Energy Consumption Impacted by Climate Change Application: Case Study Astara

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Abstract To study past climate conditions, main climatic factor related to the energy consumption namely temperature and precipitation were considered. Heating degree days (HDD), cooling degree days (CDD) and sunshine hours were analyzed. According to all reports in different scales temperature of Astara region, in last half century has been increased. In the longer future time period, the study area will face with higher values of increasing temperature. HDD with base temperature of 18 °C reduced in last 18 years. HDD in January which is cold month also reduced. Meanwhile CDD increased. CDD in July which is warm month also increased. This is in harmony with increasing the number of sunshine hours in the same time slice. By changing HDD and CDD in cool and warm seasons, it means the pattern of energy consumption in the region has changed. Astara location is included in both of Central Asia and West Asia sub-regions in IPCC AR4. Projection for temperature change in Central Asia sub-region is not in agreement with national and local downscaling results.

Keywords Climate change · Energy consumption · Local application · Astara

1 Introduction

The Intergovernmental Panel on Climate Change (IPCC) published the Fourth Assessment Report (AR4) in 2007 and stated that recent climate change and variation are induced by increases in the atmospheric greenhouse gases (GHGs)

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concentration due to anthropogenic activities. The report includes the results of impact assessments on a wide range of sectors. These assessments have been conducted based on future climate projections, which refer to aspects of the future climate evaluated by Atmosphere-Ocean Coupled General Circulation Models (CGCMs) [1]. In climate change studies context; international, regional and national research institutes according to the available data and scenarios analyze past conditions and will provide projection for the future climate changes [2–4]. Estimates for the likelihood of future climate changes in different country were made based on the projection from the IPCC climate models [5]. Therefore, provided results are different in time scales, scenarios and study areas and may not be adapted precisely. With the set of models showing increasing agreement in their simulations of twentieth-century trends in climate and of projected changes in climate on sub-continental to continental scales, the climate scenarios that were generated seem likely to provide a plausible representation of the types of climatic conditions that could be experienced during the 21st century [6].

2 Methods

Astara forest, from geographical, topographical and climatic points of views is an especial and unique ecosystem (Fig. 1, Table 1). In this investigation, past climate conditions, main climatic factor related to the energy consumption namely temperature and precipitation were considered. Heating degree days, cooling degree days and sunshine hours were analyzed.

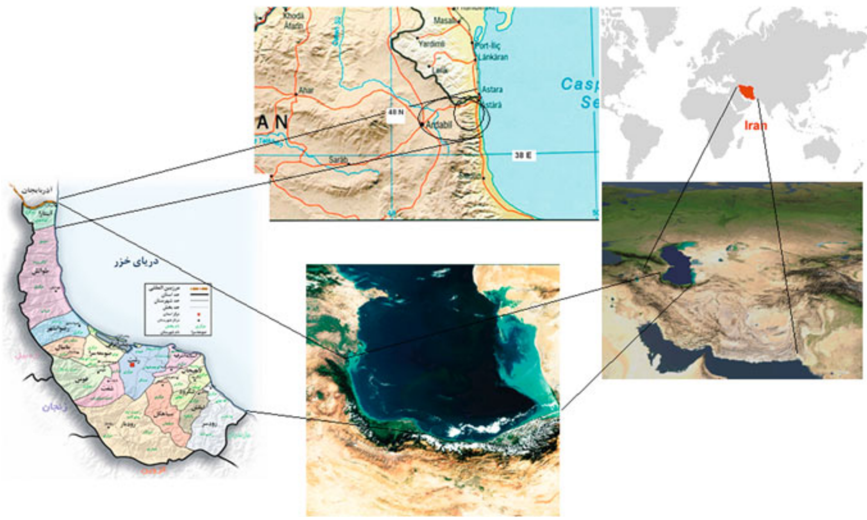

Fig. 1 Astara study location map (maps from different sources)

Table 1 Forest study zone in Astara and location of meteorology stations in Astara and Ardebil

Region/stations	Elevation from sea level (m)	Longitude E	Latitude N	Stations code
Astara chay forest—No. 1	Minimum 0 and Maximum 1,750 m and majority of forest in 100–1,000 m	48 51 45 E and 48 34 E	38 26 30 N and 38 17 30 N	(Region no. 1)
Astara synoptic	−18.0	48 52 E	38 25 N	40709
Astara climatology	+25	48 52 E	38 26 N	
Ardebil	+1,350	48 17 E	38 15 N	

2.1 What are Annual and Monthly Heating and Cooling Degree Days?

The Heating Degree Days (HDDs) and Cooling Degree Days (CDDs) are based on daily temperature observations, with each month having at least 25 records and no less than 15 years of data between [7]. Heating and Cooling Degree Days, which indicate the level of comfort, are based on the average daily temperature. The average daily temperature is calculated as follows:

$$[\text{Maximum daily temperature} + \text{minimum daily temperature}]/2.$$

If the average daily temperature falls below comfort levels, heating is required and if it is above comfort levels, cooling is required. The HDDs or CDDs are determined by the difference between the average daily temperature and the BASE (comfort level) temperature. The BASE values used are 12 and 18 °C for heating and 18 and 24 °C for cooling [7]. In this case, base degrees for heating are 18 °C and for cooling is 21 °C.

Examples 1. If heating is being considered to a temperature BASE of 18 degrees, and the average daily temperature for a particular location was 14 degrees, then heating equivalent to 4 degrees or 4 HDDs would be required to maintain a temperature of 18 degrees for that day. However if the average daily temperature was 20 degrees then no heating would be required, so the number of HDDs for that day would be zero.

2. If cooling is being considered to a temperature BASE of 21 degrees, and if the average temperature for a day was 27 degrees, then cooling equivalent to 6 degrees or 6 CDDs would be required to maintain a temperature of 21 degrees for that day. However if the average temperature was 20 degrees, then no cooling would be required, so the number of CDDs for that day would be zero.

3. In Nebraska-USA one base used for both cooling and heating degrees like: Hot days, which may require the use of energy for cooling, are measured in cooling degree-days. On a day with a mean temperature of 80 °F, for example, 15 cooling degree-days would be recorded (80–65 base = 15 CDD). Cold days are measured in heating degree-days. For a day with a mean temperature of 40 °F, 25

heating degree-days would be recorded (65 base–40 = 25 HDD). Two such cold days would result in a total of 50 heating degree-days for the 2 days period [8].

