CARBON FOOTPRINT OF TYPICAL DWELLINGS IN CYPRUS

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Abstract

Over 40% of the final energy consumption in the EU-27 is consumed by the existing building stock while dwellings are responsible for 66.62% of this. Additionally, buildings are responsible for 30% of the total carbon dioxide (CO_2) emissions in the EU-27 while dwellings are responsible for 77% of this. Specialized studies showed that there is a large potential for energy saving in this sector and particularly for Cyprus the potential of savings is even larger due to the fact that until recently there was no legislative regulation concerning the energy performance of buildings.

In this work the definition of the carbon footprint of several typical types of dwellings in Cyprus is attempted through a sample of 42 dwellings located all over Cyprus. This sample was constituted by data collected from two on-going projects namely ElihMED and "Countdown to low carbon homes, Eracobuild". The data were obtained through a formulated questionnaire and a series of onsite visits. The analysis of the data reviled some very interesting facts concerning the carbon footprint of dwellings in Cyprus. The results were also compared to the corresponding UK values available in literature.

Keywords

Typical existing dwellings, residential, carbon footprint, energy consumption, Cyprus

1. Introduction

According to the Housing Statistics in the European Union [1] the total number of dwellings in the EU-27 is about 204 millions distributed accordingly in the following countries: 19.59 % in Germany, 13.22 % in Italy, 13.2 % in France, 12.32 % in UK, 8.18 % in Spain, 6.52 % in Poland, 3.57 % in the Netherlands the rest of the dwellings, around 23.4 %, belongs to the remaining European countries. It is very interesting to compare the number of buildings with the final energy consumption in residential buildings presented in Figure 1.

As it can be observed the countries with the highest final energy consumption in residential buildings in million tonnes of oil equivalent (Mtoe) are: 60.3 Germany, 41.5 France, 40.6 UK, 27.9 Italy, 18.2 Poland, 15.2 Spain and 9.2 the Netherlands. The comparison of the results shows that they are in close correlation and they follow the same trend which means that more dwellings result to higher final energy consumption.

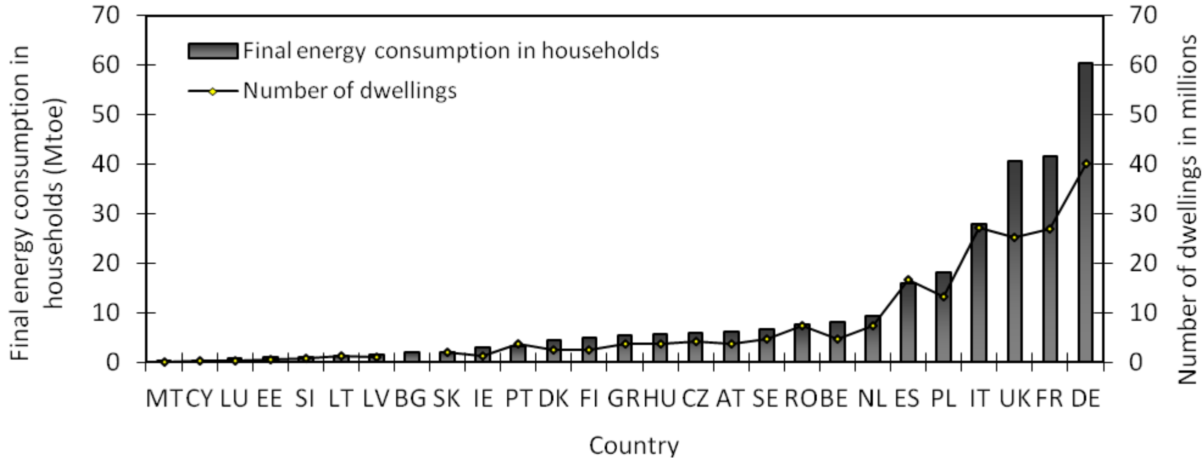

Figure 1 Final energy consumption and number of dwellings in EU-27 countries

In their study Uihlein and Eder [2] state that the total residential building stock of Europe will increase by 2.5 times in 2060, compared to 2000 levels. This is a very important fact to consider due to the consequent increase in total energy consumption in this sector.

