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Regional climate changes and their effects on monthly energy consumption in buildings in Iran

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Abstract

This present research work was carried out to evaluate the energy consumption in a typical Iranian building based on the forecast of climatic variables. Thus, the LARS-WG model was validated for some northwest stations of Iran, including Tabriz, Ardebil, Oromieh, Kermanshah, Hamedan, Sannandaj, Qazvin, and Zanjan. The average monthly outdoor temperature was forecasted from 2011 to 2100. The relevant data were generated when this model was used in three phases, including calibration, meteorological data generation, and meteorological data analysis. In the model, HADCM3 general atmospheric circulation model data was extracted each day, and a special LARS-WG model-based scenario is compiled for each general atmospheric circulation model network. The results of this study showed a delay of one month in the future yearly temperature curve and an average increment of 4°C in all the eight Iranian cities. Furthermore, as a result of these expected changes, the future maximum and minimum outdoor temperatures will be higher in the winter and reduced in autumn. Another related result of this temperature variation is a decrease in the heating energy consumption in the months of February and March and an increment in the months of November and December. On the other hand, there will be an increment in the cooling energy consumption in the months of May and June and a decrement in the months of August and September. Generally, some kinds of parameters, like the thermal inertia of the buildings and number of air changes, were combined as design proposals to define future building constructions with the lowest energy consumption. Thus, with half changes in the air and in the heating season, the energy consumption is reduced to one quarter of the initial forecast value, and in the cooling season, the energy consumption will be slightly higher, reaching the energy consumption defined today. Finally, it can be concluded that it is now the right moment to define future building design criteria.

Keywords

building, climate change, energy consumption, Iran.

1. Introduction

One of the main problems in the current century is global warming. Global warming has been aggravated due to the greenhouse effect and is expected to result in some changes resulting in different climatic variables, such as temperature, rainfall, air humidity, and solar radiation. However, the average temperature of the earth may be increased from 1.1 to 4.6°C, and may result in a global climate change occurrence by 2100 if the emission of greenhouse gases is not

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reduced (Solomon et al., 2007); the climate change occurrence may cause harmful effects on human communities in a multitude of ways.

The main side effects of climate change on humans are on the energy supply-demand system. For this reason, there are many researches that have been conducted on climate forecast and these researches need to be employed in large-scale planning in the energy supply-demand system, but it is a yearly, not a monthly forecast.

Temperature is one of the most important indexes in climate change in both regional and global scales. There is no definite pattern for climate changes in terms of location and time. Throughout the world today, many studies are in progress in this regard. Climate variables simulated on the basis of an oceanic climatic-paired model are the most accredited tools for making an analysis on the effects of climate change phenomenon. These models can simulate oceanic and climatic parameters using Intergovernmental Panel on Climate Change (IPCC) approved scenarios for a long term.

However, the main disadvantage of these models is their low power of local separation and simplifications which are considered for climatic processes. It is necessary to microscale the output of these models to enhance their power of separation before using them in climate change effects analysis (Dubrovsky and Roll, 1996; Dubrovsky, 1996). Exponential microscopy can be carried out in two dynamic and statistical methods. Common statistical methods, such as regression and meteorological generator models, can be used in statistical exponential microscaling. In the dynamic exponential microscaling method when using numerical analysis methods, such as finite difference, the equations of weather package in subnet works of a general atmospheric circulation model network are solved. The second problem of general atmospheric circulation models, as an atmospheric process simplification, can be removed using this method (Wilks and Wilby, 1999; Abassi et al., 2010; Babaeian et al., 2010). A statistical microscaling method when compared with dynamic methods has more advantages, especially in cases where it is necessary to make an analysis of the effective factors of climate changes with high speed and less costs. Among various types of statistical exponential microscaling models, are USCLIMATE TE, LARS-WG, CLIMGEN, SDSM & MET, GEM, and ROLL (Rasco et al., 1991; Babaeian and Kwon, 2004; Elshamy et al., 2005).

In this research, a statistical exponential microscaling method on the basis of a meteorological data-generating model called “LARS-WG” has been used to forecast climate changes in the Northwest of Iran. A this moment, many studies and researches have been conducted on climate behaviour models for identifying different regions of the world using meteorological data-generating models, among which are Thompson and Mullan (1995) paper about model making for the 30-year climate of meteorological stations in New Zealand. Johnson et al. (1996) also made a study on two different meteorological data-generating models called “USCLIMATE” and “CLIMGEN”. Elshamy et al. (2005) conducted a research on hydrological effects of climate change using the general atmospheric circulation models and an analogue microscaling model in the South UK. In this research, the procedure of changing monthly data to a daily one using the data-generating technique has been the subject of study. The results have shown that in the data-generating technique, daily meteorological data can be better microscaled than a seasonal one. Wilby et al. (2002) invented the SDSM model for exponential microscaling of temperature and rainfall data using a statistical methods-applying model. They made an analysis of microscaling for seasonal rainfall using the parameters generated in the UK (Elshamy et al., 2005). Wilks and Wilby (1999) have also invented a method for using climate change scenarios on the basis of the WGEN model, which is a meteorological data-generating model (Semenov et al., 1998; Semenov and Barrow, 2002). This model can be used to generate daily quantities of maximum and minimum temperature, rainfall and daily solar radiation. Other researchers (Semenov, 2007) made a study on the advantages of the CLIMGEN meteorological model in the simulation of the parameters in the meteorological stations in southern Ontario of Canada. Dubrovsky and Roll (1996) made an analysis of MET and ROLL model in the Czech Republic. An analysis has been made of the data of maximum and minimum temperatures, solar radiation, and rainfall in a meteorological station (Semenov et al., 1998; Semenov and Barrow, 2002). In a simulation study, Semenov (2007) studied the data model making use of the LARS-WG model in the UK. Semonov (2007) has also made an analysis on climate change scenarios in the UK. In this research, the LARS-WG model was used to generate daily climate scenarios, and the effect of climate change on the growth of two species of wheat, Merica and Avalon, by 2080 (Semenov, 1998). In another study by Babaeian et al. (2010), an analysis has been made on climate changes in South Korea using the LARS-WG model from 2010 to 2039. In this last work, the climate of the Northwest provinces of Iran and the energy supply-demand situation in buildings, have been a subject of study using HADCM3 and LARS-WG software for the period of 2090 to 2100.

In previous research works (Wan et al., 2012), the study of the effect of climate change in building energy consumption in China was conducted. The results showed that an increment in the building energy consumption was obtained for the near future. This increment in energy consumption will worsen the climate change effect and, consequently, some building design criteria were proposed like, better insulation to avoid energy losses. Thus, related research works (Arnfield, 2003) showed that the energy consumption per square metre of buildings can be reduced up to 35.2%, when insulation is used for external walls. Despite this, the energy study was done annually and, consequently, only general proposals were shown, like changes in the outdoor temperature in the selection of the air-conditioning systems.

Iran is one of the only countries in the world which has the complete four seasons. A large part of the country suffers great extremes of heat and cold between summer and winter (Nazemosadat and Cordery, 2000; Sabziparvar et al., 2011; Tabari and Talaee, 2011). The reason for this study is that, in Iran, the commercial and building sectors consume more energy than any other economic sectors (Farhanieh and Sattari, 2006). The present research work was carried out to study the effect of climate change in building energy consumption in the Iranian cities on a monthly basis and, consequently, new design parameters could be analysed.

2. Study area

The geographical location of the studied stations of the Northwest Iran is as shown in Figure 1. The average annual temperature of the stations in the Northwest of Iran is 11.6°C. The zone of minimum temperature is located in the capital of Ardebil province and the maximum temperature is associated with the northern regions of eastern Azerbaijan province, with Tabriz as its capital. In addition, the greater part of the provinces of eastern Azerbaijan, Kurdistan (with Sannandaj as its capital) and the north of Ardebil have temperatures higher than the average, whereas the centre and south of Ardebil province are colder than the other regions.

As shown in Table 1, some of the geographical and climatic features of the stations studied are presented.