CDD Cost calculation in USA: Degree days: A degree day gauges the amount of heating or cooling needed for a building using 65 degrees as a baseline. To compute heating/cooling degree-days, it needs to take the average temperature for a day and subtract the reference temperature of 65 °F (18 °C). If the difference is positive, it is called a "Cooling Degree Days". If the difference is negative, it is called a "Heating Degree Days". The magnitude of the difference is the number of days. For example, if your average temperature is 50 degrees for a day in September, the difference of the average temperature for that day and the reference temperature of 65 degrees would yield a −15. Therefore, you know that you are going to have Heating Degree Days that day. Since the magnitude of the difference is 15, you know that you are going to have 15 Heating Degree Days. Electrical, natural gas, power, and heating, and air conditioning industries utilize heating and cooling degree information to calculate their needs [9].

In USA, following formula is using for calculation of HDD cost:

$$\text{HDD monthly cost} = \text{HDD} \times 30\,(\text{days of month}) \times 20\,\text{US\$}$$

To calculate the CDD, take the average of a day's high and low and subtract 65. For example, if the day's average temperature is 80 °F, its CDD is 15. If everyday in a 30-day month had an average temperature of 80 °F, the month's CDD value would be 450 (15 × 30). The nominal settlement value for its month's weather derivative contract would therefore be $9,000 (450 × $20).

To calculate HDD, take the average of a day's high and low temperatures and subtract from 65. For example, if the day's average temperature is 50 °F, its HDD is 15. If every day in a 30-day month had an average temperature of 50 °F, the month's HDD value would be 450 (15 × 30). The nominal settlement value for this month's weather derivative contract would therefore be $9,000 (450 × $20) [10].

- 1 °C = 33.8 °F
- To convert °F HDD to °C HDD: (5/9) × (Temperature in Fahrenheit)
- To convert °C HDD to °F HDD: (9/5) × (Temperature in Celsius).

Note that, because HDD are relative to a base temperature (as opposed to being relative to zero), it is incorrect to add or subtract 32 when converting degree days from Celsius to Fahrenheit or vice versa.

HDD can be added over periods of time to provide a rough estimate of seasonal heating requirements. In the course of a heating season, for example, the number of HDD for New York City is 5,050 whereas that for Barrow, Alaska is 19,990. Thus, one can say that, for a given home of similar structure and insulation, around four times the energy would be required to heat the home in Barrow than in New York. Likewise, a similar home in Los Angeles, California, whose heating degree days for the heating season is 2,020, would require around two fifths the energy required to heat the house in New York City [11].

2.2 Global Projections

IPCC used different models (HadCM3, CSIRO, NCAR-PCM, ECHAM4, CGCM2, GFDL, CCSRNIES) and scenarios (A1FI, A2, B2, B1) to provide climate projection in global, continental and regional levels [12]. According to provided projection by IPCC, changes in precipitation and temperature could be considered in different scales from global to local levels.

2.3 Temperature

Based upon data provided in the map for the changes in surface temperature by IPCC [12], surface temperature in whole Iran except small area in south for the period of 1970–2004 between 1 and 2 °C was increased.

According to the map of geographical pattern of surface warming; projected surface temperature changes for the late 21st century (2090–2099), relative to the period 1980–1999, surface temperature in north of Iran based upon AOGCM and A1B SRES will increase between 3 and 3.5 °C and central and southern part will experience increase of 4 °C and more [12]. While, global mean of temperature depend on scenarios and region will experience of 1.1–6.4 degrees increase which will cause sea level rise of 0.18–0.59 m (source: Table 3.1 SPM, IPCC [12]).

According to the Atmosphere-Ocean General Circulation Model (AOGCM) projections of surface warming; projected surface temperature changes for the early and late 21st century relative to the period 1980–1999, show the multi-AOGCM average projections for the A2, A1B and B1 SRES scenarios averaged over decades 2020–2029 and 2090–2099 (Source: WGI 10.4, 10.8 Figs. 10.28, 10.29, SPM and Fig. 3.2, IPCC [12]), provided by IPCC [12], Iran's surface temperature will increase 1–2 °C for 20 s and 4–5.5 for 90 s. The rates are increasing from B1 to A2 [12].

2.4 Future Climate Projection for Asia Sub Regions

Projected changes in surface air temperature and precipitation for sub-regions of Asia under SRES A1FI (highest future emission trajectory) and B1 (lowest future emission trajectory) pathways for three time slices, namely 2020s (2010–2039), 2050s (2040–2069) and 2080s (2070–2099) was provided by IPCC for seasonal (Table 2) and annual mean (Table 3) [12]. Astara study area is part of both Central Asia and also West Asia sub-regions (Table 2).

With comparison of two sub-regions of Central Asia and West Asia (Fig. 2), which both include and cover Astara region, it could be extracted, that temperature in both sub-regions and based on both scenarios, and in four seasons, and for all tree time slices will increase.

Table 2 Projected changes in surface air temperature and precipitation for sub-regions of Asia under SRES A1FI (highest future emission trajectory) and B1 (lowest future emission trajectory) pathways for three time slices, namely 2020s, 2050s and 2080s (*Source* Table 10.5, [2])

Sub-region	Season	2010–2039				2040–2069				2070–2099			
		Temperature °C		Precipitation %		Temperature °C		Precipitation %		Temperature °C		Precipitation %	
		A1FI	B1	A1FI	B1	A1FI	B1	A1FI	B1	A1FI	B1	A1FI	B1
Central Asia (30 N–50 N; 40 E–75 E)	DIF	1.82	1.52	5	1	3.93	2.50	8	4	6.22	3.44	10	6
	MAM	1.53	1.52	3	−2	3.71	2.58	0	−2	6.24	3.42	−11	−10
	JJA	1.86	1.89	1	−5	4.42	3.12	−7	−4	7.50	4.10	−13	−7
	SON	1.72	1.54	4	0	3.96	2.74	3	0	6.44	3.72	1	0
West Asia (12 N–42 N; 27 E–63 E)	DIF	1.26	1.06	−3	−4	3.1	2.9	−3	−5	5.1	2.8	−11	−4
	MAM	1.20	1.24	−2	−8	3.2	2.2	−8	−9	5.6	3.0	−25	−11
	JJA	1.55	1.53	13	5	3.7	2.5	13	20	6.3	2.7	32	13
	SON	1.48	1.35	18	13	3.6	2.2	27	29	5.7	3.2	52	25