A very important environmental effect of buildings is the emission of carbon dioxide (CO_2) which is the major greenhouse gas (GHG) responsible for the depletion of the atmospheric ozone layer and the change of climate. According to the Annual European Community greenhouse inventory 1990-2002 and inventory report 2004 [3] the emissions of CO_2 from residential buildings accounts for 8.9% of the total GHG emissions in 2011. These numbers of course may differ from country to country depending on the fuel and method used for the production of power and electricity [4]. On their work Petersdorff *et al.* [5] say that 77% of the total CO_2 emissions in EU-15 come from residential buildings while just 23% comes from commercial buildings.

The way the existing residential building stock of Europe behaves in terms of energy has been investigated in a number of studies during the last decade and the most important of which are presented below.

The effect of thermal insulation, age and condition of heating system on the energy consumption for space heating and the resulting environmental impact is studied by Balaras *et al.* [6]. In their study they used a sample of 349 residential buildings in seven European countries following the INVESTIMMO methodology as part of the European project INVESTIMMO. The data concerning the heating energy consumption came from 193 European residential buildings from five European countries namely Denmark, France, Greece, Poland, and Switzerland which participated in the project. The results showed that 38% of the audited buildings have higher annual heating energy consumption than the European average which is equal to 174.3 kWh/m^2.

Tommerup and Svendsen [7] stated that the energy saving potential in residential buildings in Denmark is quite large since 75% of them were constructed before 1979 were no rules concerning the energy performance of buildings existed. As part of this work, they presented a series of energy saving measures along with a financial methodology used for assessing them. Detailed calculations have been performed for two typical buildings and the results identified a potential for energy saving in space heating of about 80% in a time span of 45 years (until 2050).

Santamouris *et al.* [8] investigated the relation between the energy and social characteristics of the residential sector using a sample of about 1110 households located in the wider area of Athens, Greece. From the results of this work several important conclusions have been revealed such as the fuel poverty that arises due to the increase of the oil prices. Parameters such as the quality of dwellings, operational conditions, and the energy spent, highly depend on the income of the occupants whereas low income families are more likely to live in old buildings with poor envelope conditions.

Caldera *et al.* [9] statistically analysed a sample of 50 multi-family residential buildings of the local social housing company in Turin so as to derive simplified correlations between their main geometric and thermo-physical parameters and their energy performance for space heating. The dwellings analysed where built in different time periods between the end of the 19^{th} century and the end of the 20^{th} century.

In this study the definition of the carbon footprint of several typical types of dwellings in Cyprus is attempted through a sample of 42 dwellings located all over Cyprus.

2. Characteristics of the sample

The sample used in this study counted 42 dwellings and was constituted by data collected from two on-going projects, namely ElihMED and “Countdown to low carbon homes, Eracobuild”, through a formulated questionnaire and a series of onsite visits. The distribution of the sample according to the location of each dwelling is presented in Figure 1 and as it can be seen it covers all possible locations of Cyprus. The ElihMED project aims to identify and implement innovative technical solutions to improve energy efficiency in low-income housings in the Mediterranean area and its sample included 25 dwellings in Cyprus. The project “Countdown to low carbon homes, Eracobuild” main aim is to develop a commonly acceptable methodology in order to facilitate the sustainable energy retrofit of dwellings in Cyprus and its sample included 21 dwellings.

The sample selection process was different for each project. In “Countdown to low carbon homes, Eracobuild” project the selection was based on an open expression of interest by any individual who wanted to participate and was willing to undertake an energy retrofit of his/hers dwelling. Thus, this sample was randomly selected and contains dwellings of all possible categories such as type of dwelling, year built, location and gross annual income of the occupants.

