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Effects of Climate Change on Building Energy Demand and Thermal Comfort in Buildings

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ABSTRACT

The growth of urban population as a result of economic and industrial development has transformed our habitat from a prosperous place to one of careless resource consumption. On the other hand, long-term climate change, i.e., global warming, has had an adverse impact on our resources. Some resources are on the verge of being depleted due to climate change and indiscriminate consumption of resources, unless serious measures are implemented immediately. Building sector whose contribution to urban energy consumption Significantly higher, is a key player that may successfully solve the problem. In this paper, the impact of climate change on building energy demand and thermal comfort in buildings has been examined. Currently, most countries are grappling with the dual challenge of reducing greenhouse gases and climate change in the building sector. However, their efforts in addressing this challenge and stabilizing climate change. The building sector has tremendous potential to reduce greenhouse gas emissions at relatively low costs. Long-term climate change (e.g., global warming) is driving an increase in energy consumption for cooling demand, which contributes much more to the total energy consumption of buildings than heating demand. Therefore, to conserve its resources, urban energy planning and management should focus on creating an appropriate framework of guidelines on how to reduce cooling loads in building energy consumption patterns. It was also shown that in summer and spring, entry into the thermal stress zone is external, while in cold seasons, entry into the thermal comfort zone is external.

Introduction

Energy is one of the basic requirements of the world's economic and industrial development and reliable access to its resources is an important part of the national security of countries and one of the most decisive factors in directingthe interaction of the countries of the world [1], despite the fact that Iran is one of the richest countries in the world in terms of energy, but it is among the developing countries, which is mainly due to the lack of optimal use of these resources.According to the World Energy Association, Iran was one of the countries with the highest energy intensity in the world during the years 1990-2006 [2].

Population growth, coupled with unsustainable consumption patterns, is putting increasing pressure on land, water, energy, and other essential land resources. On the other hand, the demand for energy consumption has increased with the growth of population and the advancement of technology. Therefore, the increasing consumption of fossil energies in recent decades and the major environmental problems resulting from it are serious and important concerns for human beings in the present and future [2].

The environmental and social impacts of climate change have prompted countries around the world to commit to reducing their greenhouse gas emissions. In these measures to reduce greenhouse gases, a lot of attention has been paid to the building sector [3]. In fact, buildings account for more than 30% of total global energy consumption and 19% of total greenhouse gas emissions Be. Additionally, buildings are particularly vulnerable to the effects of heat waves and climate change, as the energy required to maintain a comfortable indoor environment is strongly linked to external climatic conditions.

A significant portion of the energy consumption in office buildings is for heating and cooling the space, which makes the heating, ventilation, and air conditioning (HVAC) system vital in reducing the intensity of energy consumption while providing thermal comfort conditions for the building's occupants. Studies have shown that improvements in thermal comfort are associated with increased performance, productivity, and health of occupants, making the goal of achieving thermal comfort increasingly vital [4]. Thermal comfort is influenced by many factors, both environmental and personal. The most important environmental factors that affect occupant thermal comfort since Fanger's studies in the 1970s are air temperature, average radiation temperature, air velocity, and relative humidity [5]. Climate change due to global warming has a direct impact on HVAC's energy demand, its size, and its ability to maintain indoor temperatures within a comfortable temperature range.

The available literature (industry-specific literature) suggests that researchers typically use one of the approaches described below to address this issue.

Although it is a widely accepted thesis that climate change can have serious impacts on energy demand, most studies tend to focus on how climate change is caused by the energy sector. In response, a growing number of studies have begun to assess the adverse impact of climate change on the energy sector. Despite the widespread belief of scientists that climate change primarily affects energy consumption levels, it may not be the whole truth. Currently, the energy consumption of buildings accounts for 67% of energy demand worldwide. Important missions have been developed [6]. The energy consumption of buildings in the European Union and the United States contributed up to 40% of the total global energy demand in 2019, while according to the US Department of Energy [7], it is 36% of the total energy consumption in the United States. The consumption of residential and commercial buildings.

The first approach, which is widely used in various studies, seeks to statistical analyze the relationship between the main climate variables and energy demand variables such as: electricity consumption [8], heating and cooling energy demand [9], total energy consumption of buildings, fuel choice or cost of living, value of facilities, etc.

However, this approach is limited to the study of changes in energy demand and socio-economic systems [10]. The limitations of the first approach have prompted researchers to adopt a different approach and analyze long-term changes by simulating building energy models. In this sense, using TMY files, the long-term impact of climate change in the form of a The general year is presented in such a way that this year will represent the entire historical period of the baseline. Analyzing the impact of climate change based on TMY files based on historical baseline on global energy consumption of residential buildings for heating and conditioning purposes [11], assessing the energy consumption of buildings in the USA, Germany, and China taking into account different climatic scenarios are among the important studies in this field.