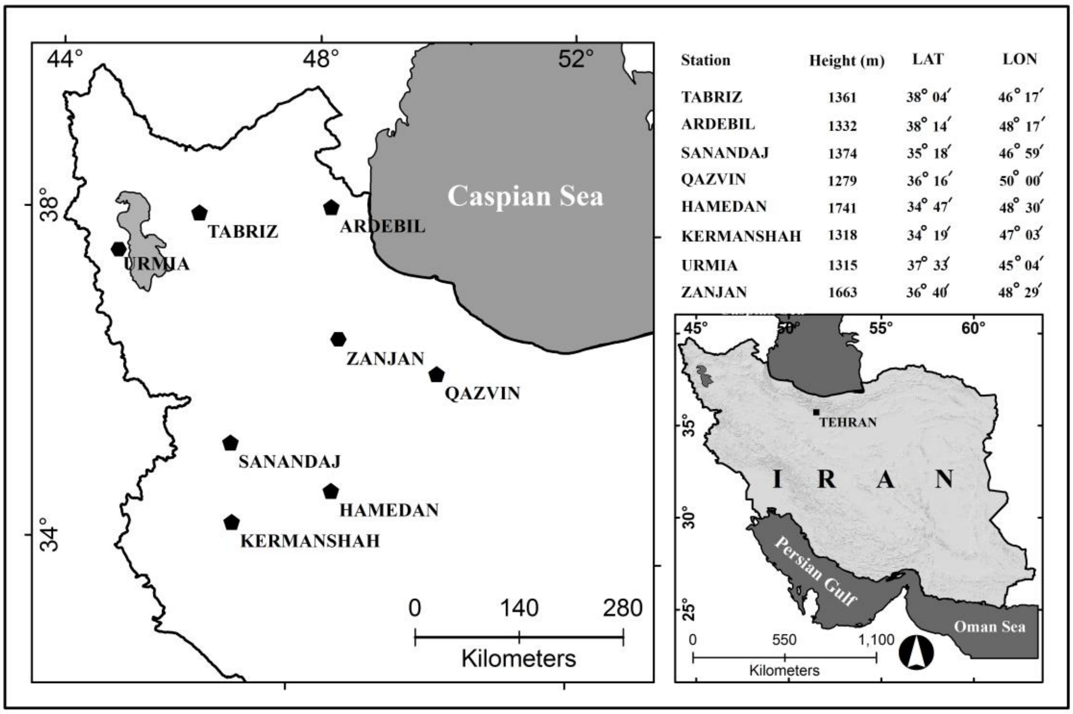


Fig. 1. Selected weather station in study area

Table 1. Positions and the averages of the observed climate data of eight synoptic stations

Statistics Station	Tabriz	Zanjan	Oromieh	Kermanshah	Ghazvin	Hamedan	Ardebil	Sanandaj
Latitude (°E)	38.05	36.41	37.32	34.21	36.15	35.12	38.15	35.20
Longitude (°N)	46.17	48.29	45.05	47.90	50.03	48.43	48.17	47.0
Elevation (MSL)	1361	1663	1315.9	1318.6	1279.2	1679.7	1332	1373.4
Available data (years)	1955–2008	1955–2008	1955–2008	1955–2008	1955–2008	1955–2008	1955–2008	1955–2008
Mean min temperature in °C	6.9	4	5.4	5.8	6.9	2.9	2.8	5.5
Mean max temperature in °C	18	18	17.6	22.6	21.2	19.1	15.3	21.4
Mean sunshine in hours	2794.3	2843	2829	2902	2955	2789	2454	2873

3. Materials and Methods

3. 1. Model description

The relevant data were generated using the model in three phases, including calibration, meteorological data generation, and meteorological data analysis. In the model, HADCM3 general atmospheric circulation model data, such as rainfall, minimum and maximum temperatures, and radiation was extracted each day, and a special LARS-WG model-based scenario was compiled for each general atmospheric circulation model network.

For compiling this scenario, network data of the HADCM3 model in the forecast period was compared with the base period. In this study, the period from 1961 to 1990 was defined as the base period and the period from 2090 to 2100 which is sought to be forecasted. For the execution of the LARS-WG model 5.11 edition, some data about the past climate behaviour were needed to calculate the network from the weather stations involved. For this reason, the daily and monthly temperatures and radiation data in the northwest stations, such as Tabriz, Ardebil, Oromieh, Kermanshah, Hamedan, Sannandaj, Qazvin, and Zanjan were applied (Fig. 1). It is also necessary to select scenario A2 for our modelling.

Furthermore, the future evolution of these same parameters for the period 2011 to 2100 was forecasted; although, this study focused on only 2090 to 2100. The model was run ten times. Then, the outputs were observed and trends for every modelling. The idea was to see how the major trends are. Also, which of future modelling is able to follow the trend of the past decade data. Then, the best output for each station was select for modelling.

During this process, the mechanisms of this model affected all monthly data according to Equation 1.

$$F_{fut} = F_{obs} + (F_{GCM}^{futt} + F_{GCM}^{bas}) \tag{1}$$

In this equation, $F_{GCM}^{fut}, F_{GCM}^{bas}, F_{obs}, F_{fut}$ represent the forecasted weather parameters for each weather station, the observed weather parameters in the same station, the forecasted weather parameter in the future period model, and the designed weather parameter in the past period model. As a result of this, the standard deviation will change according to Equation 2.

$$STD_{fut} = \frac{STD_{base}^{OBS}}{STD_{base}^{GCM}} . STD_{fut}^{GCM} \tag{2}$$

Thus, Table 1 indicates a brief explanation about climate component average in stations as shown in Figure 1. Once these data were forecasted, demand of energy consumption was estimated in accordance with ISO 13790 standard. Furthermore, the main results were compared with the base period of 1955 to 2005.

3. 2. Building and wall construction

Some works present the relationship between climatology and energy consumption in cites (Christen, 2004; Heidari and Sharples, 2002; Bergeron and Strachan, 2012). As was employed in previous works relating to energy saving and building construction, Fayaz and Kari (2009) selected buildings were naturally ventilated so as to facilitate the application of the adaptive thermal comfort models.

The composite wall is generally constructed with bricks on the outside, insulation in the middle, and layers of plaster on both sides, as shown in Table 2 (Roodgar et al., 2011).

Table 2. Building and wall construction

Element	Property	Value
Insulation	k_B	0.03 W/m ºC
	C_B	1470 J/kg ºC
	r_B	45 kg/m^3
Brick	k_D	0.75 W/m ºC
	C_D	840 J/kg ºC
	r_D	1300 kg/m^3
	Width	20 cm
Rendering (Exterior plaster)	k_A	0.79 W/m ºC
	C_A	1000 J/kg ºC
	r_A	1330 kg/m^3
	Width	2.0 cm
Interior plaster	k_E	0.51 W/m ºC
	C_E	960 J/kg ºC
	r_E	1120 kg/m^3
	Width	1.0 cm

3. 3. ISO 13790 simulation

To define a more adequate standard to be applied in this work, a review of building codes was done. In previous research works on energy conservation and building codes in Iran, some conclusions were obtained (Roodgar et al., 2011). The main conclusion is that the initial Iranian building code, called Code No. 19 developed in 1991, showed some minor problems in defining the actual energy consumption of buildings during the hot and cold seasons. In particular, the results showed that, despite the fact this code is adequate to calculate the building envelope, it presents some problems with ventilation and internal and external heat sources. As a result of this, in this work, a well known standard ISO 13790 was applied. This standard was selected due to the fact that it has been employed in the same kind of building construction in different climatic conditions, and with favourable results.

4. Results and Discussion

4. 1. Validation of simulations

This model has been estimated in 43 stations in Iran by a research group on climatology. The results showed that this model has a great power for simulation of temperature. On the other hand, the HADCM3 model was calibrated and accredited with B2 and A2 scenarios by Sayari et al. (2011).

In order to calibrate and ensure the validity of this model, the base status scenario of the statistic period from 1989 to 2008 was compiled to adjust for the LARS-WG model. Outputs of this model, including standard deviation, radiation, precipitation, and daily maximum and minimum temperatures were compared with data observed during these 20 years in the eight cities, as shown in Figure 2.