On the other hand ElihMED the selection procedure for the definition of the sample was initiated by a public call for interest released on 2^{nd} April 2012 and carried on through a series of publicity actions that included announcements on websites, advertises on national newspapers and interviews of the personnel of CEA in a number of both television and radio channels. The selection criteria were the following: the gross annual salary of the household depending on the number of occupants, the location of the household (eligible municipalities), the total area of the house (apartments below 100 m^2, and single houses below 150 m^2), the year of construction of the house (1970-1995) and the ownership of the house.

Figure 1 Location of the dwellings according to the sample

3. Methodology

In each dwelling an energy visit was performed where all required data were obtained from the owner of the house through an interview and by using a questionnaire specially formulated for this project while also an infrared thermography of the house was conducted. The data collected concerned the characteristics of the construction of the house and the energy consuming systems and devices such as HVAC systems, lighting, DHW production systems etc.

Accordingly, the data collected were analyzed and inserted into a properly modified spreadsheet in order to calculate the carbon dioxide (CO_2) emissions which resulted from the energy consumption of the dwelling. The energy consumption contained all possible energy sources such as grid supplied electricity, heating oil for the central heating system, liquefied petroleum gas (LPG) used for both heating and cooking and biomass (wood) used for heating.

It should be noted that CO_2 emissions resulting from bioenergy production have traditionally been excluded from most emission inventories and environmental impact studies because bioenergy is carbon- and climate- neutral as long as CO_2 emissions from biofuel combustion are sequestered by growing sustainable biomass. Its climate impact has not therefore been considered. Cherubini *et al.* [10] propose that CO_2 emissions from biomass combustion for bioenergy should no longer be excluded from Life Cycle Assessment studies or be assumed to have the same global warming potential as anthropogenic CO_2 emissions. Carbon dioxide is emitted when biomass is burnt and the sequestration in the new vegetation can be spread for up to several decades in the case of slow-growing biomass, like forests. Thus, in this study the effect of biomass combustion, which in Cyprus it mainly concerns the use of wood from forests in fireplaces, will be taken into consideration during the calculations of the CO_2 emissions.

The calculations of the CO_2 emissions were carried using the conversion factors of Table 1 which are given by the Cyprus Energy Service of the Ministry if Energy, Commerce and Industry in the Methodology for Assessing the Energy Performance of Buildings [11]. Specifically, the CO_2 emission factors in the Table 1 denote the CO_2 emissions released in kg of CO_2 per kWh of the building's delivered energy and the main fuels are presented here.

Table 1 CO_2 emission conversion factors from different fuel types [11]

Type of fuel	CO_2 ($kgCO_2/kWh$)
Natural Gas	0,194
LPG	0,249
Biogas	0,025
Diesel Oil	0,266
Coal	0,291
Anthracite	0,317
Biomass	0,025
Grid Supplied Electricity	0,794
Grid Displaced Electricity	0,794
Waste Heat	0,018
Kerosene	0,258

4. Results & Discussion

The analysis of the results is graphically presented in Figure 2 showed that the majority of the dwellings in the sample (52%) emit between 5-10 tons of CO_2 per year while 24% of the dwellings emit 0-5 tons of CO_2 per year, 19% emit 10-15 tons of CO_2 per year and only 5% emit over 15 tons of CO_2 per year. The mean CO_2 emission for a dwelling in Cyprus is 7.76 tons of CO_2 per year which is much lower than the corresponding value for a UK dwelling which according to Druckman and Jackson [12] is 21.5 tons of CO_2 per year.