Table 3 Annual mean (four seasons) of projected changes in surface air temperature (°C) and precipitation (%) for West and Central sub-regions of Asia under SRES A1FI (highest future emission trajectory) and B1 (lowest future emission trajectory) pathways for three time slices, namely 2020s, 2050s and 2080s (*Source* Table 10.5, [2])

Sub-region ▼	Annual mean (4 seasons)	2010–2039				2040–2069				2070–2099			
		Precipitation (%)		Temperature (°C)		Precipitation (%)		Temperature (°C)		Precipitation (%)		Temperature (°C)	
Scenarios ▶		A1FI	B1	A1FI	B1	A1FI	B1	A1FI	B1	A1FI	B1	A1FI	B1
West Asia	Mean	6.5	1.5	1.39	1.29	7.25	8.75	3.4	2.22	12	5.75	5.67	2.92
Central Asia	Mean	3.25	(−) 1.5	1.73	1.61	1	(−) 0.5	4.00	2.76	(−) 3.25	(−) 2.75	6.6	3.67

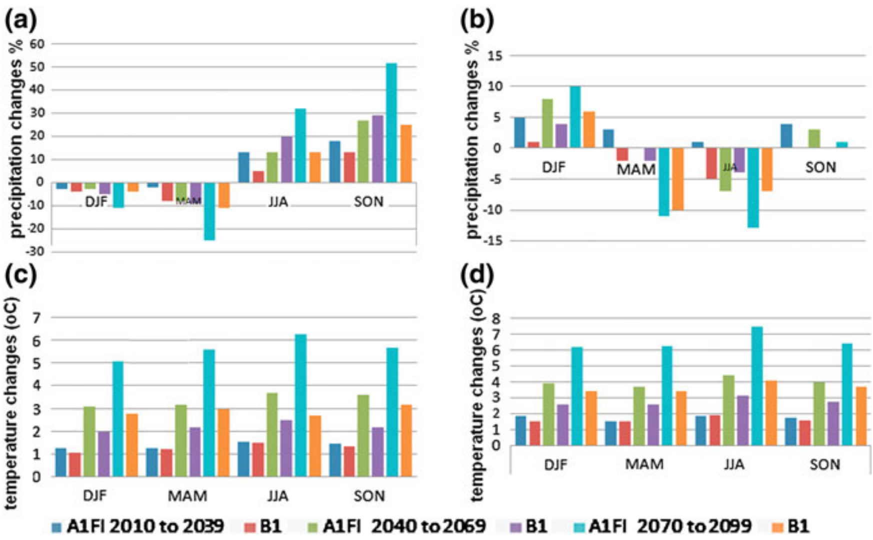

Fig. 2 Comparison of changes in precipitation (*top* graphs a and b) and temperature (*bottom* graphs c and d) in West Asia (*left* graphs a and c) and Central Asia (*right* graphs b and d) sub-regions projected under B1 and A1FI scenarios in four seasons (DJF, MAM, JJA, SON) in three 30 years periods namely 2010–2039, 2040–2069 and 2070–2099, (Graphs produced by author according to the IPCC data)

2.5 Past Climate Changes in Middle East

According to the results obtained from a study with using data for 52 stations in 15 countries including Iran, temperature increased significantly during 1950–2003 [13]. Also some changes observed in the amount of precipitation. Along with the IPCC report, for the West Asia and Middle East region including Iran, according to the climatology stations data, from 1951 to 2003 because of increase of temperature the number of frozen days significantly reduced.

2.6 Climate Projections in Middle East

Future projections for precipitation (%) and temperature (°C) changes has been provided by IPCC in the Middle East region for three time slices, namely 2010–2039, 2040–2069 and 2070–2099. Temperature in all four season according to the different scenarios (A1FI, A2, B2, B1) and using various models (HadCM3, CSIRO, NCAR-PCM, ECHAM4, CGCM2, GFDL, CCSRNIES) will increase (Figs. 3, 4, and 5). Possible precipitation changes could be summarized as follow:

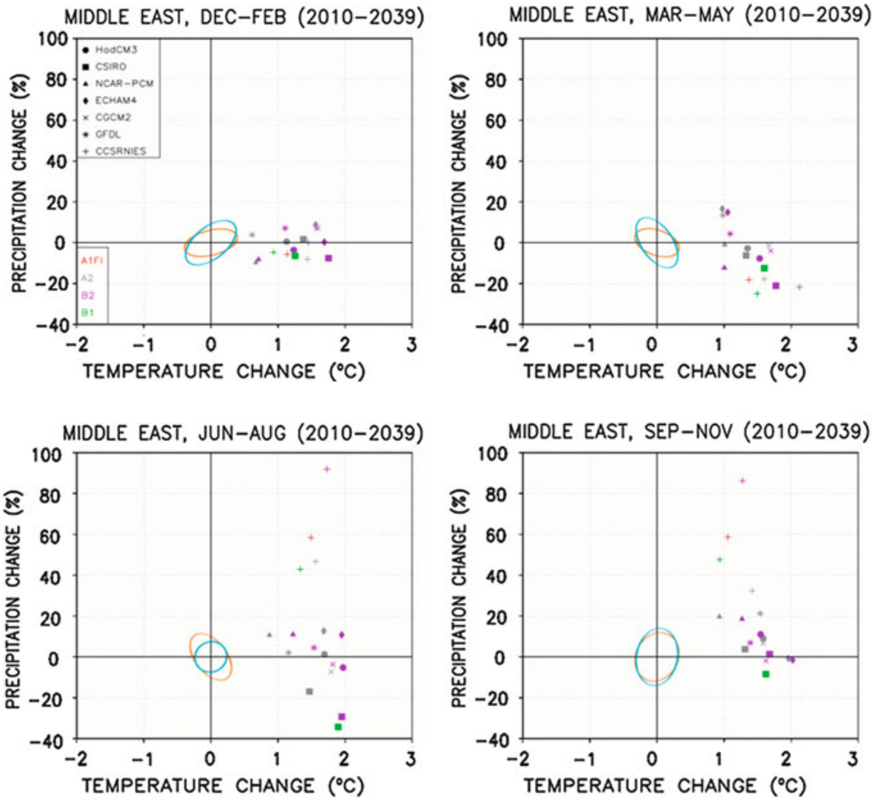

Fig. 3 Future projection of precipitations (%) and temperature (°C) changes in Middle East, for four seasons in 2010–2039 based upon 4 scenarios (A1FI, A2, B2, B1) and 7 models (HadCM3, CSIRO, NCAR-PCM, ECHAM4, CGCM2, GFDL, CCSRNIES) (*Source* IPCC [12]; Tim Carter, IPCC projections expert)

2.7 Past Climate Changes in Iran

According to the recorded data in synoptic stations (IRIMO report) significant increase in minimum, maximum and mean of temperature in most regions observed. In some region like Central, North West, North East of Iran significant decrease observed. In some station increasing pattern and in some other decreasing pattern for precipitation observed.