Although many studies have been published on energy consumption in each climate, few studies have investigated the significant impact of urban change and consequently climate change or the effect of climate conditions on energy consumption, because climate change will affect the efficiency of renewable energy technologies and the amount of demand. This issue can affect the type and capacity of energy conversion technology. Therefore, this study was conducted with the aim of the effect of climate change on building energy demand and thermal comfort in buildings.

2- Literature review

- Climate change

Evidence from global warming suggests the impact of greenhouse gases and rising average air temperatures on various aspects of urban life such as health, water resources, energy, economics, politics, etc. [12]. This is why adaptation to climate change can be considered as a critical challenge of the 21st century to mitigate the adverse effects of global warming. Several international committees have tried different ways to address this. Purpose [13]. This area of climate change impacts has been the subject of numerous studies, as it is a vital issue for human life. Subsequently, the building sector appears to be highly vulnerable to the impacts of climate change such as global warming [14]. Winter storms, floods, droughts, hurricanes, as well as global warming resulting from extreme weather patterns present a number of challenges for the building sector. Of all the side effects mentioned, global warming appears to have the strongest implications for the future energy consumption patterns of the construction sector as the Intergovernmental Panel on Climate Change (IPCC)[1] highlights its role in increasing energy demand and energy supply uncertainty.

While climate change and global warming were considered hypotheses just a decade ago, they are now recognized as critical challenges for humanity globally [15]. Drought in Australia, unusual floods in Asian countries such as Malaysia, rising sea levels, melting glaciers, extreme seasonal heatwaves in Europe, and increased ice melt The Arctic is one of the most obvious signs of climate change and global warming.

The study is based on the following definition of climate change: human-induced climate change that alters the proportion of natural greenhouse gases in the lower atmosphere. This change may occur due to advances in technology. The types of impacts of climate change can be divided into three groups:

- Initial impact (e.g. on temperature, extreme weather events, floods, strong wind speeds)
- Secondary impact (e.g., changes in wildlife and nature)
- Tertiary influence (e.g., institutional, social, behavioral changes) [14].

According to an analysis based on simulations of historical global climate data, global warming, which has been monitored over the past 30 years, is not only caused by natural forces such as tilting the Earth's axis. Therefore, the IPCC considers the possibilities of the combined effects of climate change and human activities [16]. Increasing the proportion of carbon dioxide in the atmosphere and increasing its emissions annually. Since the Industrial Revolution, as shown in Figure 1 , it has supported this situation.

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the Intergovernmental Panel on Climate Change[1]

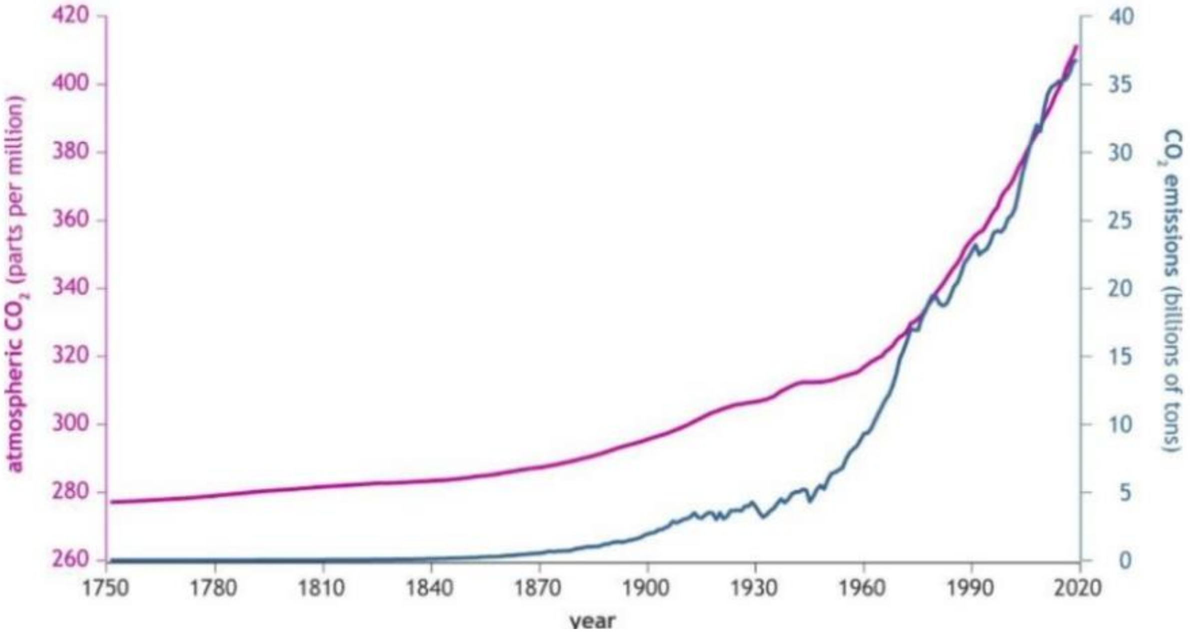

Figure 1: Carbon dioxide in the atmosphere and its annual emissions.

