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RESEARCH PAPER

The Impact of HVAC Setpoint Temperature on Reducing Building Energy Consumption in Different Climatic Regions of Iran

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Abstract

Energy consumption reduction has become increasingly important today, as buildings contribute significantly to energy use. Therefore, strategies to reduce energy consumption in this sector can have a substantial impact on reducing national energy consumption. This research analyzes the energy consumption of a building (a case study of a 492-unit residential complex in Farhang Shahr, Ahvaz) and the effect of HVAC setpoint temperature on reducing building energy consumption in four cities with different climates in Iran. To analyze the results, the building design process was simulated using AutoCAD maps in the Design Builder software, and Energy Plus was used for energy calculations. Results show that cooling accounts for 96.1% of energy use in Ahvaz, while heating comprises 84.6% in Tabriz. In Tehran and Yazd, cooling represents 54.6% and 65.5% of total consumption, respectively. Increasing the cooling setpoint from 22°C to 27°C reduces cooling load by 35.7% in Ahvaz and electricity use by 44.6 MWh annually. Lowering the heating setpoint from 21°C to 16°C decreases heating load by 36.4% in Tabriz and gas consumption by 25.8 MWh. These findings emphasize the significant energy savings achievable by optimizing setpoint temperatures based on climate conditions. Additionally, reducing the heating setpoint from 21°C to 16°C results in a 32.6% decrease in annual CO_2 emissions in Ahvaz, with further reductions of 39.6%, 40%, and 40.2% observed in Yazd, Tehran, and Tabriz, respectively.

Keywords: setpoint temperature; energy consumption; cooling load; heating load; energy savings.

1. Nomenclature

A	total and useful coolant surface of the building
C_p	the specific heat at constant pressure
f_{clo}	the clothing surface area ratio
h_i	the internal convective heat transfer coefficient
I_{clo}	the thermal resistance of clothing

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M	the metabolic rate of the body
P_v	the vapor pressure of water in the surrounding air
Q_i	the received solar heat from opaque environments
$Q_{gn,c}$	total received flux of internal and solar heat
Q_{opq}	the internal heat loads
Q_{loss}	the heat loss from the exterior walls
Q_s	solar heat received from transparent environments
q''_{con}	the convective heat transfer between the building surfaces and indoor air
q''_{ki}	conductive heat transfer from the surroundings of the building
q''_{LWS}	the radiative heat transfer flux between surfaces and radiators
q''_{LWX}	the radiative heat transfer flux between surfaces with long wavelengths
q''_{sol}	the solar radiation flux
q''_{sw}	the radiative heat transfer flux between lights and surfaces
RH	the relative humidity in the air
T	temperature
t	time
T_{si}	internal surface temperatures
T_t	the fixed indoor temperature
T_{md}	the daily average temperature
T_{rad}	the radiant temperature
T_{air}	the air temperature
T_{clo}	temperature of the clothing
U	the overall heat transfer coefficient
Y	the internal, cross-over
Z	the internal, cross-over
Ψ	flux coefficient
η_c	the loss coefficient of cooling devices

2. Introduction

Reducing energy consumption in buildings has become a major concern in recent years due to the growing environmental and economic challenges faced by countries worldwide. The building sector accounts for a significant portion of total energy consumption; thus, optimizing energy use in buildings can greatly contribute to national energy savings [1-3]. Among various approaches to enhancing energy efficiency, optimizing Heating, Ventilation, and Air Conditioning (HVAC) systems particularly adjusting setpoint temperatures for heating and cooling plays a crucial role in reducing building energy demand [4, 5].

HVAC system setpoints determine the temperature thresholds at which heating or cooling is activated, directly affecting the energy consumption required to maintain indoor comfort levels [6, 7]. Several studies have demonstrated that adjusting these setpoints can lead to significant energy savings, particularly in regions with extreme climatic conditions [8, 9]. Furthermore, research has indicated that energy performance optimization strategies tailored to local climatic conditions can enhance energy efficiency in buildings, as shown in studies focused on hot and dry climates [10, 11].

Previous research has primarily focused on HVAC optimization in temperate and mild climates, whereas the specific conditions of countries with diverse climates, such as Iran, have not been studied extensively [12, 13]. Iran's wide-ranging climate zones from hot and dry areas to temperate regions pose unique challenges and opportunities for optimizing energy consumption [14]. To bridge this research gap, the present study analyses the impact of HVAC setpoint temperatures on energy consumption in residential buildings located in different Iranian cities, each characterized by distinct climatic conditions. The focus is on residential buildings, as they contribute significantly to overall energy use in urban areas [15, 16].

In addition to traditional temperature setpoint optimization, recent research has highlighted that dynamic and automated temperature control in HVAC systems can significantly reduce energy consumption. For example, Rahimi et al. [17] found that dynamically adjusting temperature settings based on user behaviour patterns and environmental conditions can reduce energy consumption by up to 18%. Similarly, Torabi et al. [18] conducted a comparative study between residential and office buildings, revealing that HVAC setpoint optimization strategies have a higher energy-saving potential in office buildings due to more variable occupancy patterns.

Other factors, such as occupant behaviour and adaptive controls, also play a crucial role in building energy consumption. Hosseini et al. [19] demonstrated that the use of adaptive HVAC control strategies, which intelligently detect environmental conditions and occupant needs to adjust settings accordingly, can significantly reduce energy consumption. In the same context, Ebrahimi et al. [20] emphasized that occupant behaviour and interaction with HVAC systems can either increase or decrease energy use. Their study found that incorporating real occupant behaviour into energy consumption simulations enhances prediction accuracy and leads to more effective energy-saving strategies.

Mahdavi Adeli et al. [21] By examining various forms, obtained the appropriate building form with the least energy consumption for heating, cooling and lighting in Design Builder software. The results showed that the form of the building had a significant impact on energy consumption. By analyzing the parameters, the best orientation of the building was 60 degrees northeast and the window wall ratio (WWR) was 40 %.

Mahdavi Adeli et al. [22] Comparison of a conventional optimized building and optimized building with renewable energy sources in hot and dry weather conditions in Zahedan. The results show that the use of solar and wind energy can also be achieved by creating zero energy.

Mousavi Navaee et al. [23] investigated the impact of the air gap on energy consumption in buildings in Ahvaz. Their results showed that the use of an air gap led to a reduction in heating and cooling loads during different months of the year. Specifically, the monthly cooling load of the building in the hottest month of the year decreased by 10.3%, 12.8%, and 14%, respectively, while the heating load in the coldest month decreased by 32.8%, 42.3%, and 48.2%, respectively. Additionally, the building's annual heating energy consumption was reduced by 25.7%, 30.9%, and 33.6%, while the annual cooling energy consumption decreased by 8.3%, 10%, and 10.9%, which is a significant reduction considering the high annual cooling energy consumption of the building.

Building on previous studies, this research investigates the potential for energy reduction in four Iranian cities Ahvaz, Tabriz, Tehran, and Yazd by examining the effects of different heating and cooling setpoints. By simulating energy usage in a case study building from the 492-unit residential complex in Farhangshahr, Ahvaz, this study introduces a novel approach by analyzing how HVAC system setpoint temperatures influence the reduction of cooling electricity demand, heating gas consumption, and annual CO_2 emissions in buildings located in different climate zones of Iran.

3. Explanation of Problem

For the purpose of energy assessment and analysis, a real building model of a 492-unit residential complex from the National Housing Movement project in Farhangshahr, Ahvaz, has been used. Fig 1 presents the designed building plan. The building consists of five floors, with each floor containing three residential units, and a total area of 1,350 square meters. The ground floor serves as a parking area.

Considering that the fundamental basis of building design is influenced by the surrounding climatic conditions from the geometric shape and type of construction materials to the capacity of heating and cooling equipment, which all depend on weather conditions the first step in initiating the energy simulation is to select a city with specific characteristics such as geographical coordinates (longitude and latitude), altitude above sea level (elevation), and meteorological data and files to be input into the software. This information is provided in Table 1.

Table 1: The surrounding climatic conditions.