In Hyrcanian forest region in southern part of Caspian Sea [14] temperature pattern most often increased in last half century [15] and precipitation pattern in the same region mostly showed a decreasing pattern in the same period (Table 4) [15].

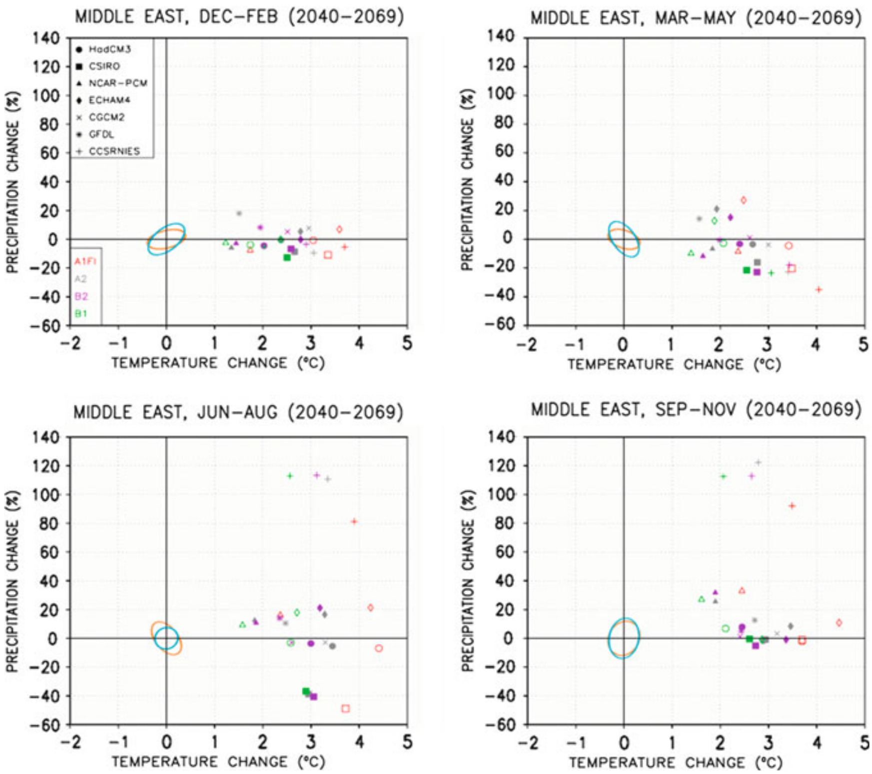

Fig. 4 Future projection of precipitations (%) and temperature (°C) changes in Middle East, for four seasons in 2040–2069 based upon 4 scenarios (A1FI, A2, B2, B1) and 7 models (HadCM3, CSIRO, NCAR-PCM, ECHAM4, CGCM2, GFDL, CCSRNIES) (*Source* IPCC [12]; Tim Carter, IPCC projections expert)

Changes in temperature and precipitation patterns could cause climate conditions change and have impacts on forests, rangelands and deserts ecosystems [15].

2.8 Past Climate Changes in Astara

Past climate condition in the region analyzed by consideration of main climatic factors such as temperature and precipitation in synoptic and climatology stations. Also parameters like humidity and wind fluctuation were investigated. Two important factors, heating degrees and cooling degrees, together with sunshine hours in Astara, were considered. Climatology and synoptic stations data were for a time period of 40 and 18 years respectively.

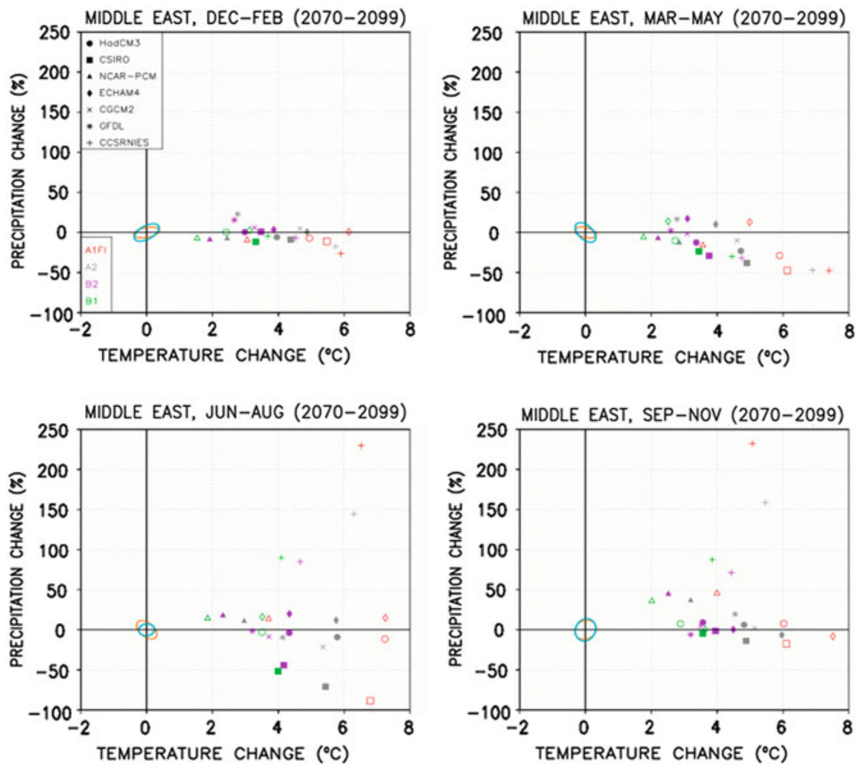

Fig. 5 Future projection of precipitations (%) and temperature (°C) changes in Middle East, for four seasons in 2070–2099 based upon 4 scenarios (A1FI, A2, B2, B1) and 7 models (HadCM3, CSIRO, NCAR-PCM, ECHAM4, CGCM2, GFDL, CCSRNIES) (*Source* IPCC [12]; Tim Carter, IPCC projections expert)

Table 4 Trend of temperature and precipitation changes in last 50 years of Caspian region [15]

Station (year)	Precipitation change (mm)		Temperature change (°C)			
			Minimum	Maximum		Mean
	Increase	Decrease	Increase	Increase	Decrease	Increase
Rasht (49)	56.4		2.45	0.08		1.28
Anzali (54)		509.4	2.10		1.18	0.40
Baboulsar (54)	184.6		1.80	1.10		1.44
Gorgan (53)		55.6	0.11	0.31		0.09

Precipitation pattern in last 40 years in Astara with annual changes were studied, (126.17 mm mean of 40 years of climatology and 1,378.81 mm mean of 18 synoptic stations). Trend of precipitation changes in Astara has an increasing rate.