-Thermal comfort

The concept of thermal comfort was introduced in 1974 by Finger. Since then, it has been studied in the interior spaces of various residential, office, medical, etc. buildings. This keyword entered the scale of outdoor spaces in 2003 with the study of Spangelo de Diere by generalizing the internal thermal comfort indices to the external thermal comfort..

The American Society of Heating, Refrigeration, and Air Conditioning Engineers defines a person's sense of thermal comfort , the position of deriving satisfaction from the environmental comfort achieved by subjective evaluation. The feeling and perception of comfort is related to the physical condition of the person, the heat exchange of the body with the surrounding environment, and physiological characteristics that the heat exchange between the person and his surroundings is affected by parameters such as air temperature, relative humidity, thermal radiation of the air flow, amount of clothing, activity level, and direct contact with surfaces (Figure 2).

According to the definition of the Swedish National Housing Board and the European standard ISO 7730, thermal comfort refers to how a space is experienced in terms of temperature and draft. Thermal comfort is achieved when the thermal balance of the human body as a whole is in equilibrium, and the thermal heat production in the body is equal to the thermal loss to the environment. This balance is influenced by individual factors such as activity and clothing, and environmental factors, including air temperature, heat radiation from surrounding surfaces, air velocity, and humidity. Building features such as the thermal insulation capacity of the materials, the size of windows, heating systems, and ventilation systems It affects the air inside the building. If the human thermal regulation is out of balance, thermal discomfort occurs. The temperature required to maintain thermal comfort includes a minimum of 21 degrees Celsius in residential spaces. In the spaces of the elderly, the minimum temperature required is 22 degrees Celsius. The maximum temperature threshold recommended by the Swedish Public Health Agency is 24 °C in winter and 26 °C in summer..

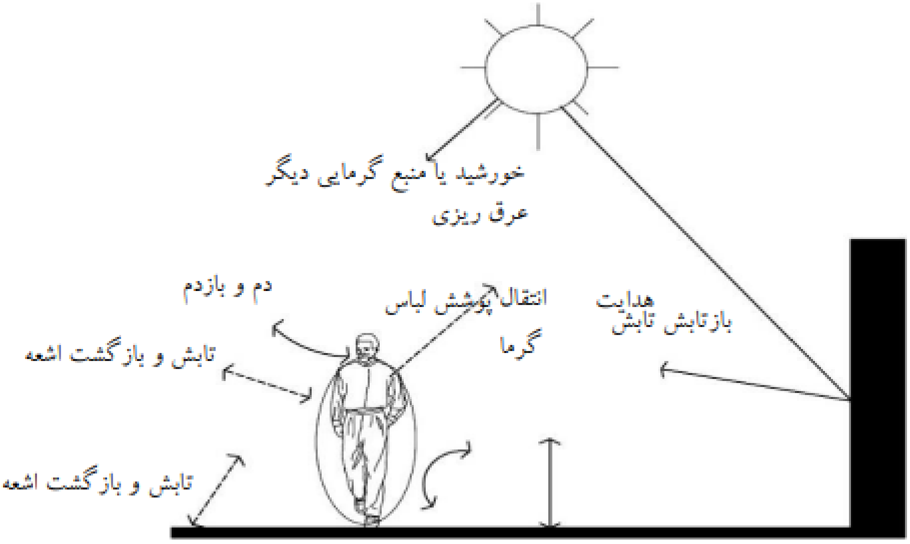

Figure 2- Components of the heat balance of the human body in the environment

- Factors affecting indoor thermal comfort

Building regulations usually do not define temperature thresholds to maintain thermal comfort. The Swedish Public Health Agency has formulated recommendations that are not based on research and therefore make no sense about when adverse health effects occur. This is mainly due to the fact that the perception of temperature depends on several factors, which makes it impossible for every human being to be satisfied with the same temperature. Individual human perceptions of overall satisfaction are influenced by environmental, constructive, and individual factors. As Figure 3 shows, these factors are interdependent..