Description	Longitude	Latitude	Elevation (m)	Pressure (Kpa)
Ahvaz	48.67	31.33	22	101.1
Yazd	54.28	31.9	1237	87.3
Tehran-Mehrabad	51.32	35.68	1191	87.8
Tabriz	46.28	38.08	1361	86

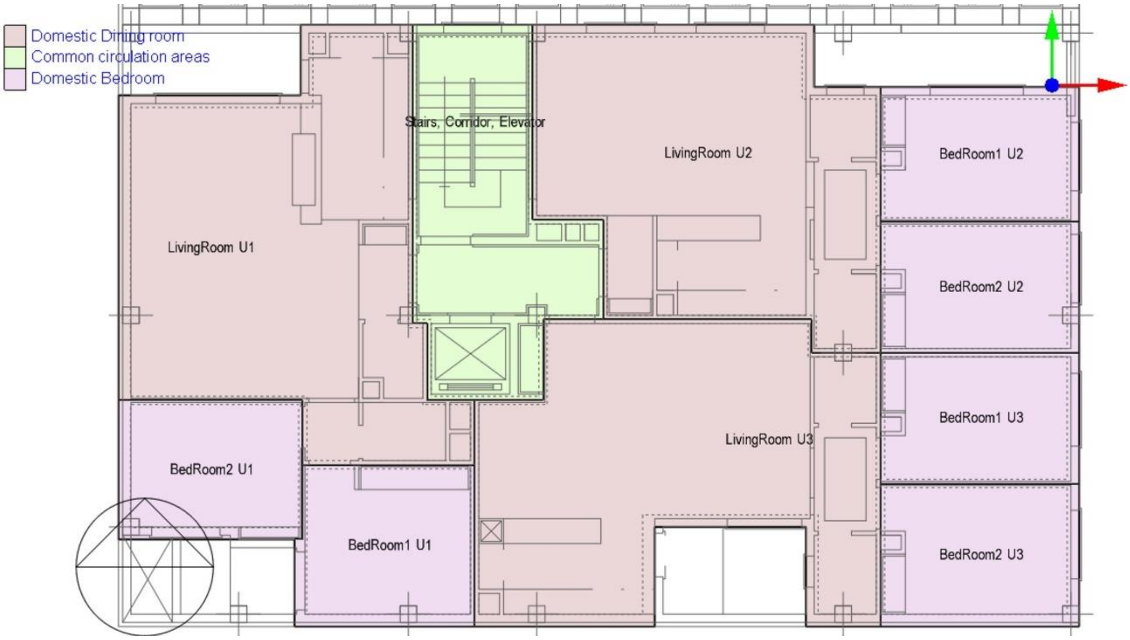


Fig 1: AutoCAD building plan for modeling in DesignBuilder software.

To simulate energy performance, the building must first be designed and constructed in the software. The building plans were exported in DXF formats from AUTOCAD to DesignBuilder. After entering the project site specifications into the software, the building was created based on the available plans. The different stages of floor construction in the software are shown in Fig 2, while the final model, including front and rear views, is presented in Fig 3.

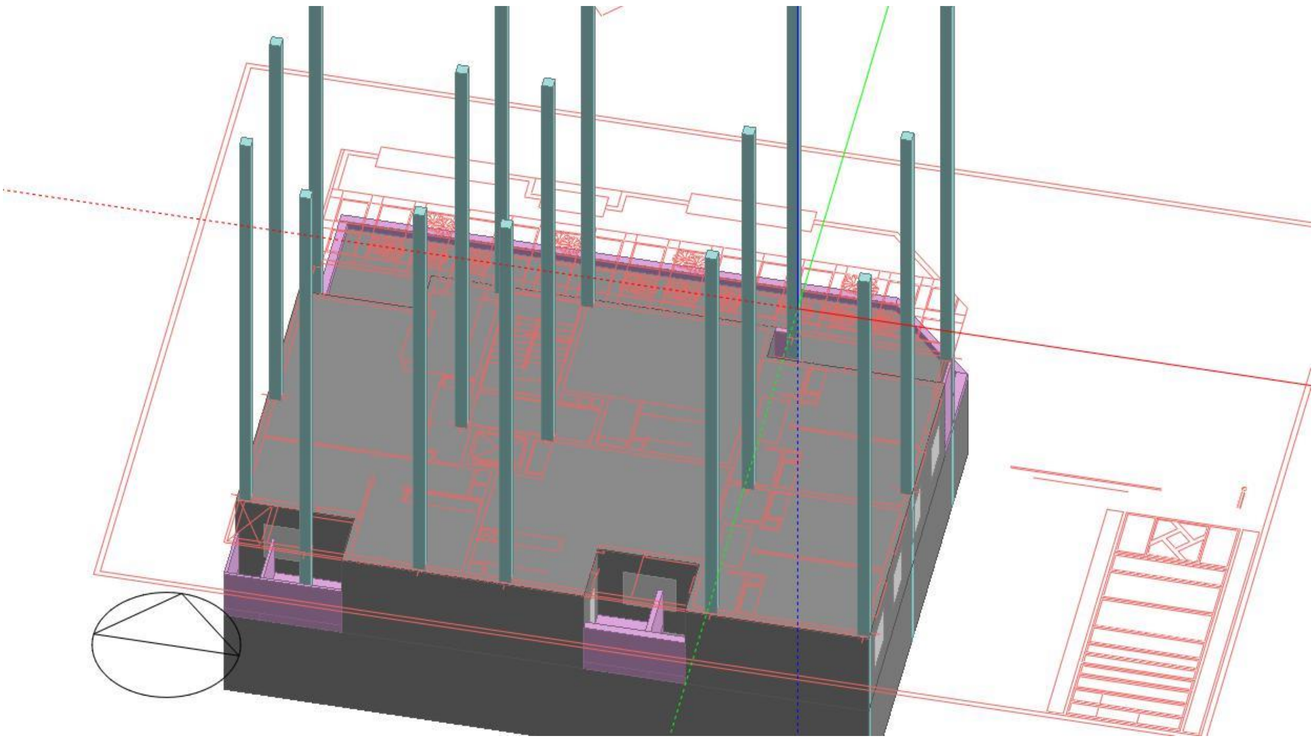


Fig 2: Construction of different building floors in the software.

After modeling the building, the material properties, including type, thickness, and characteristics such as thermal conductivity, density, specific heat, or thermal resistance of the internal and external walls, roof, and openings (doors, windows, and vents), were defined in the software. The material specifications were obtained from Chapter 19 of the National Building Regulations (Energy Conservation), Fourth Edition.

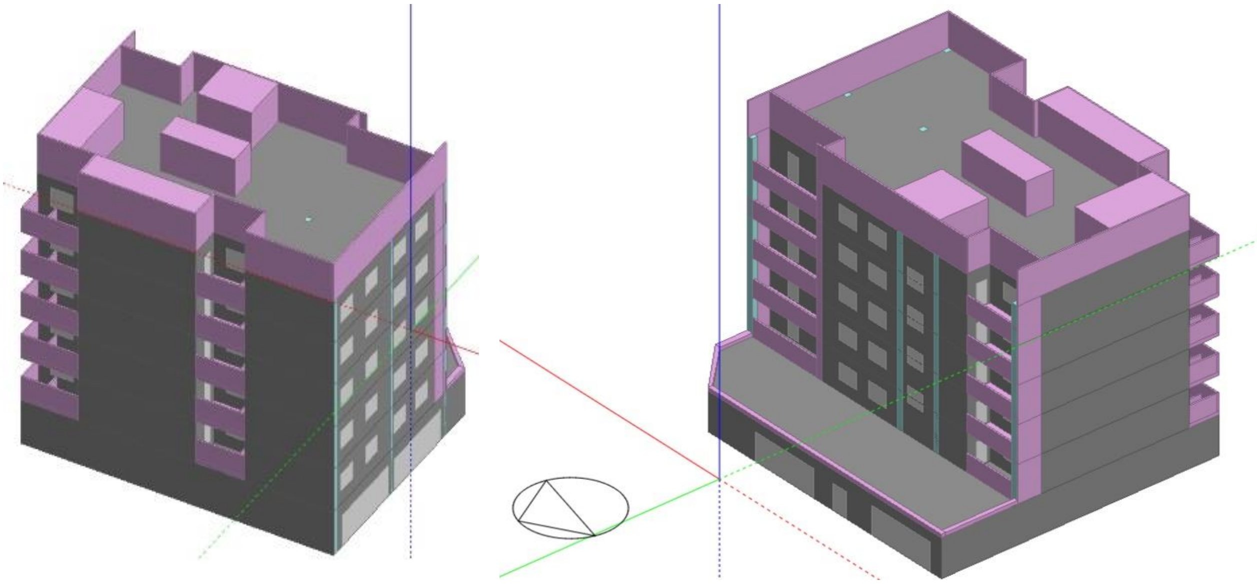
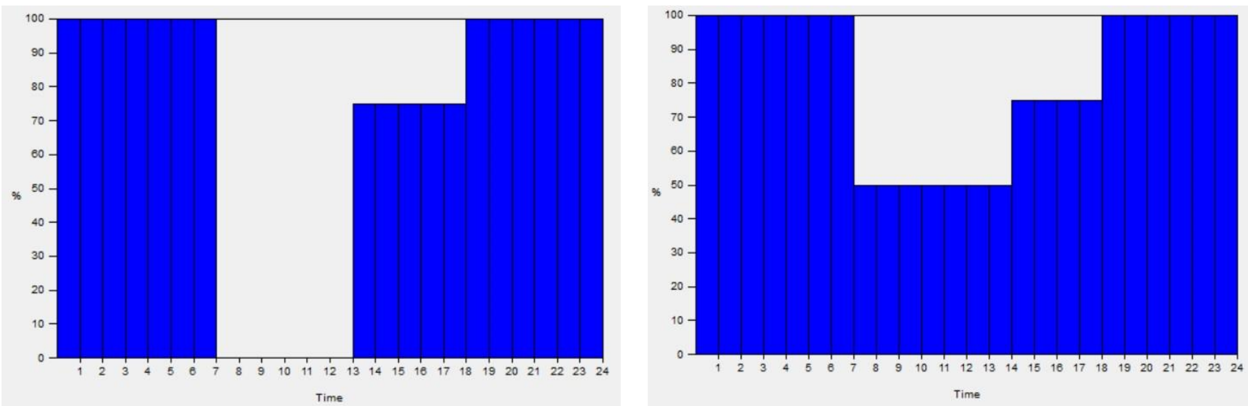


Fig 3: Final building model created in the software, showing front and rear views.