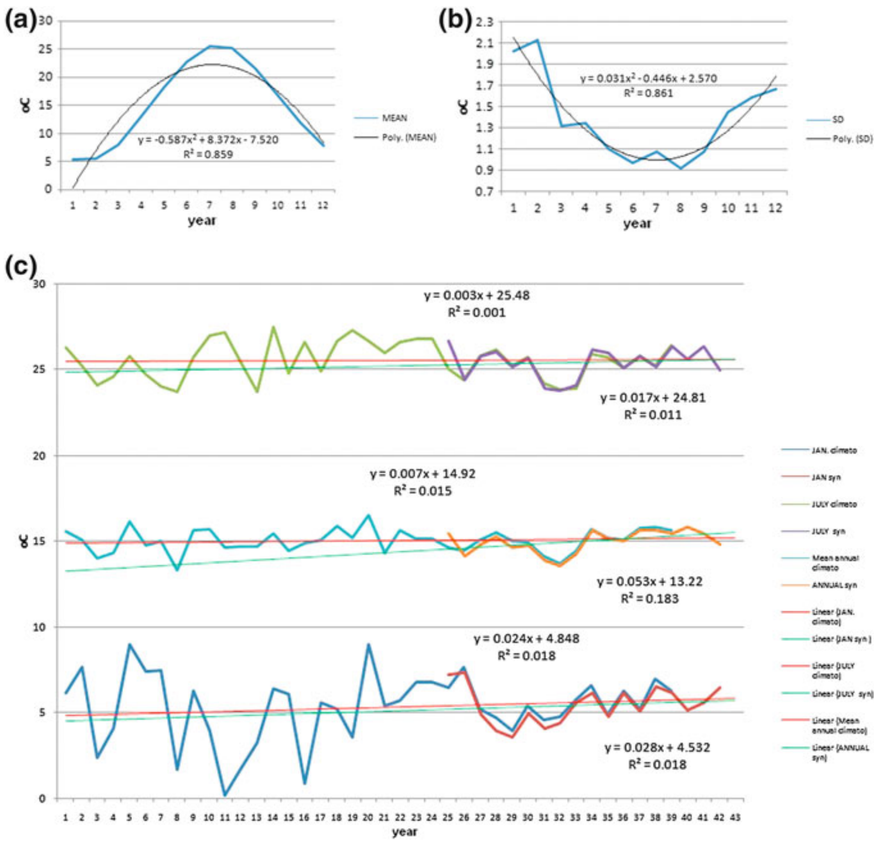

Fig. 6 Past changes of temperature in Astara. **a** Mean of daily average (monthly) temperature (*top left*). **b** Standard deviation of mean of daily average (monthly) temperature (*top right*) in Astara climatology station, 1961–2000. **c** Mean of daily temperature of January (*bottom*), July (*top*), and annual mean (*middle*) in Astara climatology station (+25 m), 1961–2000; and Synoptic station (−18 m), 1986–2003 (*bottom*)

In Fig. 6, past changes in temperature pattern in two climatology (mean of 15.09 °C in climatology and 15.02 °C in synoptic stations) (Fig. 6a), and synoptic (Fig. 6c), stations are presented, adaptation of data in cold (January) and warm (July) months and annual mean (Fig. 6c) give high level of confidence of available data. Mean annual daily temperature the same as mean annual minimum temperature has an increasing pattern, while mean annual maximum temperature has a decreasing trend. With attention to the differences of elevation between two stations, small different of trends are interesting. Standard deviation of mean daily average (monthly) temperature in Astara’ climatology station showed that, temperature fluctuation in cold months in the region are much higher than warm months (Fig. 6a, b).

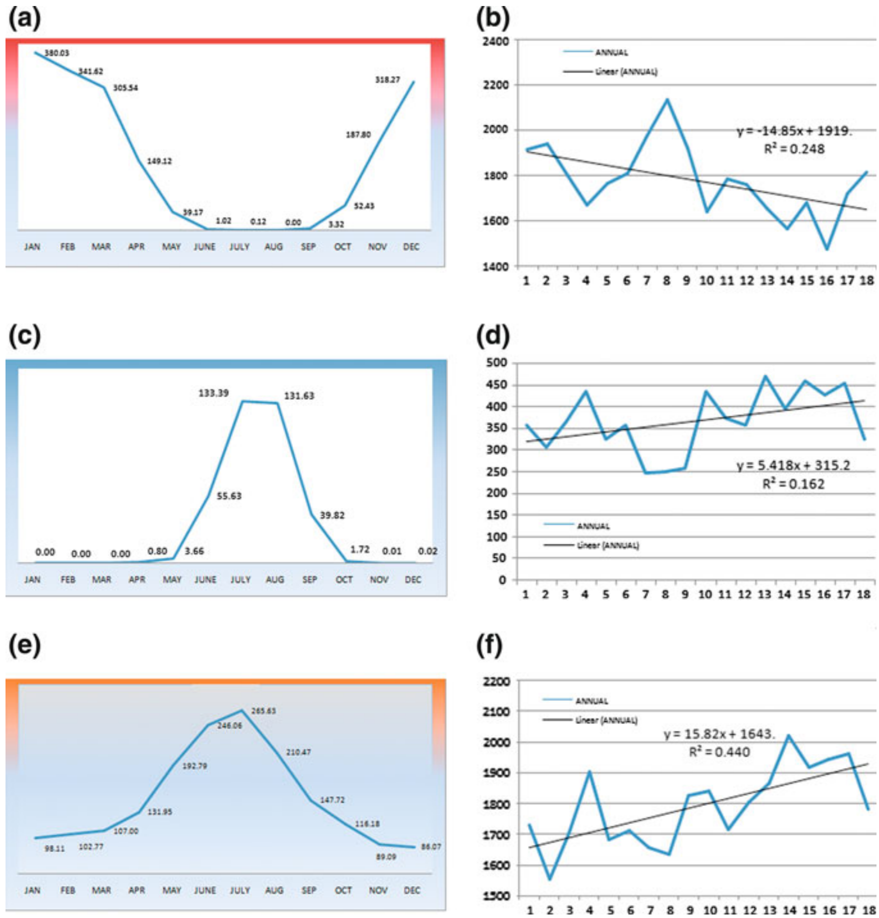

Fig. 7 Astara synoptic station, 1986–2003, total monthly mean. **a** Mean heating degrees °C (based upon 18 °C). **b** Linear trend of mean heating degrees, °C. **c** Mean cooling degrees, °C (based upon 21 °C). **d** Linear trend of mean cooling degrees, °C. **e** Mean monthly total sunshine (hour). **f** Linear trend of total annual sunshine (hour) (*Source* [15])

Changes in humidity trends and wind fluctuation in Astara are presented separately [16].

