

CO₂ Emissions in Buildings

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CO₂ is the most emitted greenhouse gas and is mainly produced by human activity. In fact, about 75% is emitted in cities and 40% of global carbon emissions is produced by the building sector.

Keywords: CO2 emissions ; buildings ; gas emissions

1. Overview

The world population living in cities reaches 55% and this percentage is expected to reach 68% in 2050. However, that percentage has already been reached in some areas. Thus, the urban population in North America, Latin America and the Caribbean is already over 80%; in Europe, it reaches 75% and in Oceania 68% ^[1]. In addition, 75% of CO₂ emissions are produced in cities and they consume between 60 and 80% of energy ^[2]. In particular, 36% of energy is consumed and 40% of emissions are produced in buildings ^[3]. However, in 2020, these values decreased by 1% and 10%, respectively, due to the COVID-19 pandemic ^[4]. The usual form of energy consumption in buildings is as electricity and as natural gas for thermal consumption ^[5].

Carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O) and hydrofluorocarbons (HFCs) are the main greenhouse gases (GHG). CO₂ is the GHG that is emitted the most, reaching 80% of the total. In addition, it is mainly produced by human activity. 77% of this pollutant comes from energy, of which transport accounts for about a third ^[6].

Energy consumption and gas emissions in cities are important; however, the area occupied by them is small. For example, in the European Union, it is only 4% ^[7]. Hence the importance of any action that is carried out in cities in general and in buildings in particular. This is reflected in the guidelines issued by the different organizations and that appear in the Sustainable Development Goals of the United Nations through Goals 7, 11, 12 and 13 ^[8]. They refer to energy, cities, sustainable and responsible consumption and production, and the reduction of emissions, respectively. At the European level, the European Green Deal aims to stop producing net greenhouse gas emissions by 2050 ^[9]. In this regard, 100 European cities have been selected to be climate-neutral and smart cities by 2030 ^[9]. With this, it is intended that they serve as experimentation and innovation hubs that make it easier for other cities to also achieve this goal by 2050.

2. Airport Facilities

Today, airports are small cities through which billions of passengers pass each year. The energy consumption, the services they need, the waste they produce and the emissions they generate are like those of any city. Numerous manuscripts on aircraft emissions have been published. However, they have not been carried out on emissions from buildings. CO₂ emissions from airport ground operations of 70 Chinese airports have been calculated. For this, fuel type consumed in on-ground airport operations and the CO₂ emission factor were used. In addition, night light data from images obtained from satellites were used. It was concluded that the factors that have most effect are urbanization, direct foreign investment, tertiary industry, passenger turnover of civil aviation and passenger turnover of railways, the latter being negative ^[10].

3. University Centers

As in other buildings for tertiary use, university centers are active mostly in the day. They may consist of several buildings or just one. They include the academic zone, administrative zone and, in some cases, laboratories. Savings measures in university centers is one of the recurrent study topics. However, emissions of this type of building have been little studied. As is generally the case in buildings, natural gas and electricity are their main sources of energy. A prediction of daily consumption has been carried out from six explanatory variables ^[11]. Due to the cessation of academic activity on weekends, the day of the week is one of those variables considered. Five-year data and a multiple regression technique

have been used to make the prediction. Data from a London university center have been used to test the forecast model and emissions, due to both electricity and natural gas having been calculated.

4. Hotel Facilities

The importance of hotels from the point of view of emissions is high, both because of the number of those that exist and because of the wide range of services that they offer to their clients. At the country level, Italy has been studied. Energy consumption has been evaluated to identify emissions. Subsequently, the potential energy savings and the possibility of implementing energy efficiency in them has been analyzed. The main saving measures are: substitutions of windows; substitution of current bulbs with LED bulbs; wall insulation; installation of condensing boilers; and installation of heat pumps ^[12]. Using a similar methodology at the city level, 28 hotels have been studied in Lagos (Nigeria) ^[13] and 17 in Hong Kong ^[14]. In the first case, the energy consumption per room was calculated, and in the second the consumption per m². Based on that knowledge, their emissions were also evaluated, starting from the fuel emission coefficient in one case and from that of electricity in another. Another way of approaching these studies has been based on the characterization of the most common type of hotels in the United Kingdom. Studying only two hotels, 67% of the hotels were covered. One of them modern and specially designed, and another old and remodeled. With this, conclusions were obtained on the measures to be considered to reduce their emissions: ventilation heat recovery through a thermal wheel; wall insulation externally or internally through expanded polystyrene or mineral fiber; argon-filled triple glazing; efficiency improvements in lighting; electrical appliances and kitchen catering equipment; efficient motors for lifts; replacement of conventional gas heating by condensing boiler; and water heating using solar thermal collectors ^[15].