Analysis of the LARS-WG model was made by comparing statistical and generated data using statistical tests. These tests include the mean absolute error (MAE), root mean square error (RMSE), Pearson’s correlation coefficient (R) and t-test and comparison charts. The results from the statistical tests include two one-sided *t*-tests for the eight stations and showed that there is no significant difference between the modelled data and real data, with a 0.05 level of significance. At the same time, the coefficient of the Pearson's correlation is accepted among real and modelled data in an acceptable table level of 0.01 significance. Also, outputs for MAE and RMSE can be observed as shown in Table 3. However, the result of Table 3 shows that the modelling has minor error and outputs have level of significance acceptability.

In this study, the period from 1961 to 1990 was selected as the reference to be compared with the forecast period from 2090 to 2100.

Figure 3 shows a comparison between simulated data for the period 2090 to 2100, in respect to the data in the reference period 1961 to 1990 for the stations located in the Northwest of Iran. In particular, the annual average temperature and solar radiation are shown.

From this Figure 3, it can be concluded that the maximum increase of long-term average temperature will be in Ardebil with about 2.58°C, reaching the final temperature of 11.45°C.

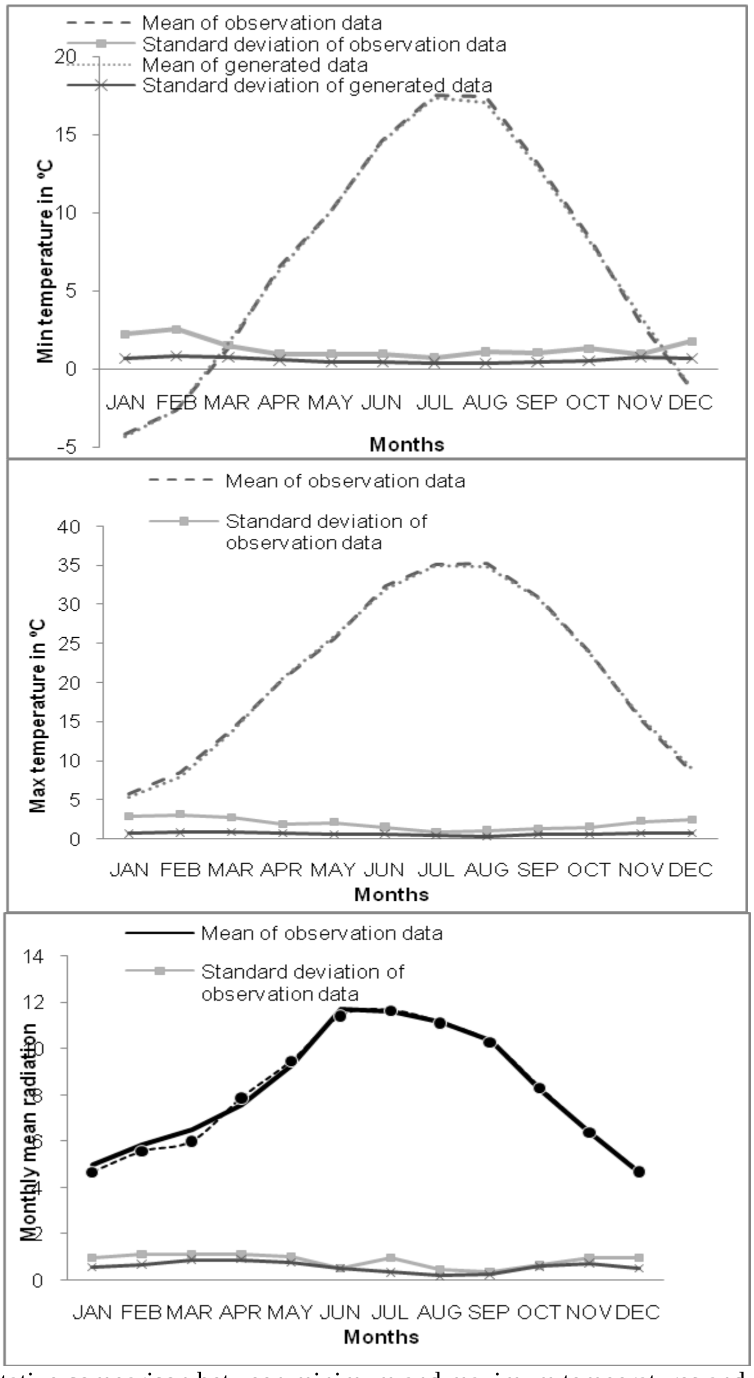


Fig. 2. Representative comparison between minimum and maximum temperatures and radiation, by the generated or simulated models, and data observed in Qazvin

Table 3. Validation data modeled using statistical tests

Climatic parameters	T Max			T min			Radiation		
Stations	RMSE	MAE	R	RMSE	MAE	R	RMSE	MAE	R
Tabriz	0.33	0.12	0.95	0.4	0.45	0.93	0.03	0.001	0.97
Zanjan	0.53	0.4	0.93	0.23	0.89	0.91	0.12	0.1	0.92
Oromieh	0.78	0.27	0.89	0.32	0.20	0.88	0.22	0.27	0.89
Kermanshah	0.66	0.10	0.91	0.44	0.17	0.93	0.23	0.42	0.91
Ghazvin	1.2	0.52	0.88	0.98	0.66	0.94	0.33	0.56	0.94
Hamedan	0.09	0.01	0.92	0.12	0.7	0.88	0.01	0.001	0.92
Ardebil	0.08	0.1	0.95	0.09	0.001	0.96	0.04	0.002	0.87
Sanandaj	0 .02	0.3	0.90	0.03	0.002	0.84	0.09	0.02	0.86

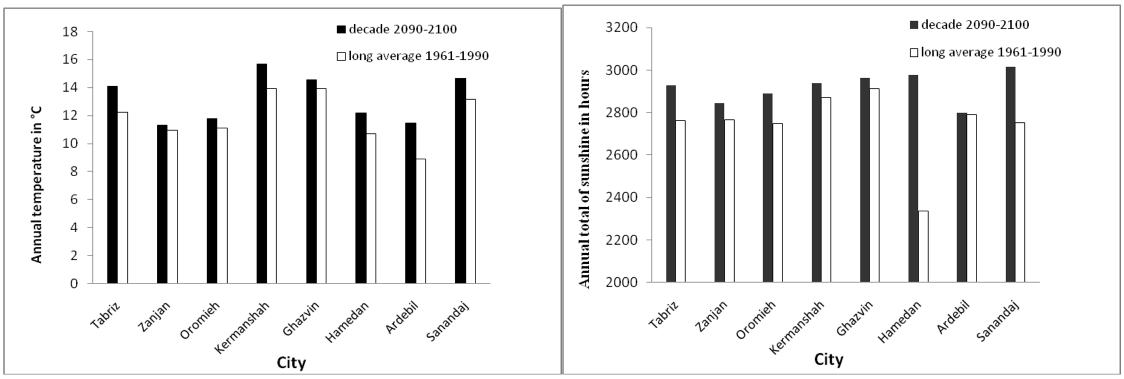


Fig. 3. Comparison between simulated data (2090–2100) and base data (1961–1990)

After Ardebil, the maximum temperature increase will be in Tabriz with 1.86ºC and Kermanshah with about 1.76ºC.

In Sanandaj station, long-term temperature average is calculated as 13.16ºC in the base year from 1961 to 1990. The simulation shows that the average temperature is increased to 14.66ºC from 2090 to 2100.

On the other hand, cities like Hamedan, Oromieh, Qazvin, and Zanjan will experience the least increase in temperature of 1.48, 0.70, 0.61, and 0.35°C, respectively.

If the number of sunshine hours was considered, then we can conclude that the annual mean average increase in sunny hours will be 642.5, 264.7, 166.2, 141.7, 79.02, 67.21, 50.21, and 7.62 in cities of Hamedan, Sannandaj, Tabriz, Oromieh, Zanjan, Kermanshah, Qazvin and Ardebil, respectively.

For this reason, it is expected that the average of sunny hours in the Northwest regions of Iran is increased to 177.39 for the base period in the simulated decade of 2090 to 2100.