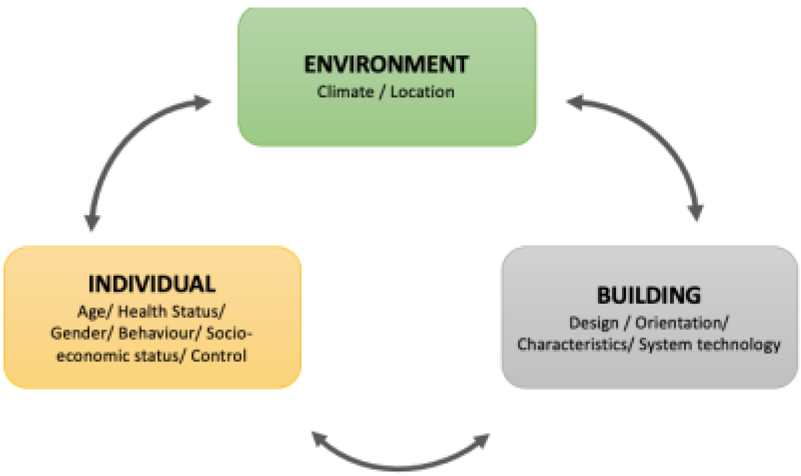

Figure 3: Three factors affecting human thermal satisfaction indoors[21].

Environmental factors include regional and local climatic conditions, and their impact depends on the adaptation potential of the population. This leads to the fact that the level of discomfort varies from human to human and depends on one's ability to adapt, resulting in different thresholds where thermal discomfort begins and temperatures can create dangerous conditions. Populations in cities with colder climates have lower thresholds than people living in warmer climates. Ormandy and Ezratty (2016) found in a study that thermal discomfort at temperatures of 22 ° C and 26 ° C is considered too hot for people living in Finland, which is normal for people living in warmer climates. Temperature adaptation has a great impact on heat-related mortality and varies for populations of different climates. While the minimum temperature threshold The indoor risk for heat-related health effects is 22-23 °C in London, around 30 °C in Thailand.

Another factor influencing mortality is the timing of heat waves. If heat waves occur earlier in the year, they will have a greater impact because people didn't have the opportunity to adapt to higher temperatures. Researchers speculate that climate change as temperatures rise may be a factor in adaptation. A building can improve human thermal satisfaction through location, orientation, height of living space, etc. affect the effectiveness of heating and cooling and the characteristics of the building[23]. If the building is in a dense urban area, the urban heat island ([2]UHI) effect can affect the indoor environment. The UHI effect is a term that describes the changes between urban and rural temperatures due to atmospheric and surface effects, such as heat reflected or emitted from people, vehicles, buildings, and roads. It is caused by rapid urbanization, leading to high urban temperatures. The temperature between urban and rural areas can vary by up to 16 percent. Studies have shown that UHI can play a role in 21% of heat-related deaths.

The orientation and height of the buildings are factors that affect the interior environment. Apartments that are located to the south and have large windows are more susceptible to additional heat than apartments that are located on the ground floor facing north. The year of construction and the specific design of the building of that period will affect the interior environment. Zalejska-Jonsson and Wilhelmsson (2013) studied Swedish houses built in different periods and their impact on the perceived interior environment, and found that various internal environmental problems and their impact on overall residents' satisfaction depended on the year of construction and design. Buildings built before the 1960s had major problems, while buildings built between 1961 and 1961 Built in 1975, they have trouble with very low temperatures. Overall, they concluded that buildings built before 1975 showed a high susceptibility to thermal comfort problems, mainly because these buildings were built with little or no insulation and energy-efficient windows.

In contrast, recently constructed buildings (built between 1996 and 2005) showed major problems with air quality, especially unpleasant odors and clogging air. Energy-efficient measures to reduce a building's heating demand , such as higher insulation thickness and increased ventilation, affect indoor temperatures. Study conducted by Mavrogianni et al. (2012) analyzed how energy-efficient buildings affect London's interior environment. Their results showed that higher wall insulation increases indoor temperatures on average. In contrast, more efficient roof and window insulation lowers indoor temperatures on average . Increased ventilation of the building covering increases indoor temperatures, as it limits heat loss through the penetration and trapping of heat from indoor and solar utilities inside.

The third factor that influences human thermal perception is individual factors. They are highly dependent on a person's health status, age, gender, and socioeconomic status, as well as behavior and awareness [26]. Older individuals (65+) and younger (up to 5 years) are at a higher risk of thermal discomfort due to their physical condition and good functioning or immature thermoregulation system. They are more susceptible to thermal discomfort indoors They spend more time at home than other age groups. Exposure to extreme temperatures indoors can have a huge impact on their health, especially if they have pre-existing conditions such as cardiovascular or respiratory diseases. Older people are less aware of changes in the thermal conditions around them, increasing the risk of heat discomfort.