After defining the material properties, the building's usage type and activities, including the occupancy schedule and the lighting system schedule for summer and winter (as shown in Figures 4 and 5), were entered into the software. The occupancy was assumed to be four people per residential unit.

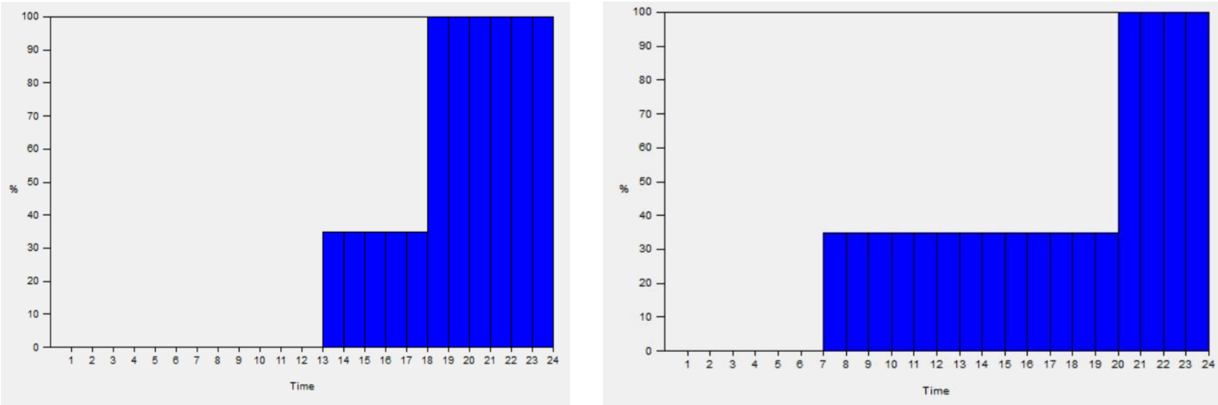
In the winter schedule, it was assumed that no one is present in the building between 7:00 AM and 1:00 PM, while in summer, due to school holidays, 50% of the occupants remain in the building during this period.

Finally, the HVAC system, lighting, and other parameters affecting energy simulation were defined in the software.



b **a**

Fig 4: Occupancy schedule during summer (a) and winter (b)



b a

Fig 5: Lighting system scheduling in the building during summer (a) and winter (b)

To reduce computation time in the software, considering that the second, third, and fourth floors have identical conditions and therefore the same heating, cooling, and energy consumption loads (three floors with identical loads), only three floors were included in the energy calculations.

The first floor and the top floor (fifth floor), having different conditions, were considered separately, while one of the three identical floors (the third floor) was selected to represent them in the calculations.

The material types, thicknesses, and specifications of the various wall layers used for the external walls are presented in Table 2. It should be noted that for defining material properties, at least one of the following parameters is required: thermal resistance, specific heat, density, or thermal conductivity. Depending on the available data, these properties can be entered into the software. For facade bricks, concrete joists, and concrete blocks, the thermal resistance values have been provided based on the properties listed in Chapter 19 of the National Building Regulations (Energy Conservation), Fourth Edition, which also includes thermal conductivity values.

The coefficient of performance (COP) of the cooling system in this simulation was assumed to be 1.8

Table 2: The wall material specifications.

Material (outside to inside)	Thickness cm	Specific heat capacity J/(kg.K)	Density kg/m^3	Conductivity W/(m.K)	R-Value $m^2.K/W$
Brickwork Outer	3	-	-	-	0.03
Plastering (cement)	2	1000	1100	0.1	-
Concrete Roof Block 20cm	20	-	-	-	0.19
Plastering (Gypsum)	2	1000	950	0.4	-

The material types, thicknesses, and specifications of the roof are also presented in Table 3. All windows used in the building are made of standard UPVC profiles with double-glazed glass and argon gas between the panes.

Table 3: The roof material specifications.

Material (outside to inside)	Thickness cm	Specific heat capacity J/(kg.K)	Density kg/m^3	Conductivity W/(m.K)	R-Value $m^2.K/W$
Asphalt	1	1000	2100	0.7	-
Glass wool	5	840	150	0.05	-
Concrete Roof Block 20cm	30	-	-	-	0.25
Plastering (Gypsum)	2	1000	950	0.4	-

4. Methodology

4.1. Analysis of Total Energy Consumption

The most significant loads in a building are cooling and heating loads. In a building, the sum of heat loss and heat gain must be equal [24], as shown in equation (1):

$$-Q_{HVAC} = \sum_{i=1}^{Nsj} \dot{Q}_i + \sum_{i=1}^{Nsurface} h_i.A_i.(T_{si} - T_z) + \sum_{i=1}^{Nzones} m_i.c_p.(T_{zi} - T_z) + m_{\inf}.c_p.(T_{ext} - T_z) \quad (1)$$

In the equation (1), the term on the left-hand side represents the total site energy consumption, the first term on the right-hand side represents the sum of heat loads resulting from internal convective heat transfer, the second term indicates the convective heat transfer exchanged due to the surfaces of different regions, the third term indicates the heat transfer resulted by the combination of air inside the regions, and the last term is the heat transfer caused by the outflow from air gaps. Heat transfers due to building components will affect the internal surface temperatures (T_{si}) and therefore convective heat transfer between the building surfaces and indoor air is given in equation (2):

$$-q''_{conv} = q''_{LWX} + q''_{SW} + q''_{LWS} + q''_{sol} + q''_{ki} \quad (2)$$

In the equation (2), q''_{LWX} the radiative heat transfer flux between surfaces with long wavelengths, q''_{sw} the radiative heat transfer flux between lights and surfaces, and q''_{LWS} the radiative heat transfer flux between surfaces and radiators are considered. Additionally, q''_{sol} the solar radiation flux and q''_{ki} conductive heat transfer from the surroundings of the building are accounted for. To calculate q''_{ki}, equation (3) can be used:

$$q''_{ki}(t) = -Z_o T_{i,t} - \sum_{j=1}^{nz} \dot{Z}_j T_{i,t-j\delta} + Y_o T_{o,t} + \sum_{j=1}^{nz} Y_j T_{o,t-j\delta} + \sum_{j=1}^{nq} \psi_j q''_{ki,t-j\delta} \quad (3)$$

In this equation, T represents temperature, the coefficients i and o represent the internal and external surfaces of the building, t indicates time in one step, and Z, Y, and Ψ represent internal, cross-over, and flux coefficients, respectively.

The required energy in terms of annual consumption for cooling the indoor environment of the building is also obtained from equation (4), which is measured in kWh/m².year:

$$CN_{usf} = (1 - \eta_c) / A \times Q_{gn,c} \quad (4)$$

Where η_c the cooling device loss coefficient, A the total cooling surface area of the building, and $Q_{gn,c}$ the total internal and solar heat flux received by the building are considered. As seen in the heating section of the building, solving these equations requires that the cooling temperature be set to a specific value during certain times of the year. To obtain the value of $Q_{gn,c}$, equation (5) is used:

$$Q_{gn,c} = Q_{opq} + Q_s + Q_i \quad (5)$$

Where Q_{opq} the internal heat loads from equipment, lights, and occupants are considered. Q_s Solar heat received from transparent environments (such as windows and other transparent surfaces) is denoted as, while Q_i is the received solar heat from opaque environments. Finally, the heat loss from the exterior walls (Q_{loss}) is obtained from equation (6):

$$Q_{loss} = U(T_t - T_{md}) \quad (6)$$

Where U the overall heat transfer coefficient, T_t the fixed indoor temperature, T_{md} and the daily average temperature are considered, and the daily average temperature is obtained from equation (7):

$$T_{md} = (T_{rad} + T_{air}) / 2 \quad (7)$$

Where T_{rad} represents the radiant temperature and T_{air} represents the air temperature.