4. 2. Simulation results

Once the ISO standard have been selected to evaluate the energy consumption in an Iranian building, it is time to analyse the main parameters that must be employed to define the energy consumption. Thus, first of all, it must be remembered that the energy consumption in accordance with ISO 13790 standard depends on the mean value of monthly outdoor temperature. Consequently, for this energy study, the maximum and minimum values must not only be considered, but must also obtain the monthly mean values to be compared with previous works on climate change and its physical effects.

The main results obtained are shown in Figures 4 and 5, and the increments between these two periods are reflected as shown in Figure 6.

At the same time, it is of special interest to define the tendencies in the minimum and maximum monthly temperatures. The result of this increment between the periods is reflected as shown in Figure 7 per each of the sampled cities.

As a final step, the heating and cooling energy consumption in each of the selected cities has been calculated in accordance with ISO 13790 standard for the building described previously. The results are shown in Figures 8 and 9, and the increment between these two periods is reflected as shown in Figures 10 and 11.

Finally, the energy consumption and carbon dioxide emissions for each building located in each city are reflected as shown in Figures 12 to 15. Furthermore, the effect of a reduced number of air changes (*n*=0.5) as a possible solution to reduce the building's energy consumption is reflected as shown in Figures 12 to 15.

As shown in Figure 4, despite the fact that there is an increment in maximum and minimum outdoor temperatures, the yearly evolution of the average outdoor temperature in the 2090s decade is delayed in respect of 1955 to 2005. Thus, a delay of one month in the same curve was observed. Consequently, the maximum yearly average temperature that is presently reached in July was shifted to June in all the sampled cities, as shown in Figures 4 and 5.

Another result obtained from this figure, in accordance with Zarghami et al. (2011) is that cities like Tabriz and Ardebil are cities with a higher temperature increment in the next century as shown in Figures 4 and 5.

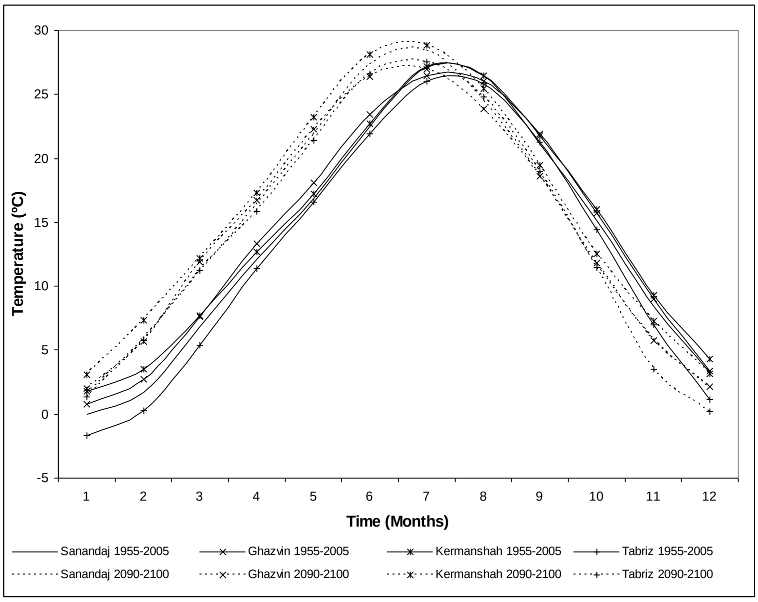


Fig. 4. Average temperature in the periods of 1955 to 2005 and in the 2090s decade (I)

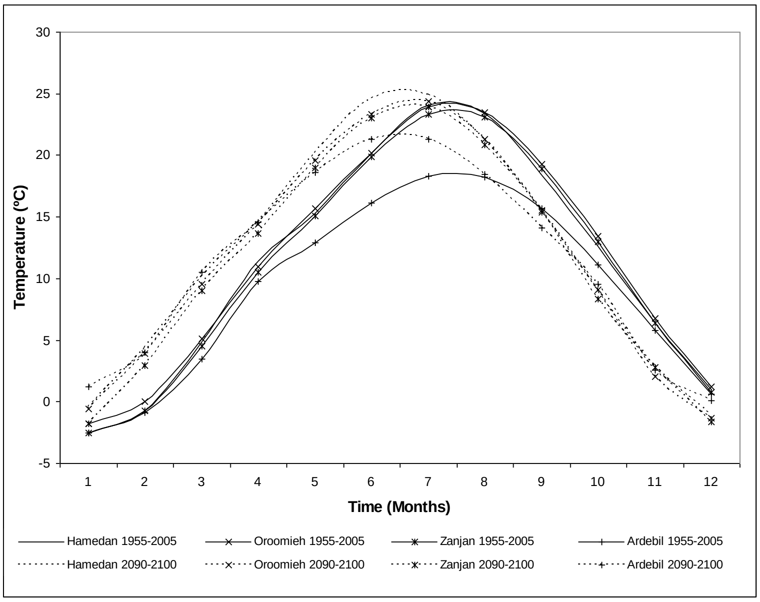


Fig. 5. Average temperature in the periods of 1955 to 2005 and in the 2090s decade (II)

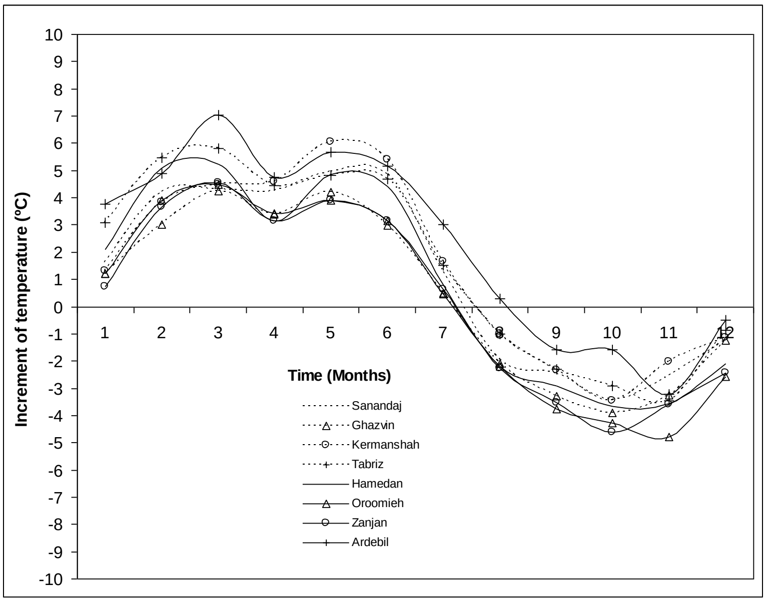
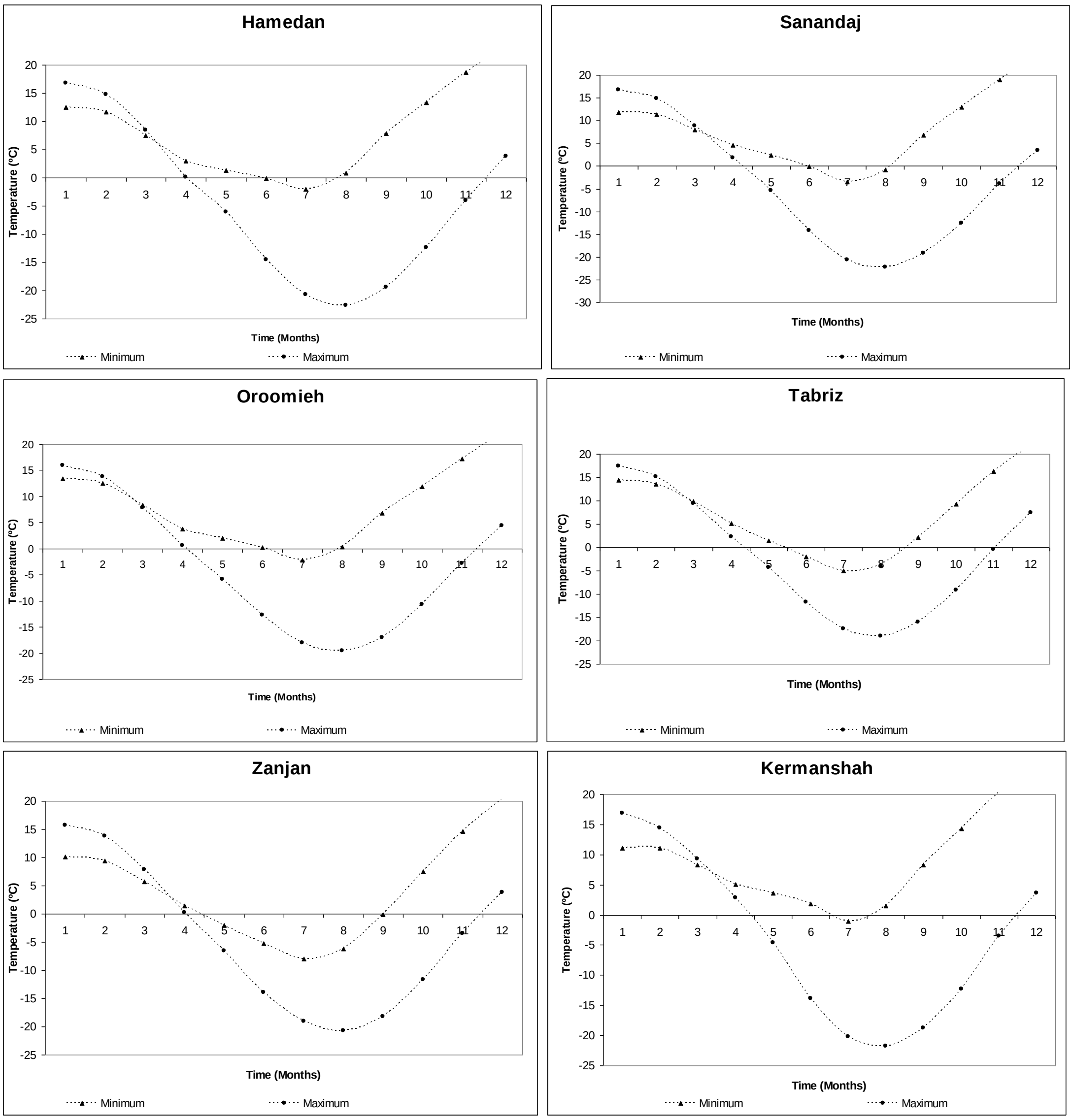