Heating degrees trend decreased in last 18 years (Fig. 7a, b), while in the same time cooling degrees trend increased (Fig. 7c, d), and this is in the same line of increasing sunshine hours (Fig. 7e, f), and total of these three factors certified warming trend in the Astara region.

2.9 Investigation on Climate Change Projections in Astara and Ardebil

Based on IPCC data and models in global scale and national data and information, downscaling maps in national and regional scales (Fig. 8) produced [17]. National and regional climate projections have some agreement and disagreement with global, continental region and sub-regions projections.

According to the downscaled outcome maps, regional distribution of mean precipitation in future (2010–2039) comparing with the past (1976–2005), Astara region between 1 and 8.7 mm (mean of +4.85 mm) will increase (will reach to 1,265.02 mm according to the climatology and 1,383.61 mm according to the synoptic stations). While in near western part of Astara in the way to Ardebil, a small area will face with reduction of 5.8–23.3 mm (mean of −14.55 mm) rainfall.

Mean precipitation of Gilan province for the time slice of 1976–2005 was about 1,569.9 mm and projected for the period of 2010–2039 precipitation will increased by 10.63 % (amount of +167 mm) and will reach to 1,736.9 mm.

Based on the same results, projections for future, the number of wet days in Astara region between 0 and 3 days will reduce, but in the same climatic area

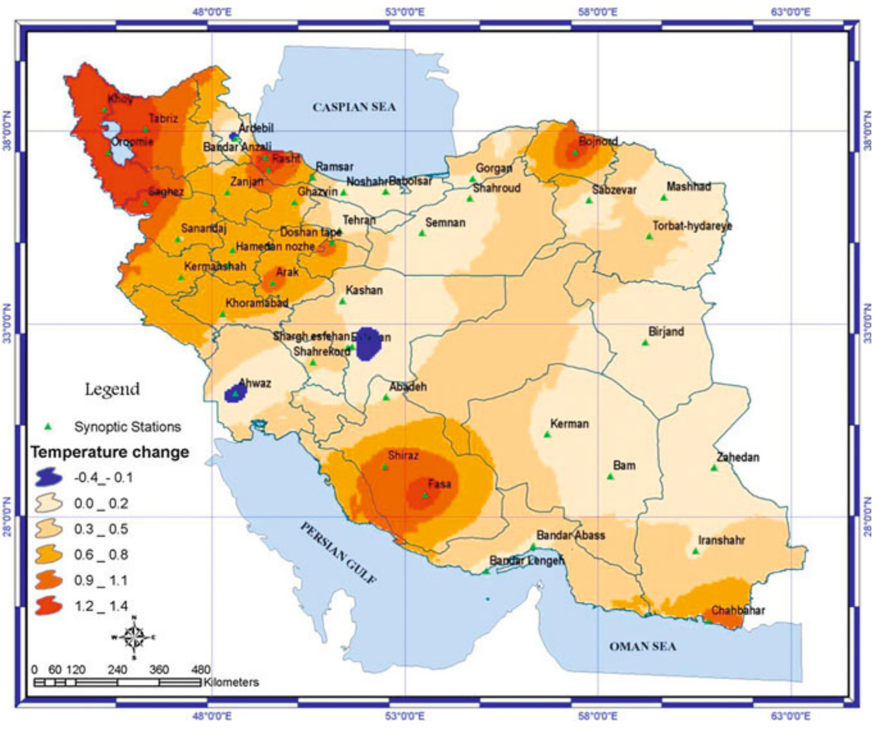

Fig. 8 Mean different distribution of temperature in 2010–2039 compare with 1976–2005 according to the downscaling ECHO-G model [17]

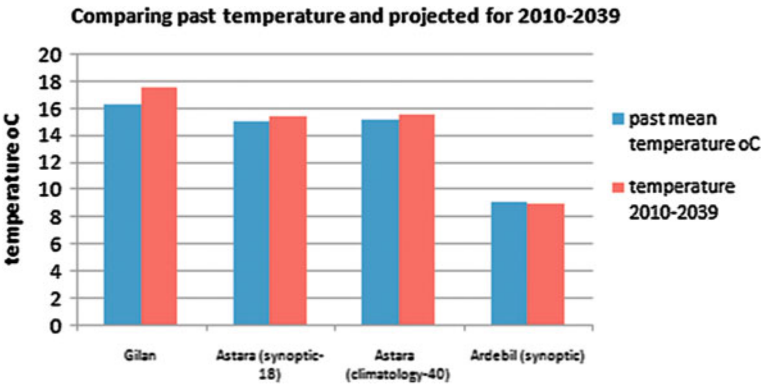

Fig. 9 Temperature changes in projected period (2010–2039), comparing with time slice of (1976–2005), in Gilan province, Astara (synoptic and climatology stations) and Ardebil forests

(west southern) will face with 1–7 days increase of wet days. Mean of dry days will increase between 4 and 9 days. Also temperature in study area of Astara between 0.3 and 0.5 °C (mean of +0.4 °C) will increase (will reach to 15.49 °C according to the climatology and 15.42 °C according to the synoptic stations) (Fig. 8).

Mean temperature of Gilan province for the time slice of 1976–2005 was about 16.2 °C and projected for the period of 2010–2039 temperature will increased by 1.3 °C and will reach to 17.5 °C (Fig. 9). It is needed to be noted that: based on downscaling produced maps in national and regional scales for 1979–2005, Astara region is in a category with temperature of 9.1–12 °C. While based upon my data calculation obtained from climatology and synoptic stations mean temperature is about 15.02 °C (Fig. 9). Probably this rose from using Ardebil synoptic station with mean of temperature of 9.1 °C for downscaling program.

Based on the same results, projections for future, the number of hot days in Astara region between 5 and 10 days will increase, and the number of freezing days will decrease between 0 and 5 days.

