, have areas of 50 m², 70 m², 90 m² and 110 m², respectively. The number of occupants has been determined by keeping the maximum level and each bedroom is used by 2 people for all dwelling types. The periods are given to describe the time spent in the different parts of dwellings.

According to the scenario, it is assumed that all the occupants are participated during all the periods. It is assumed that WC, bathroom, and kitchen are used between 07:00 – 08:00, 13:00 – 14:00 and 18:00 – 19:00. The whole dwelling is ventilated between 08:00 – 13:00, 14:00 – 18:00 and 20:00 – 00:00. It is accepted as a sleeping period between 00:00 – 07:00 and the bedrooms are ventilated during this period.

If mechanical ventilation is preferred to increase the indoor air quality at acceptable levels, it is necessary to heat or cool the fresh air given to the environment depending on the seasons. Furthermore, the CO_2 amount, which is a basic indicator for pollutants, is kept at allowed levels of concentration [15]. For the solar power ventilation system, PV system sizing is simulated using PVsyst. The optimum inclined placement of the PV modules offers the opportunity to make better use of the sun's daily movement.

Results

Calculating the required total flow rate according to CO_2 ratio gives a more realistic result for personal preferences. The important point to note here is, in the case where the number of people living in different sized dwellings is the same, the total air flow required for the smaller dwelling type and the total air flow required for the bigger dwelling type are very close. According to this result, the number of occupants is more important parameter than the size of dwelling.

In this study, the maximum amount of 1000 ppm CO_2 was accepted as the limit, and the minimum air flow per person was calculated using the iteration method depending on the number of people and the volume of the area. Due to meet the total air flow requirement, the necessary electrical energy was supplied from the PV system.

On grid PV system details for 1 room 1 living room and 4 room 1 living room dwelling types are given in the **Table 2**. PV system sizing is calculated according to the lowest solar irradiation month (December). In case the system is off grid, more energy produced in spring and summer is stored as unused energy in batteries. Therefore, the performance ratio (PR) drops considerably. In one example for Spain, the same components in the on-grid system were also selected for an off-grid system and only a battery was added. System performance has decreased to 60.6% for 1-bedroom residence and 75.3% for 4-bedroom residence.

As seen in the PV system results, the number of PV modules did not change in the sizing for the Mediterranean countries. Since different components are preferred, there are differences in the PR. The main factors affecting the PR such as the amount of solar irradiation, the efficiency between energy production and consumption, the efficiency of the components, the current and voltage values are the parameters to be considered during sizing.

Conclusion

In this paper, different residential designs based on ventilation standards were compared for Mediterranean countries such as Portugal, Spain, France, Italy, Greece, Turkey. The first aim of the study is to find out the difference of ventilation requirements among National Standards (if it exists) and European Standard, under the same design conditions (total number of occupants, total area of indoors and daily scenario). Additionally, CO_2 concentrations were calculated to determine the closest approach of occupant needs to the reality by using daily scenario.

The second aim is to design PV systems with proper sizing. The combination of solar energy system and ventilation system gives new opportunities to reduce the building caused carbon emissions. The proper

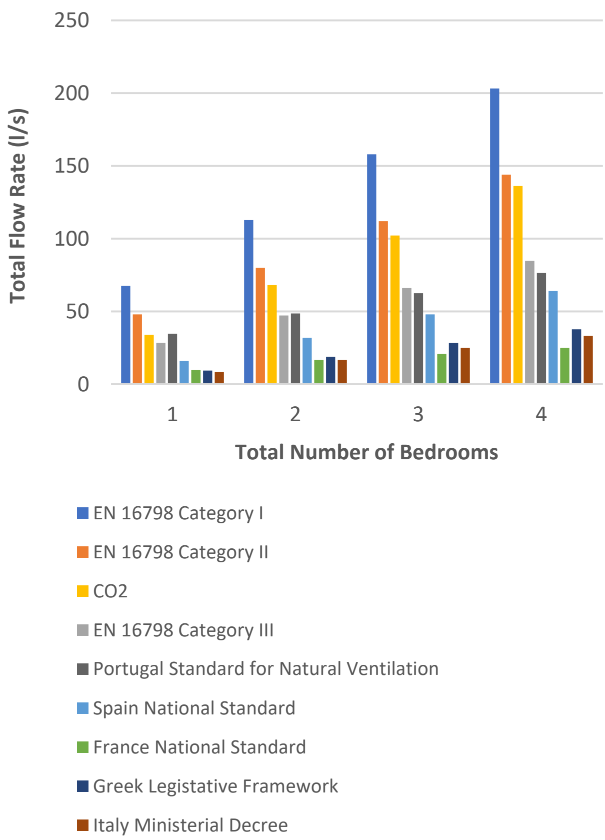

Figure 2. The Comparison of Total Flow Rates.

Table 2. *PV sizing results for Mediterranean countries*

	Portugal		Spain		France		Italy		Greece		Turkey	
PV Tilt (°)	33		33		36		36		32		32	
Dwelling Type (#of bed flat)	1	4	1	4	1	4	1	4	1	4	1	4
Planned Syst Power (kWp)	0.2	0.9	0.2	0.9	0.2	0.9	0.2	0.9	0.2	0.9	0.2	0.9
Number of PV Module	1	3	1	3	1	3	1	3	1	3	1	3
PV Module Power [Wp]	250	290	215	280	285	330	290	300	275	310	230	320
PR (on-grid) [%]	81.6	83.1	80.6	83.1	83.9	83.9	84	82.9	82	82.1	80.6	83

calculation of flow rate is important while designing a system and its efficiency. In this way, a comparison of the flow rates obtained from the CO_2 calculation with the scenario requirements was provided. The resulting differences contributed to an understanding of the perspectives on the application of standards to buildings in each Mediterranean country.

Furthermore, designing PV systems is also significant as well as ventilation needs. The performance of PV system was simulated by PVsyst tool. The tilt for each Mediterranean country was considered the location where the cities were chosen. The minimum air flow differences between the existing standards create uncertainty for the user in the selection of the ventilation unit. In this regard, it is important to develop methods for the compatibility of the required minimum air flows in the current standards and the air flows that the existing ventilation units can meet to improve the indoor air quality. The fact that the ventilation demand of ventilation systems is high, this demand can meet by clean and renewable energy sources in nature rather than being met by the fossil energy sources, is an important contribution to the protection of the climate balance.

PV system sizing has been calculated separately for Mediterranean countries and different components were preferred as much as possible. Due to the climatic conditions of the Mediterranean countries, the solar irradiation amounts are very close to each other. Therefore, when conducting PV system sizing, examining the dwelling types with the same consumption with different components under similar solar irradiation amounts gives us an idea about the preferable PV module power range. As a result of this study, which are obtained by increasing the indoor air quality and using PV systems, show that the Mediterranean countries have similar needs. Mediterranean countries, whose climate characteristics are similar, have a great benefit potential within the framework of common measures taken against global warming. ■

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