Fig. 6. Increment of the average temperature between periods 1955 and 2005 and in the 2090s decade.



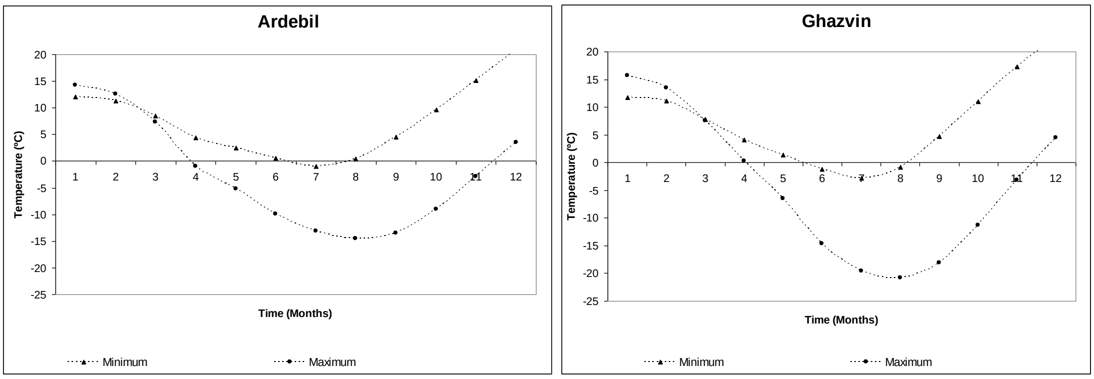


Fig. 7. Increment of maximum and minimum temperatures from the present period (1955–2005) to (2090–2100)

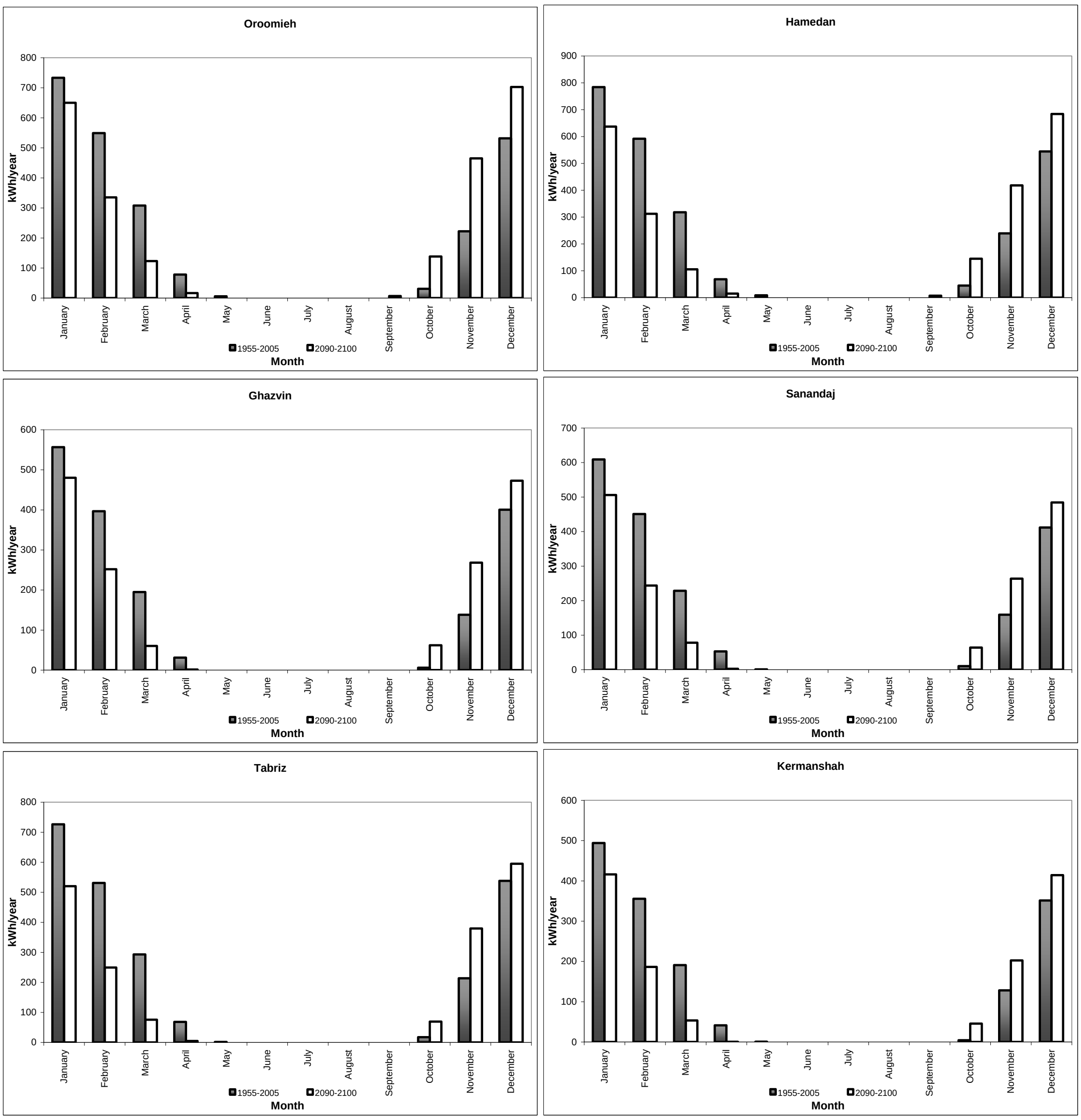


Fig. 8. Average energy consumption due to heating in the present period and 2090s decade