-Climate change and outdoor thermal comfort

The spatial patterns of cities, their growth and development are affected by climate change. Buildings andurban developments affect the absorption and reflection of sunlight and the ability to store heat and evaporability.

Human activities have an effect on the climate in such a way that part of the human heat created is due to the abandonment of activities and the creation of air pollution, which affects the incoming and outgoing radiation. The presence of aerosols in the air is the result of the activities of vehicles and

[2] Urban Heat Island

industrial sectors. The amount of solar radiation in most cities is less than 10%. However, in polluted cities, this amount increases by up to 20 percent. This heat causes the temperature to drop. The higher the air temperature, the less the external thermal comfort of the people, which causes health problems for humans. It can be said that climate change, such as heat waves, affects the living environment of humans. On the other hand, the increase in ambient temperature has an adverse effect on the comfort of residents and the level of presence in urban open environments.

Extensive reports show that during the period of heat wave and rising ambient temperatures, hospital admissions in the field of stroke have increased and the death rate has increased. Research shows that an increase in ambient temperature increases 1.35% of mortality, 1.72% of cardiovascular diseases, 3.30% of respiratory problems, and 1.25% of brain complications..

-Different scenarios in the energy process

Predicting climate change for a period of more than 100 years is used as a mere scenario rather than an accurate forecast because several uncertain variables must be taken into account when interpreting future climate parameters. These uncertainties include the climate system's response to climate change, carbon emission levels, and socio-economic progress. GCM Atmospheric-Ocean Models (General Circulation Models) developed by the IPCC for the purpose of weather forecasting. The GCM method predicts most of the spatial separation levels derived from atmospheric motion physics (5×5° latitude and longitude)[27]. The emissionscenario developed by the IPCC Working Group, which describes potential energy trends, is presented in Table (1)

Table 1 – Energy trend scenarios based on emission scenarios[27].

Family Number		Description
A	1	Alternative energy systems such as non-fossil resources, compact or balanced fossil systems are changing as a result of economic development and rapid population growth.
	2	Economic growth while population growth continues
B	3	Clean, resource-efficient technologies and a service and information economy became a global trend as a result of the economic changes caused by the peak of population in the mid-21st century .
	4	Achieving social, environmental and economic sustainability along with economic development and moderate population growth through local solutions

An overview of the impact of climate change on the energy consumption of buildings should contextualize the different climate scenarios that need to be considered. According to Clark et al. [28], there are three possible climate scenarios.

- Constant climate
- Climate: 4/5
- Climate 5/8

While the first scenario seems unlikely, it should still be considered as a benchmark for other scenarios. This scenario assumes that there will be no significant change in temperature (HDD as the degree of heating and CDD as the degree of the cooling day). The 4.5 climate scenario is based on the precise spatial network of temperature profiles that originate from the CESM (Community Earth System Model) and the RPC 4.5 concentration path.It is. The 8.5 climate scenario also relies on the same information from CESM and the RCP 8.5 concentration path, where the CESM model was actually developed in the Fifth Paired Model Comparison Project (CMIP5). The numbers (4.5 and 8.5) before the names relate to the stabilization of radiant pressure levels at 4.5 W/m2 or 8.5 W/m2 by 2100. While the two scenarios are only slightly different, the first – the constant weather scenario – is very different. So, in fact we focus only on two groups of climate scenarios to analyze, which consider both global population and per capita income to be the same. All of the scenarios listed above believe that the increase in average global temperature is a parameter that indicates gradual warming. The IPCC claims that this parameter has increased by about 1°C since the 18th century , which is shown in Figure 4. It rises to 5.8° C and extreme weather phenomena occur more frequently around the world.

Figure 4 – Global surface temperature since 1880.

The Impact of Climate Change on Energy Consumption of Buildings

It has been proven that the type of environment and climatic conditions affect various aspects of the energy consumption of buildings [30]. This effect can be categorized into the following three groups:

1) HVAC System (Heating, Ventilation & Air Conditioning)
2) Heating & Cooling Demand
3) Demand for courier electricity

1) HVAC System

Today, most buildings are designed to use natural ventilation instead of any electrical cooling device (such as air conditioning units) to reduce environmental impact. Nevertheless, as temperatures in the summer are more and more likely to reach very high values, we can see a gradual growth in HVAC-related energy consumption [31]]. As a result of extreme weather conditions, natural ventilation is often inadequate, resulting in an increasing demand for cooling in the summer. For example, it is predicted that by 2080, energy demand for air conditioning needs in buildings will increase by 30% in Athens in July and August.