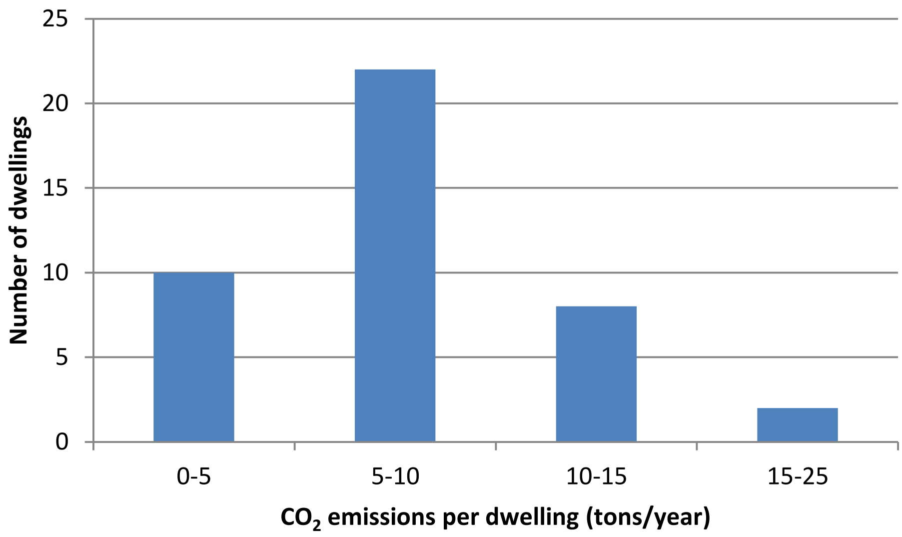

Figure 2 CO_2 emissions per dwelling (tons/year) in 42 dwellings in Cyprus

The results were correlated with several important parameters such as the number of occupants, the type and the area of the dwelling.

The results of the CO_2 emissions according to the dwelling's area are presented in Figure 3. The highest emission of CO_2 according to the dwelling's area (33%) is between 41-60 tons of CO_2 per m^2 year followed by 30% of the dwellings which emit 21-40 tons of CO_2 per m^2 year. Accordingly, 14% of the examined dwellings emit 61-80 tons of CO_2 per m^2 year, 10% emit 0-20 tons of CO_2 per m^2 year, 7% emit 81-100 tons of CO_2 per m^2 year and only 5% emit over 100 tons of CO_2 per m^2 year.

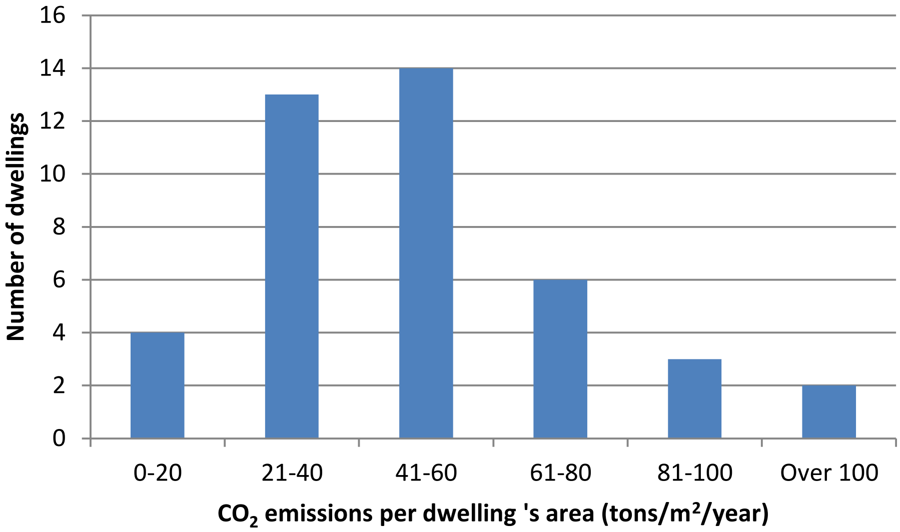

Figure 3 CO_2 emissions per dwelling's area (tons/m_2/year) in Cyprus

According to the results presented in Figure 4 the mean CO_2 emission per capita in Cyprus is 2.5 tons of CO_2 per year and the majority in the sample (55%) are responsible for the emission of 0-2 tons of CO_2 per year for their housing needs excluding other activities such as transportation. Consequently, 29% are responsible for the emission of 2-4 tons of CO_2 per year, 12% for 4-6 tons of CO_2 per year and just 2% for 6-8 tons of CO_2 per year. These values are also much lower than the mean UK value which is 9 tons of CO_2 per year per capita excluding transport [12].