4.2. Thermal Comfort

The thermal comfort equation, Finger's equation to obtain the PMV, is derived from the heat balance equation as follows [22]:

$$PMV = \left[0.303e^{-0.036M} + 0.028\right] \times \left\{D - 3.05\times10^{-3} \times \left(5733 - 6.99D - P_v\right) - 0.42\times\left(D - 58.15\right)\right.$$
$$-1.7\times10^{-5} \times M \times \left(58.67 - P_v\right) - 1.4\times10^{-3} \times M \times \left(34 - T_{in}\right) \quad (8)$$
$$\left. -3.96\times10^{-8} \times f_{clo} \times \left[\left(T_{clo} + 273\right)^4 - \left(T_{mrt} + 273\right)^4\right] - f_{clo} \times h \times \left(T_{clo} - T_{in}\right)\right\}$$

Where is D=M-W and h the coefficient of convective heat transfer, which is obtained from equation (9):

$$h = \begin{cases} 2.38\times\left|T_{clo} - T_{in}\right|^{0.25} & if: \ 2.38\times\left|T_{clo} - T_{in}\right|^{0.25} \geq 12.1v_{rel}^{\ 0.5} \\ 12.1\times v_{rel}^{\ 0.5} & otherwise. \end{cases} \quad (9)$$

Additionally, the surface temperature of the clothing (T_{clo}) is obtained from equation (10):

$$T_{clo} = 35.7 - 0.028D$$
$$- I_{clo} \times \left\{3.96\times10^{-8} \times f_{clo} \times \left[\left(T_{clo} + 273\right)^4 - \left(T_{mrt} + 273\right)^4\right] + f_{clo} \times h \times \left(T_{clo} - T_{in}\right)\right\} \quad (10)$$

For f_{clo} the clothing surface area ratio, which represents the body surface to the clothing and to the bare body surface, equation (11) is used:

$$f_{clo} = \begin{cases} 1 + 1.29\times I_{clo} & if: \ I_{clo} \leq 0.078m^2k/W \\ 1.05 + 0.645\times I_{clo} & otherwise. \end{cases} \quad (11)$$

In these equations, M represents the metabolic rate of the body in W/m^2, while W represents mechanical work in the body in W/m^2, T_{clo}, T_{mrt} and T_{in} represent the surface temperature of clothing, mean radiant temperature, and indoor air temperature in degrees Celsius, respectively. I_{clo} the thermal resistance of clothing is represented in m^{2}k/W, and P_v the vapor pressure of water in the surrounding air (KPa) is measured in equation (12) [22].

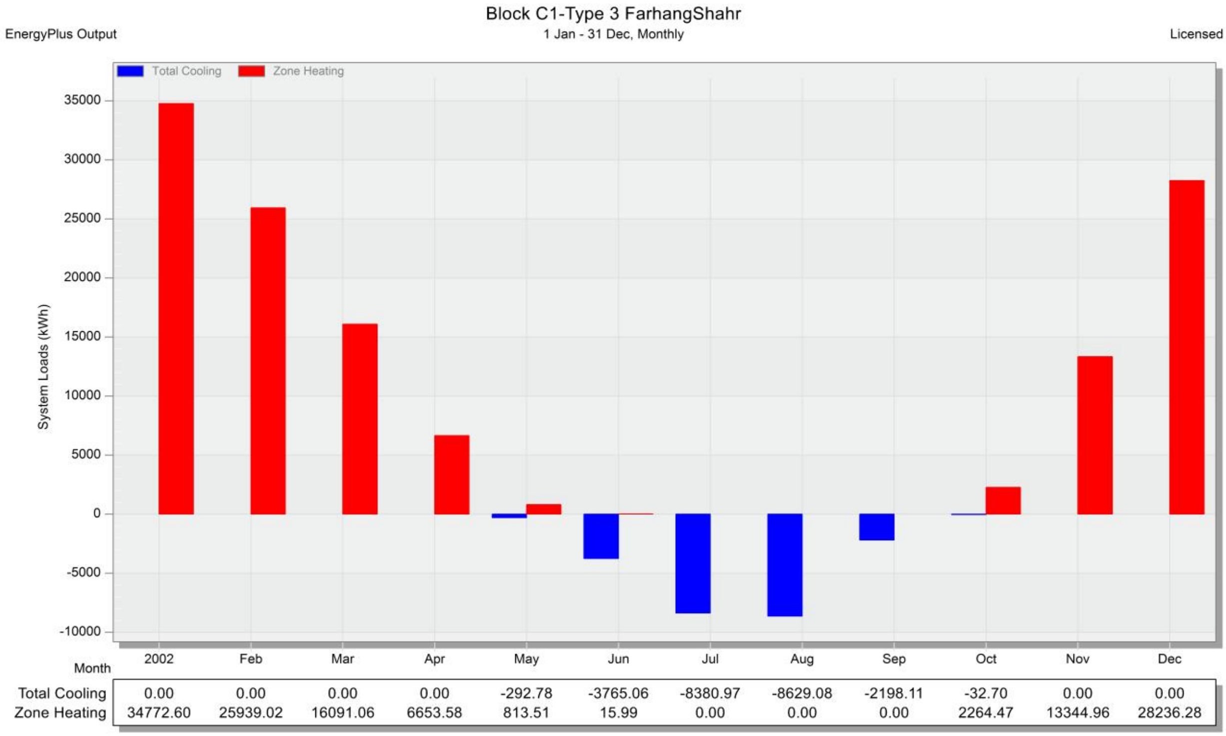
$$P_v = RH \times 610.6 \times e^{\left[\left(17.26\times T_{in}\right)/\left(273.3 + T_{in}\right)\right]} \quad (12)$$

In the equation (12), RH is the relative humidity in the air, measured in percentage. Finally, the predicted percentage of dissatisfaction (PPD) can be obtained from equation (13):

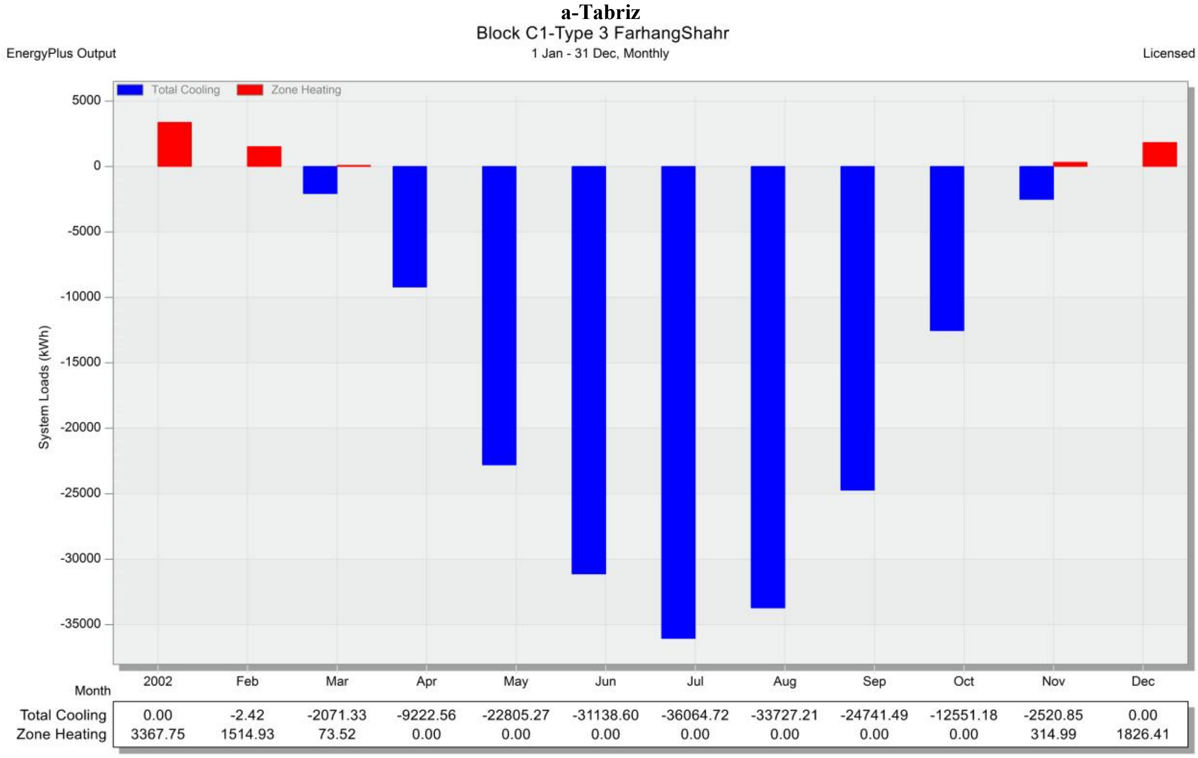
$$PPD = 100 - 95\times e^{-0.03353PMV^4 - 0.2179PMV^2} \quad (13)$$