2.10 *Climate Condition in Astara Especial Forest Ecosystem (District 1)*

For assessment of past climatic condition of Astara region data from climatology and synoptic stations were considered (Table 1 and Figs. 6 and 7). To analysis of higher elevation changes, data from nearest station of Ardebil has been used. Ardebil station which is in high mountain in the west part of Astara, despite of difference in elevation (1,325 m) which cause difference in temperature (5.2–8.3 °C), have good correlation in trend of temperature changes (Fig. 10). A detail of stations' characteristics is presented in Table 1.

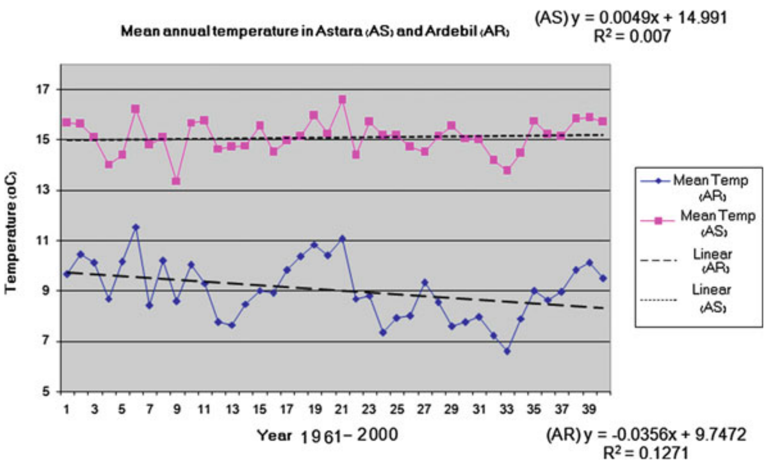

Fig. 10 Mean annual temperature in Ardebil and Astara stations

In 40 years ago, in Astara region with each 252.95 m going upward, temperature was reducing by 1 °C. At the present condition (year 2000) because of increasing trend of temperature in Astara and decreasing trend in Ardebil with changing elevation of 193.04 m temperature will reduce by 1 °C.

Climatology curves (amberotermic graphs) for different stations in Caspian region including Astara stations which are located in southern part of Caspian Sea from west to east were considered (Fig. 11). In produced graphs climatic differences clearly can be distinguished from wet in west to drier condition in the east. To this extend, can be conclude that main difference in climatic conditions in Caspian region raise form differences of the amount of precipitation, and temperature has a secondary effect.

Geographical situation in Astara district. Astara district is situated on western part of Albourz Range Mountain, with north-south direction. Therefore forest covers are on the west-east slops. This region is among those limited areas which from west are affected from Mediterranean (European) climate and from east north from Caspian currents.

Forest conditions and topography of Astara district. Total area of Astara district is about 22,481.25 ha including 18,328.13 ha forests (total Gilan province 511,306 ha), 545.31 ha cool condition rangelands (total Gilan province 467,167 ha), and 3,607.81 ha of farmlands and villages areas. 60 % of forest natural regeneration is from seed sources and 40 % from seeds and copies [18]. Astara forest canopy classification according to the volume is from less than 100 to more than 350 m^3/ha. Astara, land classification of forest area according to the volume per hectare is about 85.92 up to 350 m^3/ha and about 14.07 % with more than 350 m^3/ha. Mean volume per hectare is about 157.17 ± 8.8 (m^3).

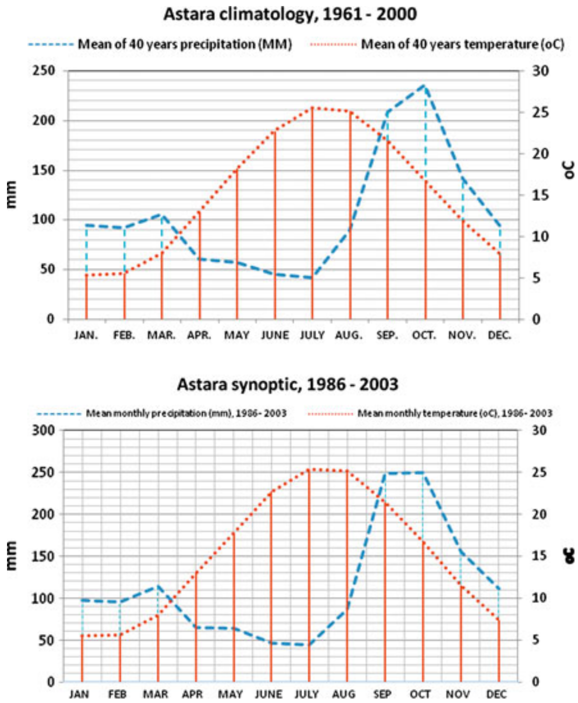

Fig. 11 Climatology curves (amberotermic graphs) for Astara stations in Caspian region for climatology (1961–2000) (*top*) and synoptic (1986–2003) (*bottom*)

3 Results

3.1 Precipitation Changes

Last 40 years of recorded climatology station's data showed an increasing trend in Astara total annual precipitation. Seasonal distributions of rainfall in last 40 years are: fall (Oct., Nov. and Dec.) 38 %, summer 26 %, winter 23 % and spring 13 %. It means two seasons of autumn and summer received main percentage (64 %) of annual precipitation. Warm seasons (summer and spring) received 39 % of annual precipitation while cool season (autumn and winter) received 61 %. In above mentioned time slice October received maximum (240 mm) and July minimum (40 mm) amount of rainfalls.

3.2 Temperature Changes

Based on recorded data in climatology station, in Astara during last 40 years differences of daily maximum and minimum of temperature as a 2nd degree curve first showed increasing and then decreasing patterns. Trend on linear pattern showed a little decrease.

Trend of average daily mean temperature (monthly), showed increasing from January, and in July–August reach to its warmest position and then decline to minimum amount in December (Fig. 6a). Data approved that temperature fluctuation changes in cold months are greater than warm months. Standard deviation (SD) of temperature in cold months is about 2 °C and in warm months about 1 °C (Fig. 6b). Changes in daily mean temperature (annual) in Astara station in last 40 years as linear and 2nd degree curves trends showed increasing patterns. According to the recorded data, mean of annual minimum temperature in cold month (January), warm month (July) and annul mean had increasing trends (Fig. 6c). Mean of annual maximum temperature in warm month (July), slightly in cold month (January), and for annul mean had decreasing trends (Fig. 6c). Hot days which started from May, continue up to October and reach its maximum values in July–August showed a decreasing trend both in linear and 2nd degree curves. According to the data recorded in the synoptic station, mean annual temperature, January and July temperature (Fig. 6c), had increasing patterns in last 18 years.