The results for the CO_2 emissions according to the type of the dwelling (Figure 5) show that detached dwellings represent 71% of the sample and have the highest average emissions of CO_2 (8.25 tons of CO_2 per year). Terraced dwellings represent 17% of the sample and emit 7.19 tons of CO_2 per year while apartments represent 10% of the sample and emit 6.03 tons of CO_2 per year. In contrary when the emissions of CO_2 per dwelling type are expressed in terms of CO_2 emissions per m^2 of the area of the dwelling (Figure 6) then the apartment type has the highest emissions of CO_2 followed by terraced and detached dwelling. This is attributed to the fact that detached dwellings in Cyprus have much larger area (on average $150m^2$) than apartments and terraced dwellings (on average less than $100m^2$) [13].

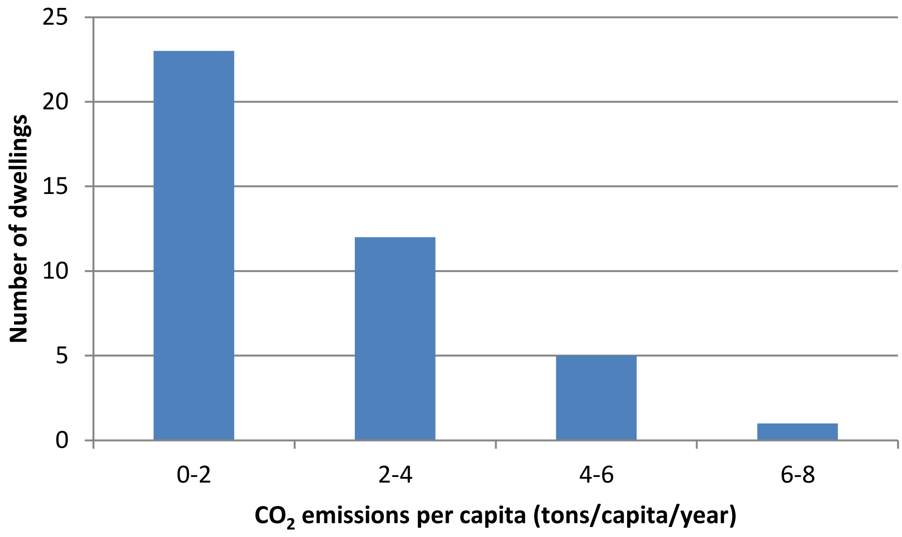

Figure 4 CO_2 emissions per capita (tons/capita/year) (residential sector excluding transport)