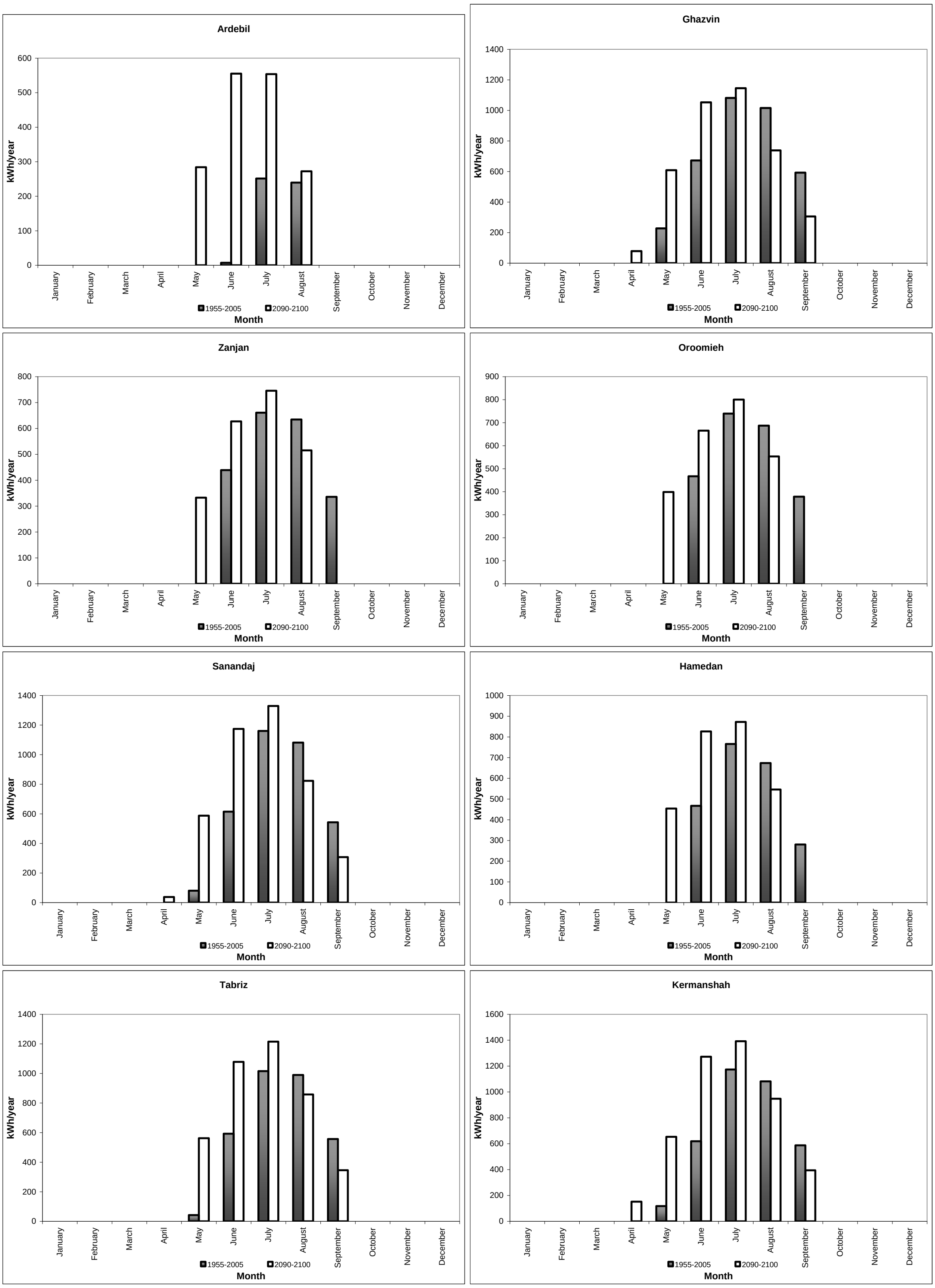


Fig. 9. Average energy consumption due to cooling in the present period and 2090s decade