Benchmarking has also been done on the Singapore hotel industry. For this, 29 hotels have been studied, electricity being the main source of energy. As a relevant conclusion, it was obtained that the characteristic that serves to normalize hotels must be very well chosen because carbon intensity is very sensitive to it ^[16]. The complete life cycle of a hotel has also been studied. For this, 31 hotels in the Balearic Islands (Spain) were analyzed. Both CO₂ emissions and generated waste were studied. The results show that the operation phase is the one with the greatest impact ^[17].

5. Public Buildings

CO₂ emissions produced in public buildings have been analyzed in 119 buildings in China. Hospitals, office buildings and schools have been studied. The former are those that produce the greatest emissions and the latter those that produce the least, with a difference between them of more than 100%. Emissions are obtained from energy consumption. These have been compared with those of the United States, United Kingdom and Japan. Energy consumption per unit of construction area is lower in China than in the first two and close to the last ^[18].

6. Residential Buildings

CO₂ emissions in the residential sector show sustained growth of 2% per year so far this century ^[19].

6.1. Rural Residential Buildings

Studies of emissions from residential buildings in rural areas are very scarce and limited to specific areas. Thus, the main source of energy in the province of Hubei (China) is biomass, coal and wood. A study of the emissions of the stoves used is carried out, showing which ones are better and calculating their emissions from field tests ^[20]. Furthermore, a study of the rural areas of Gansu, Qinghai and Ningxia provinces in China has been carried out. In this case, emissions were related to the type of agriculture developed, family income and family size. The following conclusions are reached: the highest proportion of emissions is due to the subsistence needs of families; emissions increase as income increases; and family size is inversely related to emissions ^[21]. Emissions in Wattwil (Switzerland) have also been shown from the statistical census. In this case, in addition to those due to residential buildings, those corresponding to land mobility have been included. In addition, the life cycle has been considered, identifying the factors that have the most influence on emissions ^[22].

6.2. Urban Residential Buildings

Studies that exclusively refer to urban residential buildings are few. The influence of one or several characteristics on the calculation of emissions is investigated. One of the most studied is income. The influence has been studied in China ^[23] ^[24] ^[25] ^[26], India ^[27], Lebanon ^[28] and Melbourne ^[29]. In all cases, the higher the income, the higher the emissions. In the case of China, other characteristics were also included, such as the influence of urbanization, education, marital status and number of inhabitants per household. As for Indian cities, their emissions are like those of Chinese cities. For

Lebanon, the number of residents was also considered. In addition, for the case of Melbourne, emissions due to automobiles were also included. In Japan, the influence that head-of-household age has on emissions was studied, being greater the older their age [30].

In urban areas, buildings are grouped into neighborhoods. In them, population density, accessibility to public transport [31], urban morphology and construction technologies influence emissions [32]. Furthermore, at the district and city level, calculation tools, emission assessment systems and efficiency measures at the urban level have been analyzed. These measures have been classified into urban morphology, buildings' efficiency, systems' efficiency and individual behaviors [33].

6.3. Rural and Urban Residential Buildings

Studies on emissions from residential buildings, without distinguishing between rural and urban or separating them, have been more numerous. They analyze the different factors that influence emissions. The income variable is once again recurrent in the studies. In addition to this, others that the researcher wants to highlight are included, such as, for example, the age of the residents [34], or the rural or urban location [35][36][37][38][39][40]. The conclusion reached with respect to the income level is that the higher it is, the higher the emissions. However, the emission intensities are the opposite in the Netherlands and United Kingdom [41].

Other factors have been analyzed individually. This is intended to improve emission-producing equipment and its environmental impact. This has been the case of air-conditioning equipment, whose use accounts for 33% of energy consumption in the homes analyzed [42], or the air or water adaptation systems inside the home [43], or the influence of the age of the dwelling [44]. Finally, the influence that government measures and the potential for emission reduction have in different countries has also been investigated [45][46][47][48].

6.4. Direct and Indirect Residential Emissions

CO₂ emissions can have a direct or indirect origin. Those of direct origin come from the use of energy by consumers of residential origin. While those of indirect origin are a consequence of the purchase and use of products and services by consumers to satisfy their basic needs. These residential emissions are those that cause the greatest growth in direct and indirect CO₂ emissions [49]. Thus, these two types of emissions represent more than 40% of carbon emissions in China [50], while estimates for the USA reach 80% [51].

Some studies have focused solely on the urban residential sector. Their conclusions are as follows: emissions are higher in cold regions and lower in larger cities [52]; depopulation of cities can generate higher emissions [53]; emissions increase with income [54]; the greater the number of people per household, the lower the emissions [55].

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