5. Results and discussion

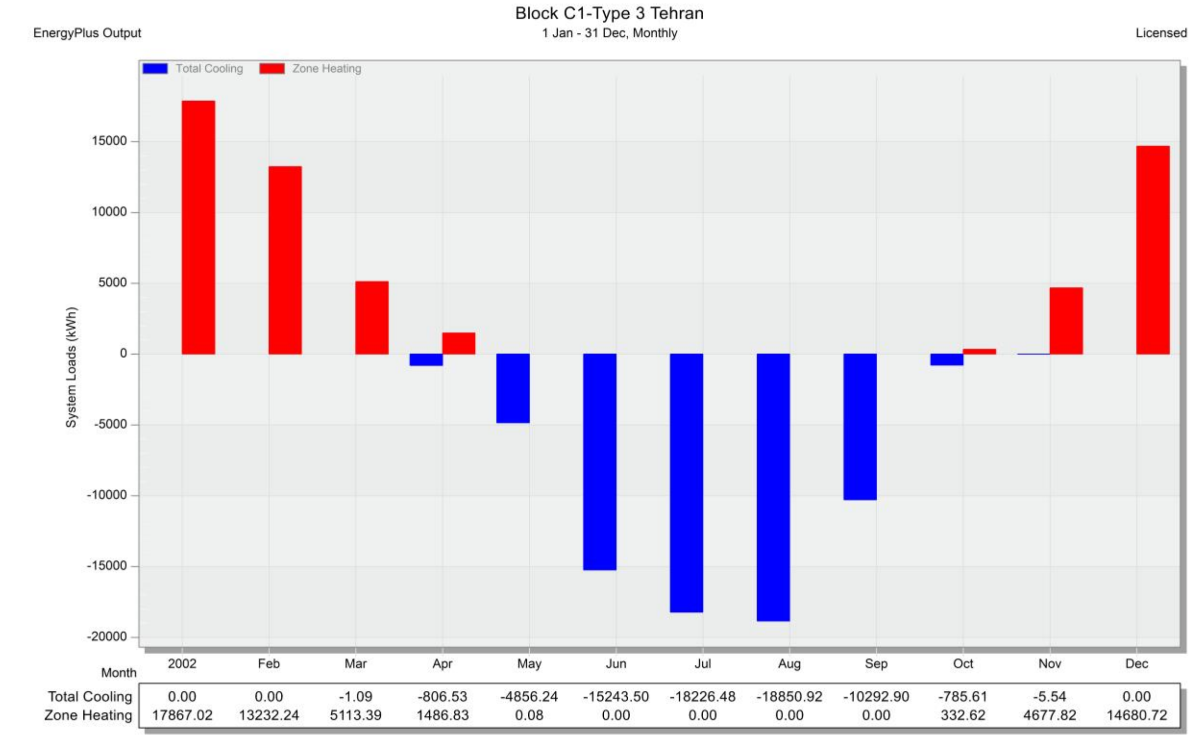
To examine the impact of cooling and heating system (HVAC) setpoint temperatures on building energy consumption in various climatic regions of Iran, energy simulations were conducted for four cities. The results of cooling and heating loads for different months of the year, with a cooling setpoint of 25°C and a heating setpoint of 18°C, are presented in Fig 6. As shown in this figure, in Ahvaz, the majority of the building's annual energy consumption is attributed to cooling (approximately 96.1%), whereas in Tabriz, most of the energy consumption is dedicated to heating (around 84.6%). In Tehran, energy consumption for cooling (54.6%) and heating (45.4%) is relatively balanced. In Yazd, which has a hot and dry climate, cooling accounts for approximately 65.5% of the energy use, while heating represents 34.5%. These variations in cooling and heating energy consumption are influenced by the location and climatic conditions of each city.



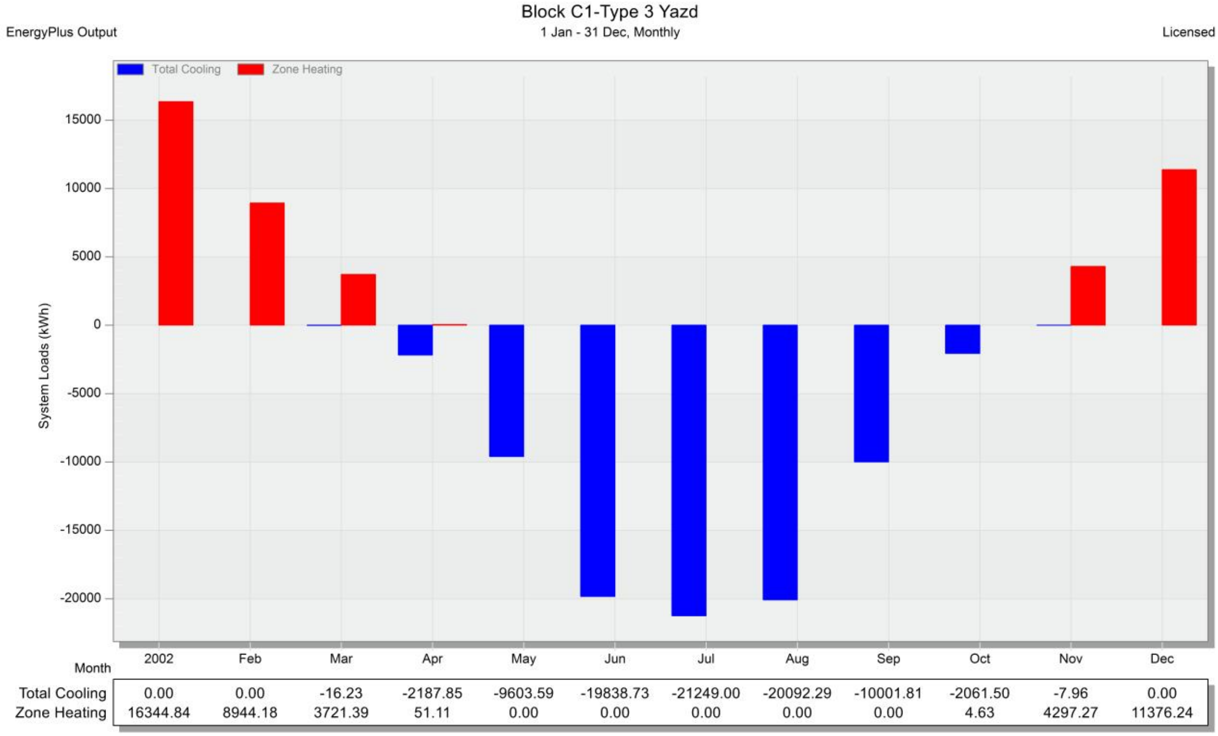
a-Tabriz



b-Ahvaz



c-Tehran



d-Yazd

Fig 6: Monthly cooling and heating loads for a cooling setpoint of 25°C and a heating setpoint of 18°C

Fig 7 shows the effect of cooling setpoint temperature on the annual cooling load in four cities with different climatic conditions. The results indicate that increasing the cooling setpoint temperature reduces the cooling load across all climates. In Ahvaz, which has the highest cooling energy consumption, raising the setpoint temperature by 5°C (from 22°C to 27°C) decreases the cooling load by approximately 80.3 MWh (35.7%). The reduction percentages for Yazd, Tehran, and Tabriz are 47.2%, 49.6%, and 71.2%, respectively. Although the percentage reduction in cooling load for Ahvaz is lower, the significant amount of cooling energy consumption in this city means that the reduction has a substantial impact on the annual energy consumption of the building.

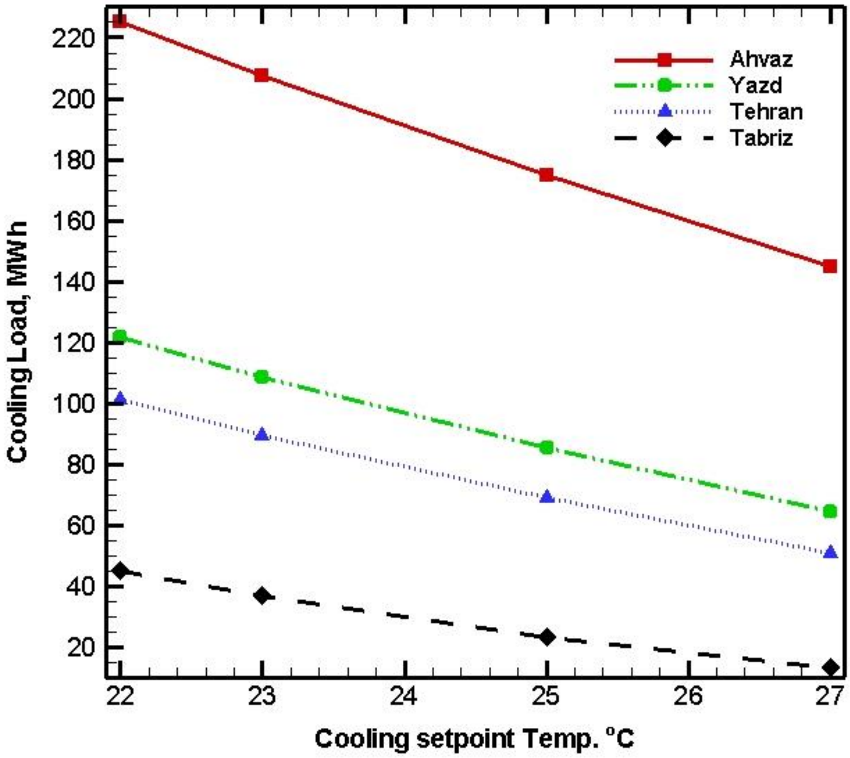


Fig 7: The impact of the cooling setpoint temperature on the building's annual cooling load