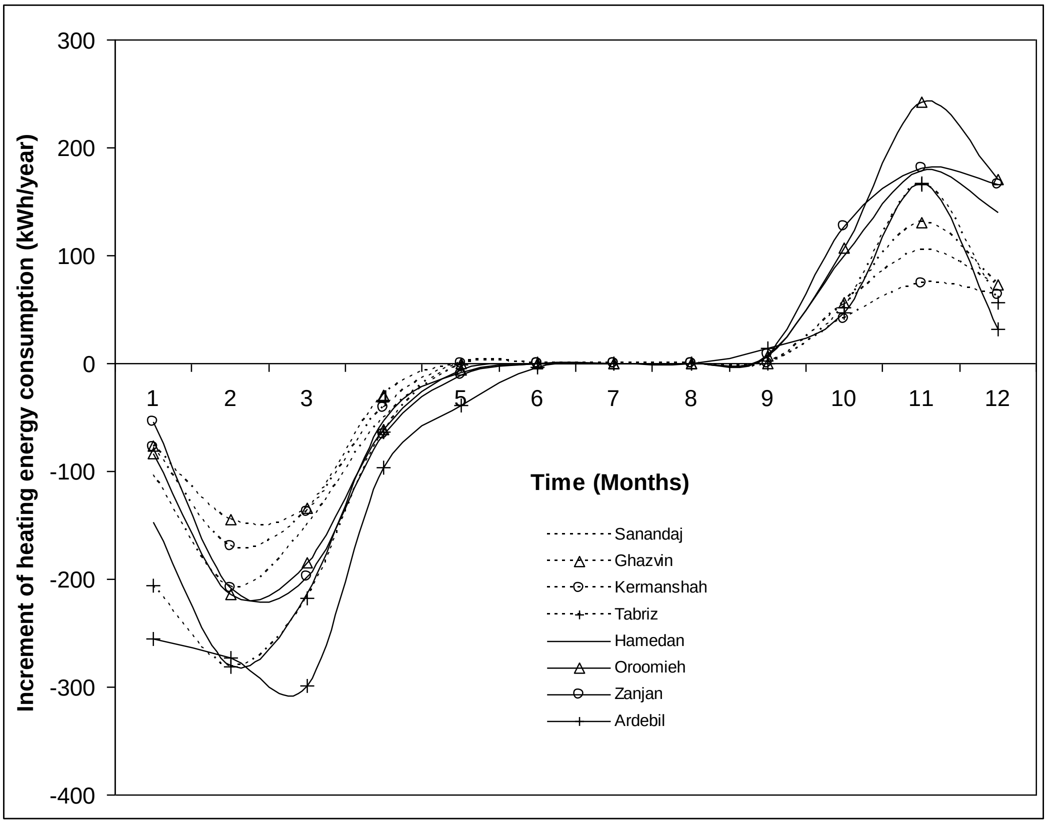


Fig. 10. Increment of heating energy consumption

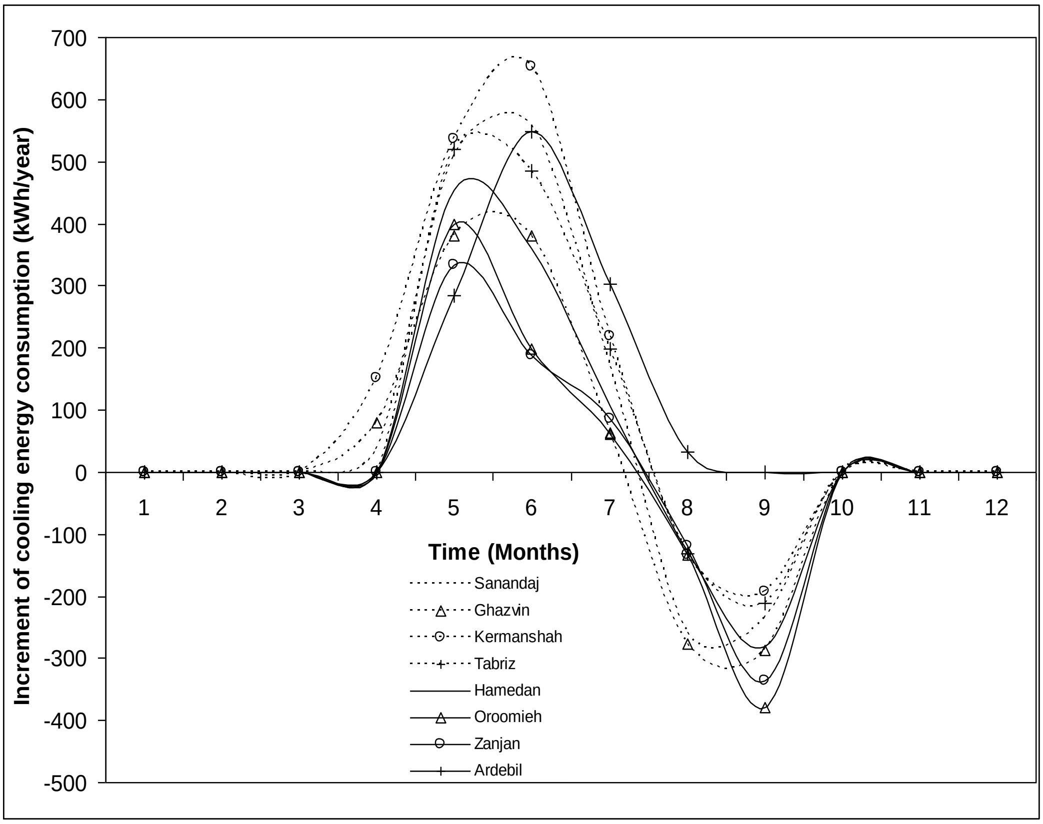


Fig. 11. Increment of cooling energy consumption

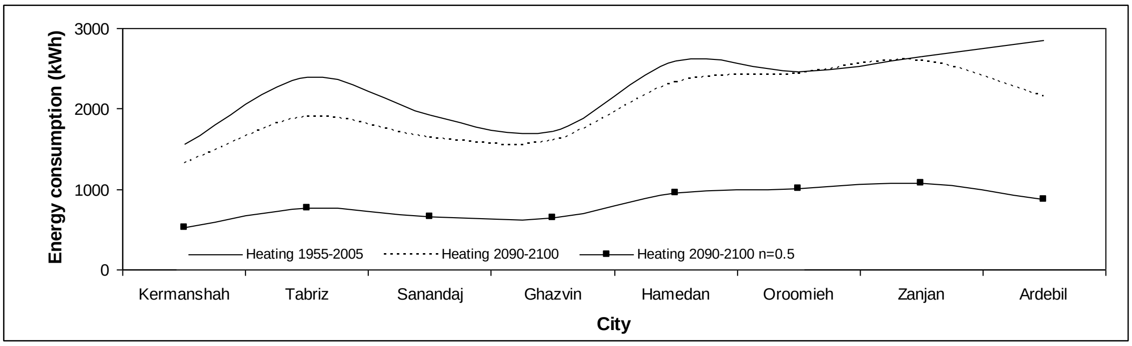


Fig. 12. Average heating energy consumption in the present period and 2090s decade

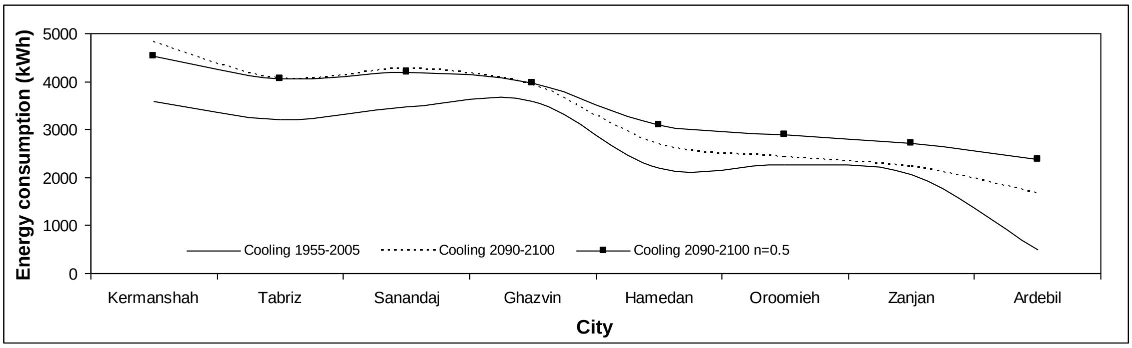


Fig. 13. Average cooling energy consumption in the present period and 2090s decade

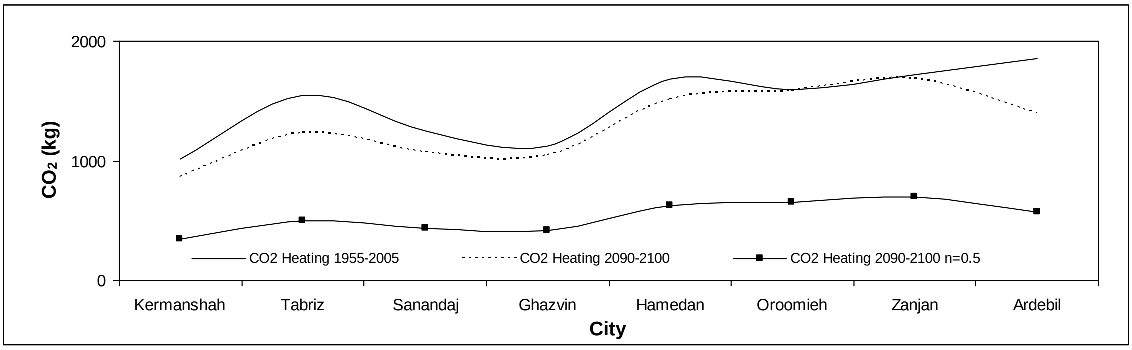


Fig. 14. Average CO_2 emission due to heating in the present period and 2090s decade

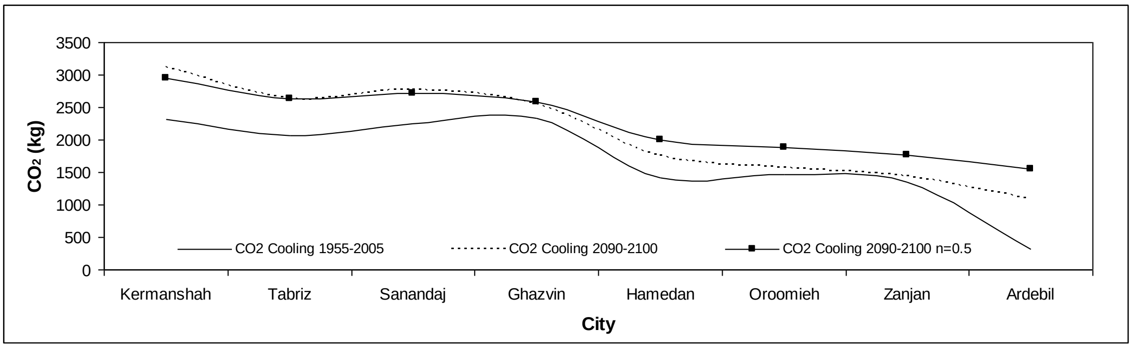


Fig. 15. Average CO_2 emission due to cooling in the present period and 2090s decade

Figure 6 shows the increment in the mean monthly temperature in the range between 3 and 6°C, with a mean temperature increment of 4°C in all the cities. These results are in clear agreement with previous research works (Zarghami et al., 2011) which showed an average change of 4ºC in Iran from 2011 to 2100, as shown in Table 3.

In our research work, a next step was undertaken showing the monthly evolution of this climate change, and is a useful tool to calculate the building energy consumption during each extreme season in accordance with the ISO standard.

Table 4. The average changes in east Azerbaijan for the baseline period (1951–2008) of 12.9ºC (Zarghami et al., 2011).

	Change in mean annual temperature (ºC)
2011–2030	0.88
2080–2099	4.83

Consequently, it was concluded that there is no increment in the mean outdoor temperature only in the month of July, in respect of the last few decades. From this month, there is a clear decrement of the mean outdoor temperature in respect to the present period. This decrement of outdoor temperature was predicted in the other half of the year, reaching decrements of 6ºC.

On the other hand, as is well known, to describe the future evolution of weather conditions, the minimum and maximum temperatures are usually employed. In particular, different time series were obtained in Iran, but these have never been related in a monthly way, as it has been done in this work. Thus, previous works, like those of Tabari and Talaee (2011), who have analysed the effect of climate change by time series of the minimum and maximum temperatures in Iran. Their results were useful for noting the tendency till 2005, reflecting a slight increment in maximum and minimum temperatures. Furthermore, this increment was stronger in the minimum values and in summer and winter seasons and especially clear in the North Western regions of Iran.