2) Heating & Cooling Demand

The most obvious impact of climate change on the energy consumption of buildings is the increase in the consumption of cooling and heating energy. This can be attributed to the increasing need for adequate thermal comfort in buildings during hot summers and cold winters. Studies have shown that the trend of rising temperatures in recent years on a global scale has caused more discomfort in the summer and less discomfort in the winter. Changes in the demand for heating energy and Cooling is considered to be the result of day-to-day degree changes [32].

The last of these variables mentioned is strongly influenced by the geographical location of the analysis area. The types of possible impacts of climate change have been on cooling and heating loads, which are key parameters in determining the energy consumption of buildings.

Using computational methods, most studies predict a drastic decrease in heating energy demand and a significant increase in cooling demand in the building sector [33, 32]. Studies have observed that the future decline in heating energy demand will outweigh the rate of day-temperature reduction in heating, while the potential cooling energy demand is projected to increase significantly. According to the rate of cooling degrees, the demand for cooling energy is projected to increase by 2100% during the period from 1975 to 2085. This confirms the results of previous studies that show a decrease in demand for heating and an increase in demand for cooling in the building sector. This is why higher energy demand is expected in summers and springs in warm countries (such as Mexico), while cold countries (such as Canada, Norway) are expected to consume less energy in winter. In temperate countries (such as Italy) there is an additional demand for cooling energy During the summer it is balanced by a decrease in heating energy demand in winter and spring.

- Electricity demand courier

Most studies on the impact of climate change on the peak demand for electricity in buildings indicate a sharp decline in the demand for heating energy and a significant increase in the demand for cooling energy in recent years.Some researchers were of the opinion that the increase in cooling demand would be balanced by a decrease in heating demand, while others predicted that cooling energy demand might completely dominate the electricity sector [34]. However, it should be noted that the impact of climate change on the energy consumption of buildings is also influenced by other factors, such as climate change scenarios and building types.[35] It has also predicted a sharp decline in energy demand in colder regions in the future. Although lighting and electrical loads appear to be primary sources of electricity consumption in buildings, cooling loads have been found to account for a major portion of electricity consumption, which is expected to increase by more than 50% in the next 100 years [14]. Therefore, it is concluded that the impact of climate change on electricity consumption in the building sector has led to an increase in energy consumption due to increased demand will be used for cooling. However, the rate of increase in consumption varies depending on the type of building and its size, which determines the sensitivity of a given building to climate change.

3. Results and Discussion

By applying climate scenarios (Table 2), we can reduce the number of variables and analyze each scenario according to the conditions of the case group. The first scenario assumes climate as a constant variable. However, there is a wide range of uncertainties that need to be taken into account that we can cope with by improving adaptation [36], including socioeconomic trends Probable bases such as population and average global income (per capita income) that is expected to grow and construction technology that is expected to improve. These variables follow the path introduced by Frico [37], which predicts that the world's population will peak in 2070 and decline by the end of the century. It is assumed that this peak occurs mainly in developing countries, while the population in industrialized areas (developed countries) is expected to remain almost unchanged. Given the potential significant economic growth, per capita income in developing countries may eventually converge with income generated in developing countries.

It should be noted that there are significant risks to the collapse of civilization, also in terms of the peak of the global population, before 2070 due to the overexploitation of natural resources.On the one hand, since building technologies are expected to make significant advancements (e.g., increasing building shell efficiency), the demand for heating and cooling will decrease as a result. On the other hand, innovative solutions in their cooling and heating equipment are leading to a decrease in the demand for cooling and heating systems.

It can be seen that the trend of energy consumption in buildings is focused on the energy demand for cooling and heating. More specifically, according to Clark [28], the number of degree-days of heating and cooling in 2010 shows that despite the significant difference in cold and hot regions, the cumulative number of these variables is almost the same as shown in Figure 5 .

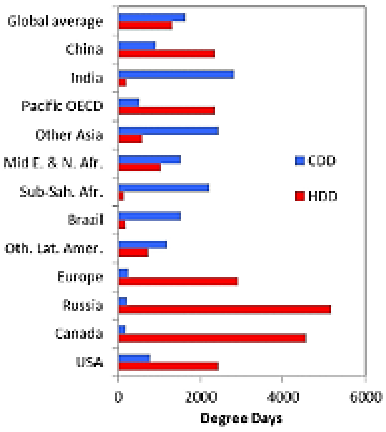

Figure 5 - Number of degrees of days in different regions in 2010

By analyzing the entire dataset from different regions of the world, global trends in the energy consumption of buildings can be defined based on the degree-day of cooling and heating. Fig. 5 shows that the CDD numbers are clearly increasing, while the HDD number shows a slight increase and then a sharp drop. This means that at some point in the future (close to 2070), cooling energy loads will increase. The demand for heating energy in the building sector will be greater, and since then, the difference between these variables is likely to increase rapidly.