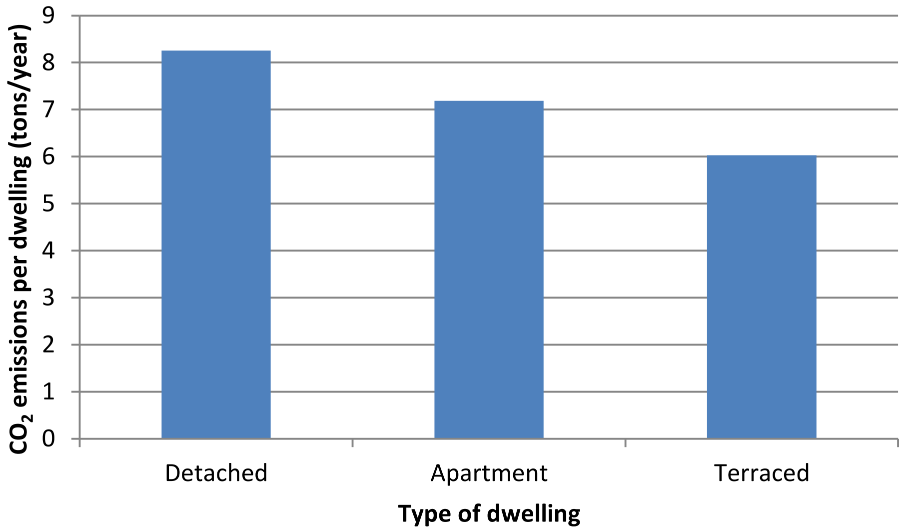

Figure 5 CO_2 emissions per dwelling type (tons/year)

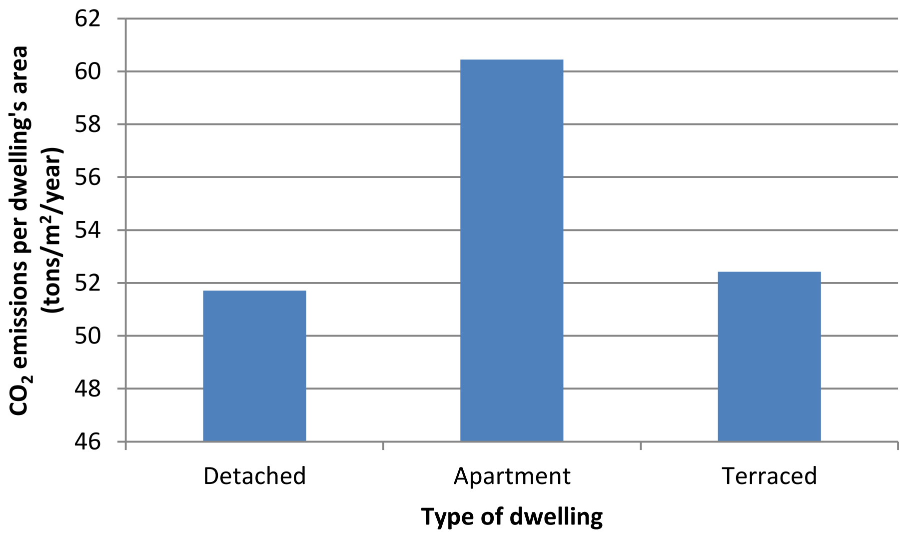

Figure 6 CO_2 emissions per area per dwelling type (tons/m^2/year)

5. Conclusions

In this work the definition of the carbon footprint of several types of dwellings in Cyprus was attempted through a sample of 42 dwellings located all over Cyprus. This sample was constituted by data collected from two on-going projects namely ElihMED and “Countdown to low carbon homes, Eracobuild”.

The analysis of the work reviled some very interesting results concerning the carbon footprint of dwellings in Cyprus. The majority of the dwellings in the sample (52%) are responsible for the emission of 5-10 tons of CO_2 per year while the mean CO_2 emission for a dwelling in Cyprus is 7.76 tons of CO_2 per year which is much lower than the corresponding value for a UK dwelling.

The highest emission of CO_2 according to the dwelling’s area (33%) is between 41-60 tons of CO_2 per m^2 year followed by 30% of the dwellings which emit 21-40 tons of CO_2 per m^2 year.

The mean CO_2 emission per capita in Cyprus is 2.5 tons of CO_2 per year and the majority in the sample (55%) are responsible for the emission of 0-2 tons of CO_2 per year These values are also much lower than the mean UK value which is 9 tons of CO_2 per year per capita.

Finally, the results for the CO_2 emissions according to the type of the dwelling showed that detached dwellings represent 71% of the sample and have the highest average emissions of CO_2 equal to 8.25 tons of CO_2 per year. Terraced dwellings represent 17% of the sample and emit 7.19 tons of CO_2 per year while apartments represent 10% of the sample and emit 6.03 tons of CO_2 per year.

Acknowledgments

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