The influence of heating setpoint temperature on the annual heating load is depicted in Fig 8. The results reveal that lowering the heating setpoint temperature reduces heating load in all climatic regions. In Tabriz, which has the highest heating energy consumption, reducing the setpoint temperature by 5°C (from 21°C to 16°C) decreases the heating load by approximately 60.9 MWh (36.4%). The reduction percentages for Tehran, Yazd, and Ahvaz are 51.5%, 55.6%, and 89.8%, respectively. Although the percentage reduction in Tabriz is lower, the substantial absolute energy savings significantly impact the annual energy consumption.

Fig 9 illustrates the percentage reduction in the annual cooling load due to increasing the cooling setpoint temperature. In Ahvaz, increasing the setpoint temperature by 2°C (from 23°C to 25°C) reduces the cooling load by approximately 14.5%. The same 2°C increase results in cooling load reductions of 19.3%, 20.2%, and 30.2% for Yazd, Tehran, and Tabriz, respectively. Although the percentage reduction in Ahvaz is lower compared to other cities, the absolute energy savings are significant due to its high cooling energy demand.

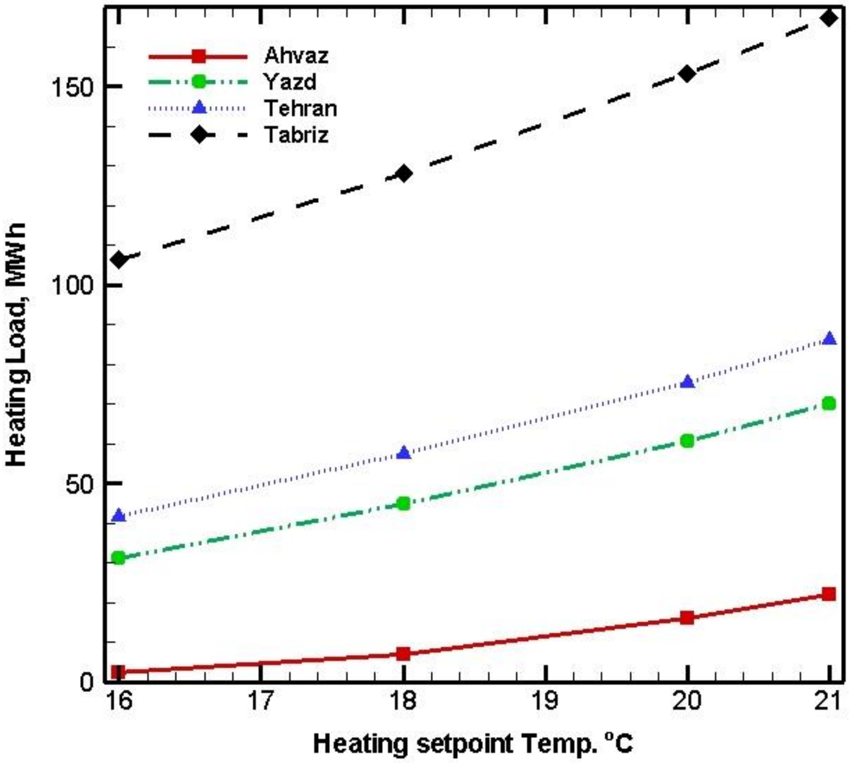


Fig 8: The impact of the heating setpoint temperature on the building's annual heating load

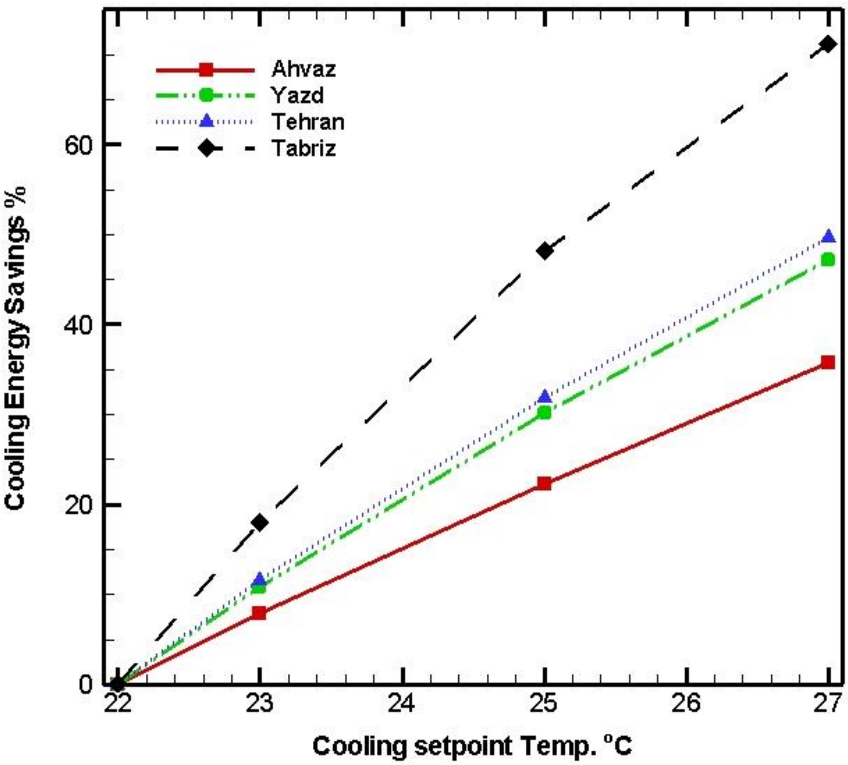


Fig 9: Percentage reduction in cooling load as a function of the cooling system setpoint temperature

Fig 10 presents the percentage reduction in the annual heating load due to decreasing the heating setpoint temperature. In Tabriz, lowering the setpoint temperature by 2°C (from 20°C to 18°C) results in a heating load reduction of approximately 15%. The same 2°C reduction leads to heating load decreases of 21.1%, 22.7%, and 40.1% for Tehran, Yazd, and Ahvaz, respectively. Despite the lower percentage reduction in Tabriz, the total heating energy savings are substantial, significantly contributing to lower annual heating energy consumption.

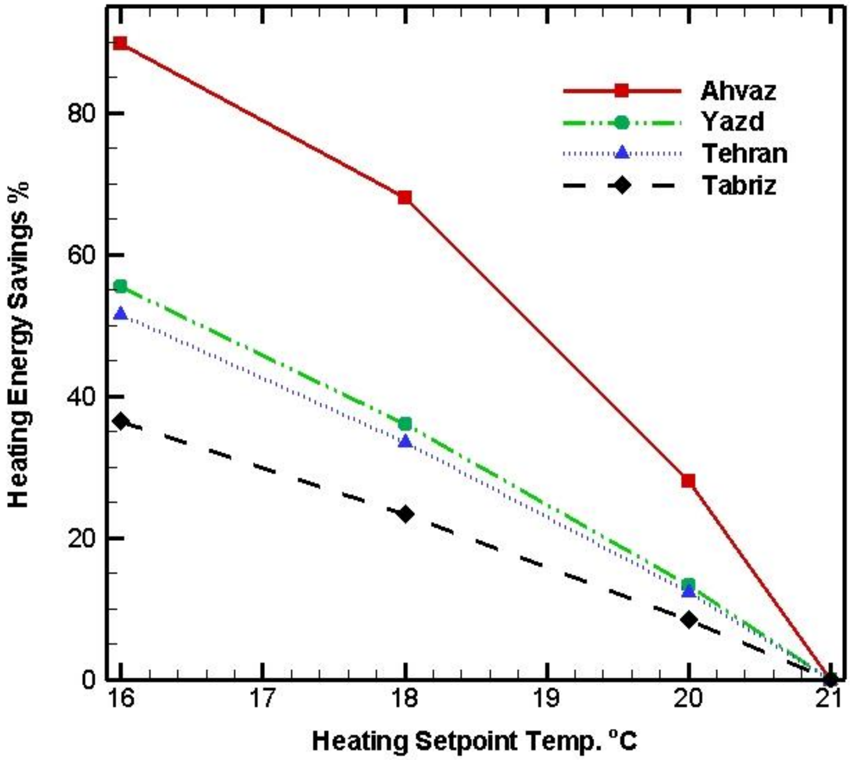


Fig 10: Percentage reduction in heating load as a function of the heating system setpoint temperature

Fig 11 illustrates the effect of cooling setpoint temperature on cooling electricity consumption in different climatic zones. The results show that increasing the cooling setpoint temperature reduces annual electricity consumption for cooling. In Ahvaz, increasing the cooling setpoint by 5°C (from 22°C to 27°C) decreases annual cooling electricity consumption by approximately 44.6 MWh. The reductions for Yazd, Tehran, and Tabriz are 31.9 MWh, 27.9 MWh, and 17.8 MWh, respectively.