From our study, these results have been arrived at and it was observed that the minimum temperature experiments reveal an increment during the cold seasons from October to March, reaching an increment of 15ºC in December, as shown in Figure 7. At the same time, from the same figures, it can be concluded that the maximum temperature experiences an increment in these same cold seasons, and that it experiences a clear reduction of 20ºC in summer.

From these figures, it can be concluded that the future maximum and minimum outdoor temperatures will be higher during the winter and reduced in autumn, due to the displacement of the average outdoor temperature. As a result of these variations of temperature, it can be concluded that the cold season will experience temperatures not so cold, and the hot seasons will not reach up to the high values seen in the last few decades. Besides, it can be concluded that temperature conditions will present higher and lower mean temperature values, during each half of the year, but with lower oscillations.

Once the mean, minimum, and maximum temperature conditions expected in that future period have been described, then it is time to analyse its effects over energy consumption of the buildings. First of all, energy consumption, in accordance with ISO 13790 standards must be remembered depending on the mean value of monthly outdoor temperature, so, for this energy study, the maximum and minimum value must not only be considered, but also be forecasted in order for the average temperature to be analysed in-depth. It is an engineering parameter that is not usually defined by most climatology researchers. As expected, this future change of outdoor temperature will have clear effects over the monthly energy consumption, as show in Figures 6 and 7. These figures were obtained in accordance with ISO 13790 standard calculation procedure, like in previous papers, for the same building construction. As was previously commented, a monthly analysis of the effect of this outdoor temperature change is reflected as shown in Figures 8 and 9 for the cooling and heating seasons, respectively. The white columns represent the energy consumption in respect of the black columns that represent the baseline of the energy consumption for the period 195 to 2005. Analysis of the increment or decrement of the cooling and heating energy consumption in each of the eight Iranian cities, has been represented in Figures 10 and 11.

From Figure 10, a clear decrement of the heating energy consumption was noted in the months of February and March, with about –275 kWh/year. At the same time, this same figure shows a clear increment of heating energy consumption in the months of November and December, estimated to be about 200 kWh/year. On the other hand, it can be observed from Figure 11, that there will be an increment in the cooling energy consumption in the months of May and June from 400 to 500 kWh/year. Furthermore, a decrement in the cooling energy consumption in the months of August and September between 300 and 400 kWh/year was expected. Finally, the average cooling energy consumption of all the cities analysed will increase to 648.5 kWh/year. The first conclusion that was drawn based on these results is that the global heating energy consumption in the 2090s decade will be reduced when compared with today, as shown in Table 5. Furthermore, this reduction will be higher than the increment in the cooling energy consumption. Consequently, the total annual energy consumption will be lower, but it will not be as homogeneous as in the present period. Specifically, it will experience peaks of energy consumption during the summer season.

Table 5. Increment of energy consumption

City	Heating kWh/year	Cooling kWh/year
Kermanshah	–160.2	1232.2
Tabriz	–321.7	861.9
Sanandaj	–182.1	778.8
Ghazvin	–82.3	340.3
Hamedan	–179.2	511.1
Oroomieh	–14.2	145.5
Zanjan	–34.9	150.6
Ardebil	–458.7	1167.3
Total	–1433.6	648.5

Finally, Figures 12 and 15 show the actual and future heating and cooling energy consumption per metre square, and per year, with continuous and discontinuous lines, respectively. From Figure 12, it can be concluded that there will be a slight decrement in the heating energy consumption, and that this decrement will be glaring especially in cities like Tabriz and Ardebil. At the same time, in cities like Oromieh and Zanjan, the heating energy consumption will remain constant.

On the other hand, from Figure 13, it can be concluded that there will be a slight increment in the cooling energy consumption in cities like Kermanshah, Tabriz, Ardebil, and Hamedan.

Finally, this variation in energy consumption will be directly related with the carbon dioxide emissions, as shown in Figures 14 and 15.

Once the main simulations were developed, and the expected energy consumption was defined, it is time to analyse possible solutions to reduce energy consumption in these buildings. It must be remembered that it is an office building, so the main activities take place during some daylight hours. Thus, due to the mean life of most buildings, which is about 100 years, this is the opportune time to define better building-designing criteria in accordance with the expected weather changes. As a consequence of this, different simulations in ISO 13790 standard parameters were carried out to define ideal modifications that will help to reduce energy consumption in buildings.

To proceed in this task, previous research works were analysed as a guide for the main parameters to be improved in efficient-energy building designs (Heidari and Sharples, 2002). In these works, some kinds of proposals, for instance, to obtain a low U-value and a high thermal inertia by means of good properties in walls and roofs, and to employ darker colours that absorb the heat during the day and release this heat during the night are shown. In particular, the effect of insulation over building energy consumption in Iranian buildings, was analysed by other authors (Fayaz and Kari, 2009), showing a reduction of one-third per metre square of building area in building energy consumption, when this insulation is used in external walls.

Taking as reference, in these works, some parameters like building thermal inertia and number of air changes were simulated in order to reduce the energy consumption of future buildings. The results showed that to change the wall construction of a building is not a realistic solution, due to the total energy consumption that does not experience any kind of variation, and the mean in this monthly study proposed by ISO standards. Therefore, it is strongly advised that an hourly study needs to be developed to make future works more meaningful.

At the same time, energy consumption was calculated under a reduced number of air changes of 0.5. Its results are as shown in Figures 12 to 15. From these figures, it can be concluded that during the heating season, the energy consumption, with half the air changes, is reduced to one quarter of the initial forecast value. At the same time, during the cooling season, the energy consumption will be slightly higher than under double the air changes, reaching the energy consumption defined presently.

It is related with the fact that air changes are employed to remove indoor air in accordance with the heat and humidity sources, as is the case with human beings and computers. Thus, it must be clarified that the number of air changes must never be below the value of 0.5, and as a realistic proposal, these kinds of office buildings must attend to a reduced number of clients, and should have no people waiting to be attended to inside the building. Therefore, another kind of booking system must be introduced, which will reduce the number of air changes, and consequently, the energy consumption, without requiring any other technical modification in the air-conditioning system (HVAC) or building construction characteristics.

It is a clear example of sustainable modifications that must be considered in designing future buildings and in the modification and operation of existing buildings.

5. Conclusions

The present research work evaluates the energy consumption in a typical Iranian building based on the forecast of the main parameters that must be employed. Therefore, once the LARS-WG model was validated for this region, the mean value of the monthly outdoor temperature from 2011 to 2100 was carried out, and taking a baseline period of 1955 to 2005.

The results showed that a delay of one month of the yearly temperature curve is expected, along with an increment in the mean monthly temperature of 4°C in all the eight cities. Furthermore, the future maximum and minimum outdoor temperatures will be higher during the winter and reduced in autumn, as a result of the displacement of the average outdoor temperature. In particular, it was concluded that the mean average temperature increase for the northwest of the country will be 1.35ºC in the late 2100s.

As a result of this temperature variation, a clear decrement of the heating energy consumption in the months of February and March, and a clear increment of heating energy consumption in the months of November and December, are expected. On the other hand, there will be an increment in the cooling energy consumption in the months of May and June, and a decrement of the cooling energy consumption in the months of August and September. Consequently, the average cooling energy consumption of all the cities that have been analysed will be increased to 648.5 kWh/year.

Finally, taking these works reference, some parameters like building thermal inertia and the number of air changes were simulated to reduce the future energy consumption in buildings. The results show that changing the building wall construction is not a realistic solution, but how to min in accordance with a monthly study.

On the other hand, with half the air changes and during the heating season, the energy consumption is reduced to one quarter of the initial forecast value, and during the cooling season, the energy consumption will be slightly higher than under double air changes, reaching the energy consumption presently defined. Finally, it can be concluded that this is the opportune time, based on the methodology developed in this paper, to define more research works taking into consideration the hourly rise in outdoor temperature, to define the effects if building thermal inertia rises above its energy consumption.

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