4. Conclusion:

This paper seeks to provide a detailed overview of the impact of climate change as a severe consequence of economic, industrial, and similar changes such as technological advancement and population growth on the energy consumption of buildings. After analyzing the current state of knowledge on the subject, presented in the industry-specific literature, the study confirms that global warming is the most severe consequence of climate change that we are likely to face in the future Was. It goes on to study possible energy trends and climate change scenarios. Assuming the scenarios presented as input data and using the existing analysis methods, the relevant results have been obtained taking into account all possible aspects of energy consumption in buildings affected by climate change. The demand for cooling and heating energy, which contributes the largest to energy consumption in the building sector, has been confirmed as the main factor, which clearly shows the impact of climate change on the energy consumption of buildings. Using the degree-day method, the authors have interpreted the results of studies in this field to define global trends in energy consumption in the building sector caused by the impact of climate change. The study conducted by the authors concluded that the demand for cooling energy is increasing, while the energy demand for heating in buildings is decreasing drastically. This means that the issue of cooling needs to be addressed urgently to ensure that comfortable temperatures are maintained in buildings that will be exposed to higher and higher ambient temperatures in the future.

As a result, by comparing the data and projected values of HDD/CDD in different regions, it is estimated that colder regions such as Russia and Canada, for example, will consume less energy, because the cooling demand in those regions is negligible, while the overall energy consumption in the building sector will decrease significantly in these regions. On the other hand, regions with temperate and warm climates will see more cooling demand. and as a result, the building sector in those areas will consume more energy. On a global scale, a decrease in thermal energy demand at a certain point will be in the future equilibrium with an increase in cooling demand (around 2070), after which we can expect a sharp increase in cooling loads, leading to higher energy consumption in the entire building sector. It was also shown that in the summer and spring the entry into the thermal comfort zone is external, while in the cold seasons it is the entry into the thermal comfort zone is the external, therefore, it is important to consider the effects of climate change on humans and their health when constructing new buildings. The design should reduce energy demand, without compromising thermal comfort and thus increasing the risk to humans.

References

[1] Abounouri, A., Delfan, N. The Effect of Targeted Subsidies on the Inequality of Electricity Consumption Distribution in Semnan Province, Quarterly Journal of Fiscal and Economic Policies, 2019, No. 26: 185-211.
[2] Akbari, N., & Talebi, H., Jalei, A. Investigating the Social and Cultural Factors Affecting Household Energy Consumption after the Implementation of the Subsidy Targeting Law (Case Study: Isfahan City), Applied Sociology.Res., 27:26-1.
[3] Berardi U. A cross-country comparison of the building energy consumptions and their trends, *Resources, Conservation and Recycling* ; 123: 230-241, 2017.
[4] Aghniaey S, Lawrence TM. The impact of increased cooling setpoint temperature during demand response events on occupant thermal comfort in commercial buildings: A review, Energy and Buildings ; 5:173:19-27, 2018.
[5] Al Horr Y, Arif M, Kaushik A, Mazroei A, Katafygiotou M, Elsarrag E. Occupant productivity and office indoor environment quality: A review of the literature. Building and environment; 15; 105:369-89, 2016.
[6] Mahdavinejad M, Didehban M, and Bazazzadeh, H. Contemporary architectural heritage and industrial identity in historic districts, case study Dezful. Journal of Studies on Iranian Islamic Cities; 6(22): p. 10,2016
[7] Madlener R, Sunak Y. Impacts of urbanization on urban structures and energy demand: What can we learn for urban energy planning and urbanization management? Sustainable Cities and Society; 1(1): p. 45-53, 2011.
[8] Sailor, D.J. and A.A. Pavlova, Air conditioning market saturation and long-term response of residential cooling energy demand to climate change. Energy; 28(9): p. 941-951, 2003.
[9] Attarian K, Safar B, Najar, A. Vernacular and historic underground urban facilities and sustainability of cities case study. Journal of Cultural Heritage Management and Sustainable Development; 9(1): p. 2-23, 2019.
[10] Isaac M, van Vuuren, D.P. Modeling global residential sector energy demand for heating and air conditioning in the context of climate change. Energy Policy; 37(2): p. 507-521, 2009.
[11] ZhouY, Eom J, Clarke L. The effect of global climate change, population distribution, and climate mitigation on building energy use in the U.S. and China. Climatic Change; 119(3): p. 979-992, 2013.
[12] Bazazzadeh H, Mahdavinejad M, Ghomeshi M, Safaei SS. Requirements for comprehensive management of industrial heritage sites and landscapes; 2018.
[13] Mancin F, Lo Basso G. How Climate Change Affects the Building Energy Consumptions Due to Cooling, Heating, and Electricity Demands of Italian Residential Sector. Energies; 13(2): p. 410, 2020.
[14] Yau Y.H, Hasbi, S. A review of climate change impacts on commercial buildings and their technical services in the tropics. Renewable and Sustainable Energy Reviews ; 18: 430-441, 2013.
[15] Bazazzade H, Ghomeshi M. The black Bridge of Ahwaz. TICCIH Bulletin, 2018. 80.
[16] Obasi G.O.P, Dowdeswell E. Climate Change 1995: IPCC Second Assessment: A Report of the Intergovernmental Panel on Climate Change Ipcc. 1998: Diane Publishing Company; 1995.
[17] Adminstration, N.O.a.A. Trends in atmospheric carbon dioxide. 2020 Dec. 27. 2020]; Available from: www.esrl.noaa.gov.