Fig 12 illustrates the reduction in annual gas consumption due to lowering the heating setpoint temperature. The results indicate that decreasing the heating setpoint temperature reduces gas consumption in all climate zones.

In Tabriz, reducing the heating setpoint by 5°C (from 21°C to 16°C) lowers annual gas consumption by approximately 25.8 MWh. The corresponding reductions for Tehran, Yazd, and Ahvaz are 16.5 MWh, 18.9 MWh, and 8.5 MWh, respectively. These findings highlight the critical role of setpoint temperature adjustments in optimizing energy efficiency and reducing annual energy consumption across different climatic regions.

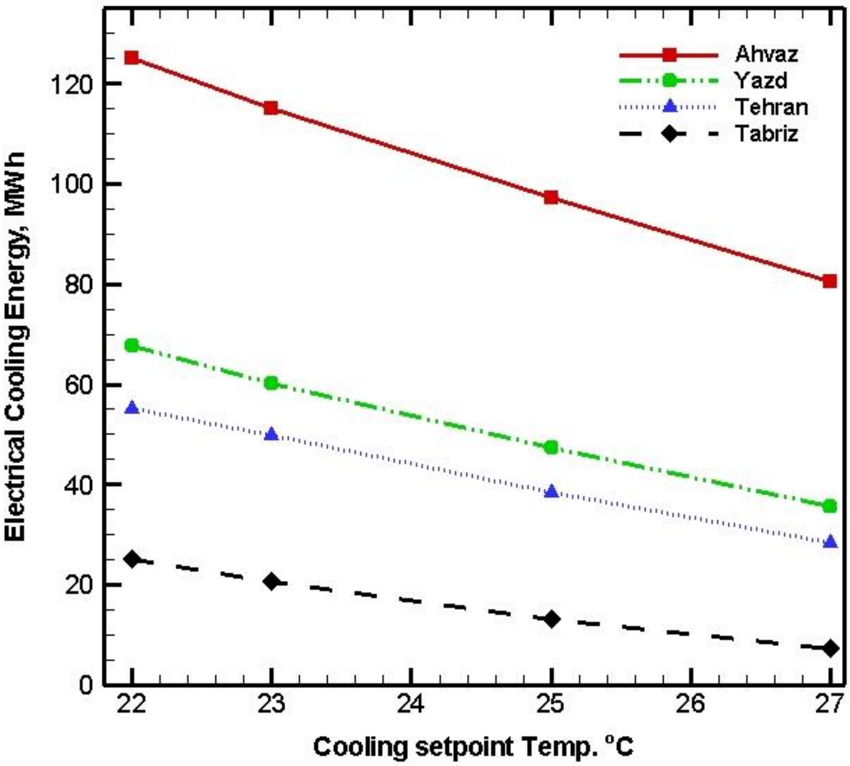


Fig 11: Amount of reduction in electrical energy consumption as a function of the cooling system setpoint temperature

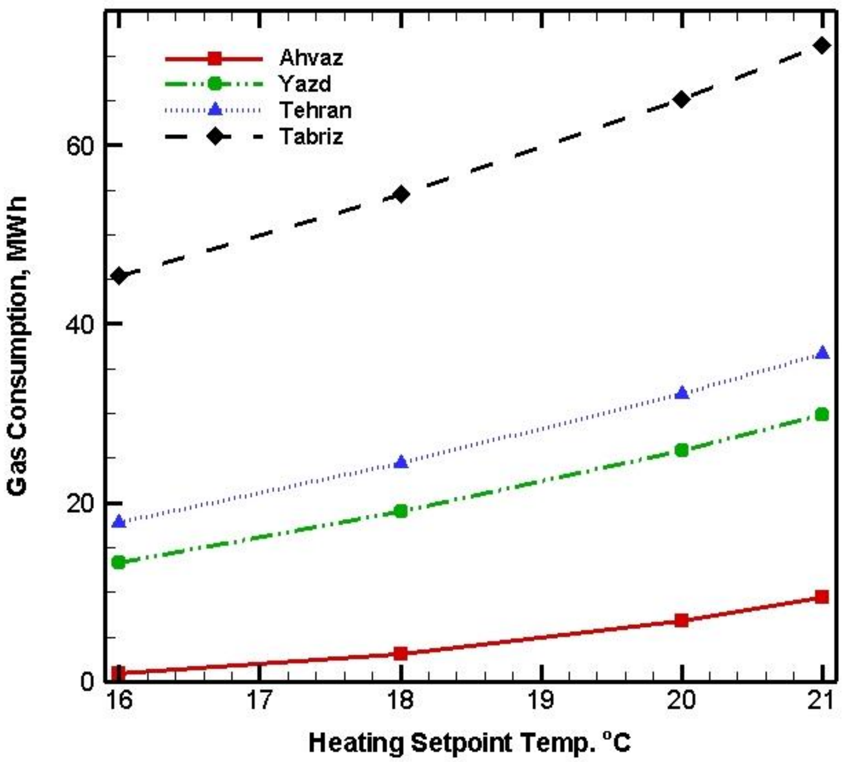
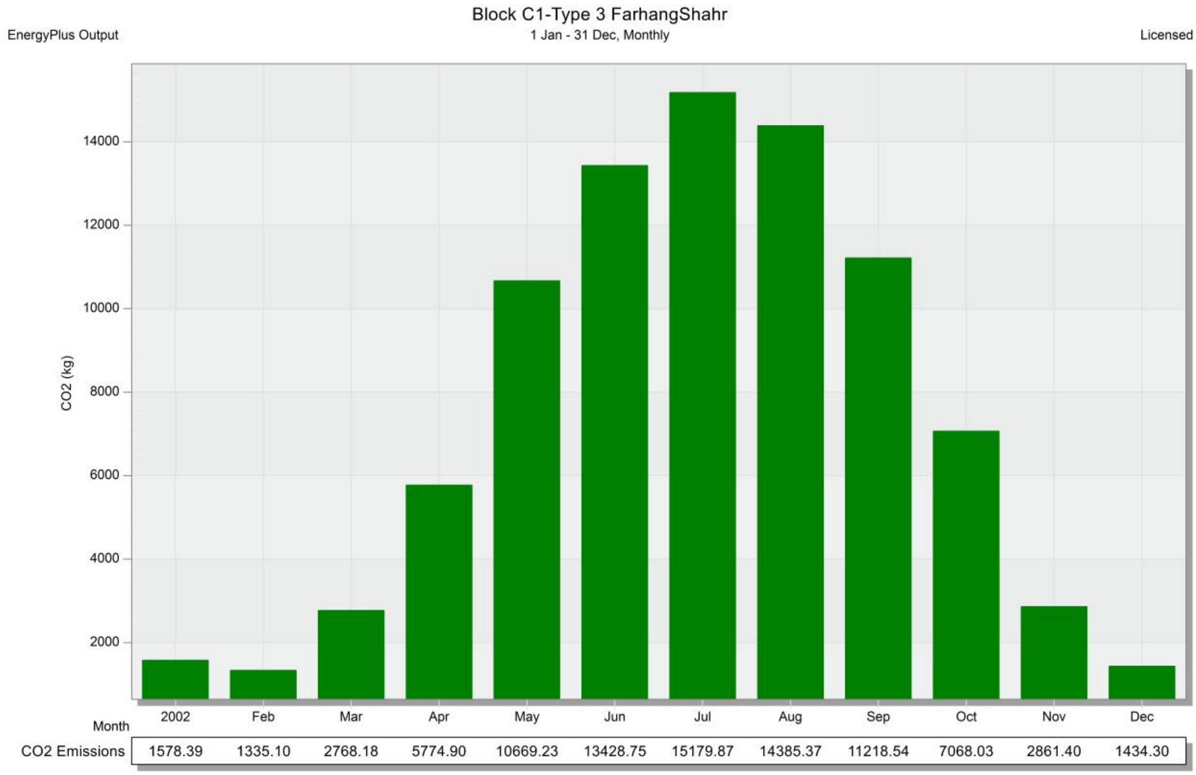
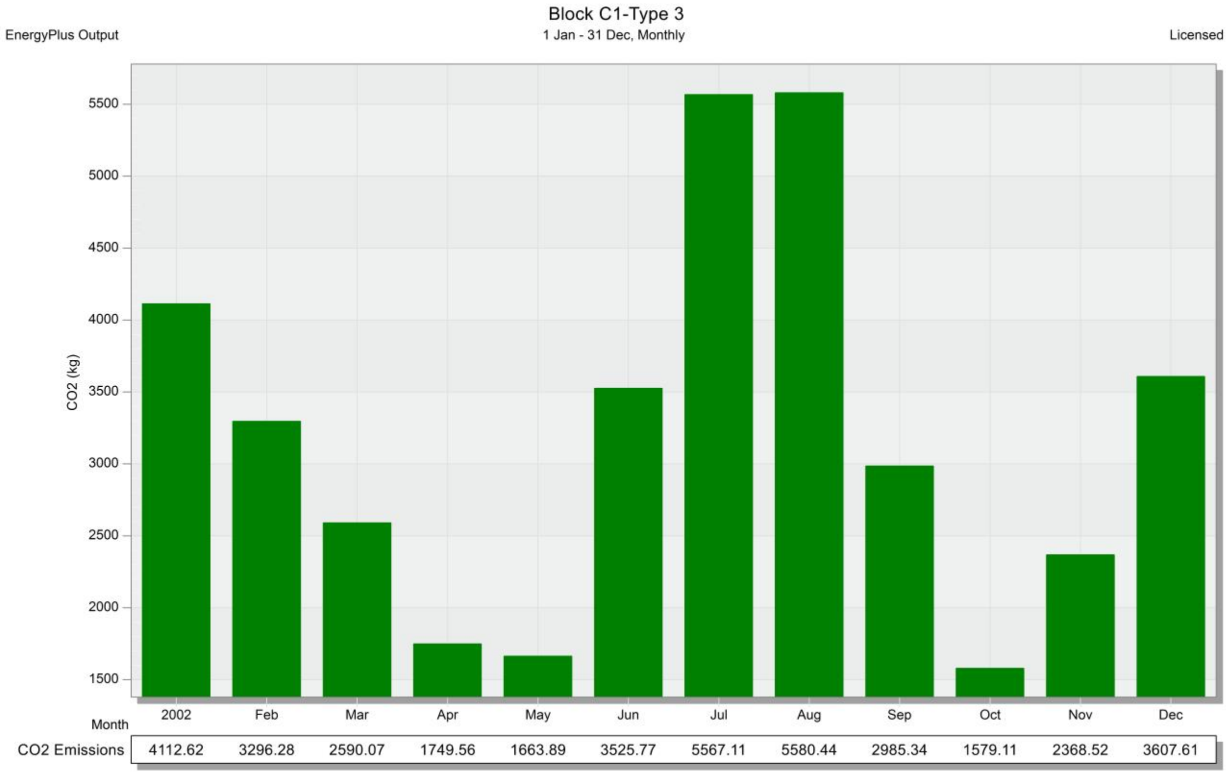


Fig 12: Annual gas consumption as a function of the heating system setpoint temperature

Figure 13 presents the effect of setpoint temperatures on the annual CO_2 emissions reduction of a building in four different climatic cities. Additionally, the results for monthly CO_2 emissions throughout the year, based on a heating setpoint temperature of 21°C and a cooling setpoint of 22°C, are presented in Figure 14 for the cities of Ahvaz which has the highest annual CO2 emissions and Tabriz, which has the lowest. As can be seen in Figure 13, the lowest CO_2 emissions occur at a heating setpoint of 16°C and a cooling setpoint of 27°C, while the highest annual CO_2 emissions are associated with a heating setpoint of 21°C and a cooling setpoint of 22°C. An increase in the heating setpoint temperature and a decrease in the cooling setpoint temperature led to higher CO_2 emissions in all climatic zones. The reduction in annual CO_2 emissions resulting from lowering the heating setpoint temperature from 21°C to 16°C in Ahvaz where cooling energy consumption is the highest among the four cities is approximately 32.6%. This reduction is 39.6%, 40%, and 40.2% for the cities of Yazd, Tehran, and Tabriz, respectively.



a-Ahvaz



b-Tabriz

Fig 13: Monthly CO_2 emission for a cooling setpoint of 22°C and a heating setpoint of 21

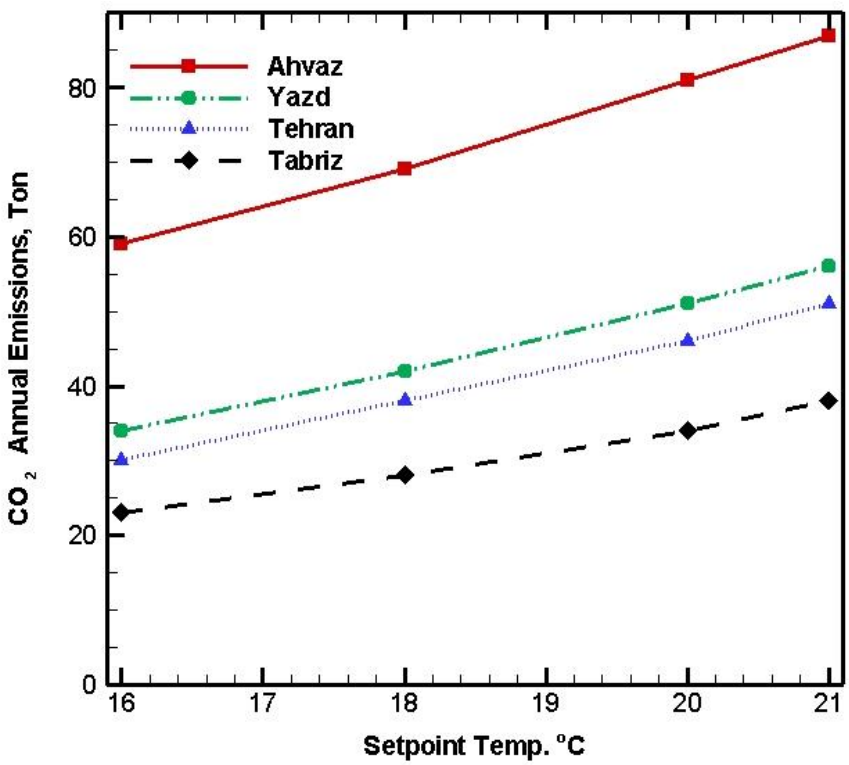


Fig 13: CO_2 Annual emission as a function of the setpoint temperature

6. Conclusions

In this study, the impact of the setpoint temperature of heating and cooling systems on building energy consumption in different climates of Iran was investigated. Energy simulations were conducted for a residential building in the 492-unit Farhangshahr housing complex in Ahvaz as a case study, as well as for the four cities of Tehran, Tabriz, Yazd, and Ahvaz. Based on the analyses performed, the following results were obtained:

1- Impact of Climate on Energy Consumption: In Ahvaz, 96.1% of the building's energy consumption is related to cooling, while in Tabriz, 84.6% is used for heating. Tehran has a balanced energy consumption between cooling (54.6%) and heating (45.4%). In Yazd, 65.5% of energy consumption is for cooling, and 34.5% is for heating.

2- Effect of Increasing Cooling Setpoint Temperature on Cooling Load Reduction: Increasing the cooling setpoint temperature from 22°C to 27°C reduced the cooling load in Ahvaz by 80.3 MWh (35.7%). This reduction for Yazd, Tehran, and Tabriz was 47.2%, 49.6%, and 71.2%, respectively.

3- Effect of Decreasing Heating Setpoint Temperature on Heating Load Reduction: Decreasing the heating setpoint temperature from 21°C to 16°C reduced the heating load in Tabriz by 60.9 MWh (36.4%). This reduction in Tehran, Yazd, and Ahvaz was 51.5%, 55.6%, and 89.8%, respectively.

4- Reduction in Cooling Electricity Consumption**:** Increasing the cooling setpoint temperature by 5°C in Ahvaz reduced cooling electricity consumption by 44.6 MWh. This reduction for Yazd, Tehran, and Tabriz was 31.9 MWh, 27.9 MWh, and 17.8 MWh, respectively.

5- Reduction in Annual Gas Consumption for Heating: Decreasing the heating setpoint temperature by 5°C in Tabriz reduced annual gas consumption by 25.8 MWh. This reduction for Tehran, Yazd, and Ahvaz was 18.9 MWh, 16.5 MWh, and 8.5 MWh, respectively.

6- Lowering the heating setpoint temperature from 21°C to 16°C leads to a reduction of approximately 32.6% in annual CO_2 emissions in Ahvaz, the city with the highest cooling energy consumption among the four studied. In comparison, the reductions for Yazd, Tehran, and Tabriz are about 39.6%, 40%, and 40.2%, respectively.

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