[18] Dai Q. The impact of urban form on thermal comfort across street zones. (PhD), The Chinese University of Hong Kong; 2014.
[19] BoverketBoverkets författningssamling 11 ;2020.
[20] Göransson A, Götharson S. Room Indicators in Miljöbyggnad-A Comparative Study of Simplified and Detailed Methods and Their Influencing Parameters ; 2015.
[21] Šujanová P, Rychtáriková M, Sotto Mayor T, Hyder A. A .healthy, energy-efficient and comfortable indoor environment, a review. Energies; 12(8):1414, 2019
[22] Ormandy D, Ezratty V. Thermal discomfort and health: protecting the susceptible from excess cold and excess heat in housing. Advances in building energy research; 210(1):84-98, 2016.
[23] Anderson M, Carmichael C, Murray V, Dengel A, Swainson M. Defining indoor heat thresholds for health in the UK. Perspectives in public health; 133(3):158-64, 2013.
[24] Javanroodi K, Nik VM. Interactions between extreme climate and urban morphology: Investigating the evolution of extreme wind speeds from mesoscale to microscale. Urban Climate; 1(31):100544, 2020.
[25] Mavrogianni A, Davies M, Taylor J, Chalabi Z, Biddulph P, Oikonomou E, Das P, Jones B. The impact of occupancy patterns, occupant-controlled ventilation and shading on indoor overheating risk in domestic environments. Building and Environment; 1(78):183-98, 2014.
[26] Ormandy D, Ezratty V. Thermal discomfort and health: protecting the susceptible from excess cold and excess heat in housing. Advances in building energy research; 10(1):84-98, 2016.
[27] IPCC, Climate Change 2007 - The Physical Science Basis: Working Group I Contribution to the Fourth Assessment Report of the IPCC; 2007.
[28] Clarke L, Eom J, Marten EH, Horowitz R, Kyle P, Link R, Mignone BK, Mundra A, Zhou Y. Effects of long-term climate change on global building energy expenditures. Energy Economics; 1(72):667-77, 2018.
[29] Mashhoodi, B., The Spatial Dimension of Household Energy Consumption. A+BE Architecture and the Built Environment. Delft, Netherlands: TU Delft; 2019.
[30] Bazazzadeh H. Truth of sincerity and authenticity or lie of reconstruction; whom do the visitors of cultural heritage trust? ; 2020.
[31] Pérez-Lombard L, Ortiz J, Pout C. A review on buildings energy consumption information. Energy and buildings; 40(3):394-8, 2008.
[32] Aguiar R, Oliveira M, Gonccedilalves H. Climate change impacts on the thermal performance of Portuguese buildings. Results of the SIAM study. Building Services Engineering Research and Technology; 23(4):223-31, 2002.
[33] Christenson M, Manz H, Gyalistras D. Climate warming impact on degree-days and building energy demand in Switzerland. Energy conversion and management; 47(6):671-86, 206.
[34] Huang WZ, Zaheeruddin M, Cho SH. Dynamic simulation of energy management control functions for HVAC systems in buildings. Energy conversion and management; 47(7-8):926-43, 2006.
[35] Hadley SW, Erickson III DJ, Hernandez JL, Broniak CT, Blasing TJ. Responses of energy use to climate change: A climate modeling study. Geophysical research letters; 33(17), 2006.
[36] Bazazzadeh H, Nadolny A, Mehan A, Safaei SS. The importance of flexibility in adaptive reuse of industrial heritage: Learning from Iranian cases; 2021.
[37] Fricko O, Havlik P, Rogelj J, Klimont Z, Gusti M, Johnson N, Kolp P, Strubegger M, Valin H, Amann M, Ermolieva T. The marker quantification of the Shared Socioeconomic Pathway 2: A middle-of-the-road scenario for the 21st century. Global Environmental Change; 1(42):251-67, 2017