Freezing days which started from November, continue to May next year, and reach its maximum values in January and February presented decreasing trend both in linear and 2nd degree curves.

Heating Degree Days (HDD) with base temperature of 18 °C reduced in last 18 years (Fig. 7a, b). HDD in January which is cold month also reduced. In the same time Cooling Degree Days (CDD) increased (Fig. 7c, d). CDD in July which is warm month also increased. This is in the same line of increasing the number of sunshine hours in the same time slice (Fig. 7e, f).

Temperature changes recorded for 18 years in synoptic station for cold season (January), warm season (July) and annual mean are in a harmony with last 18 years of changes which recorded for 40 years in climatology station. This can be interpreted of high level of confidence for the precise data (Fig. 6c).

3.3 Other Climatic Factors Changes

As consequence of temperature and precipitation changes, other climatic factors also will change. Relative humidity and thunder and storm are presented and discussed elsewhere [15, 19].

4 Discussion

As a fact, Iran is located on dry belt of the earth and its vegetation cover and forest ecosystems are valuable resources [20, 21]. Also there are limited of adequate research on climate change [2]. So consideration of past climatic changes and investigation on future climate projection have very important role in development

Table 5 Comparison of past changes on Astara temperature in different scales

Scale of study	Temperature (past)
Global	1–2 °C increase (1970–2004)
Asia	
Central Asia	
West Asia	Increase (1951–2003)
Middle East	Increase (1951–2003)
National	
Gilan	Increase
Ardebil	Decrease
Astara	Increase

programs [16, 22]. Even though, the changes in temperature and precipitation are consistent with the other factors [5].

Assessment of all data, document and reports on the past climate changes in the region confirmed that, temperature in last half century increased (Table 5). Studies on the past temperature changes related to the Astara region in global, continental, national and local levels do not have significant differences, except small variation in seasonal changes. Temperature changes had a reducing trend in Ardebil region, which is in the high mountains of western part of Astara. Projections for future temperature changes in Astara are mainly documented for increasing temperature and its amount are different based on employed scenarios (Table 6). Elsewhere, research outcome show that all the IPCC scenarios have similar patterns and only differ in amplitude [23]. From time slices point of view, longer time will experience higher degrees of temperature changes. Astara is located in both Central Asia and West Asia sub-regions in IPCC assessments [2]. Based on the projection for Central Asia sub-region, the region will face with higher degrees of temperature changes, which this is not in the same line as national and local downscaled projections. Downscaled projections in local level prove that Gilan province as whole will have higher degree of temperature changes than Astara which is in the western part of the province, and going more westwards, which is mountainous area of Ardebil; this will change to reduction of temperature. Downscaling and projection of seasonal extreme daily precipitation has been studied elsewhere [24].

Precipitation trend in Middle East region decreased in last half century with some seasonal increase. Precipitation in Gilan province decreased in Anzali station and increased in Rasht station, precipitation showed a seasonal changes pattern (Table 4). Astara experienced in increase of precipitation for last 50 years with some reduction in seasonal levels. Based on global projection with A1B scenario in time period of (2090–2099) Astara which is in the western part of Caspian Sea, in winter season despite of reduction of precipitation in west part of the country, will have 10 % increase of rainfall, and in summer will face with 20 % reduction of precipitation, which these are in the same line of IPCC projection for the Central Asia sub-region and against its projection for the West Asia sub-region. Projections for Middle East region and downscaled projection in national and local levels are more or less in harmony with these projections.

Table 6 Comparison of future projections changes on Astara temperature in different scales

Scale of study	Temperature (projections)
Global	3–3.5 °C increase in 90s (2090–2099, scenario A1B)
	1–2 °C increase in 20s (2020–2029, scenarios B1, A1B, A2)
	4–5.5 °C increase in 90s (2090–2099, scenarios B1, A1B, A2)
Asia	
Central Asia	Increase (in 4 seasons, 2 scenarios—B1, A1F1-, 330 years time slices from 2010 to 2099) From 1.6 to 6.6 °C increase
West Asia	Increase (in 4 seasons, 2 scenarios—B1, A1F1-, 330 years time slices from 2010 to 2099) From 1.2 to 5.6 °C increase
Middle East	Increase up to 2 °C (2010–2039)
National	
Gilan	Increase 1.3 °C (2010–2039)
Ardebil	Decrease 0.1 °C
Astara	Increase 0.3–0.5 °C (2010–2039)

It seems for future projection on precipitation changes in the Astara region it is possible to benefit of global, Central Asia sub-region, Middle East and downscaled national level projections.

5 Conclusion: Astara Climate Change and Energy Balance

Energy balance can be considered from climate change points of views. Energy optimization solution also could be considered, as it has been studied in Nigeria for a given GSM Base Station Site and location in rural area [25].

The theoretical model even could be improved for the reduction in energy consumption, as it has been studied in Greece for the improvement of building energy performance (17). Heating degrees, cooling degrees and total sunshine are factors which are effective on energy consumptions. These data are recorded in Astara synoptic station in period of 1986–2003.

In Astara case study, total monthly heating degrees recorded in winter season reached up to 380.03 °C (January) which is about 12.66 degrees per day. In the same time cooling degree is zero and total monthly sunshine is 98.11 h (January) which is about 3.27 h per day.

Total monthly cooling degrees recorded in summer season reached up to 133.39 °C (July) which is about 4.44 degrees per day. In the same time heating degree is about zero and total monthly sunshine is 265.63 h (July) which is about 8.85 h per day.

Total annual heating degrees in 18 years ago in Astara station was 1,919 °C and total annual cooling degrees was recorded as 315 °C and total annual sunshine was about 1,643 h. During this 18 years period of time trend of mean annual temperature increased from 14.51 °C by about 0.954–15.46 °C.

This warming caused decrease of total annual heating degrees by about 267.3 °C per year down to total annual of 1,651.7 °C. Total annual cooling degrees increased by about 97.38 °C per year up to total annual of 412.38 °C. Total annual sunshine in creased by about 284.76 h per year up to total annual of 1,927.76 h.

Decrease of 267.3 °C per year of heating degrees and increase of 97.38 °C of cooling degrees gives a difference of total of 169.92 °C (267.3–97.38 =169.92 °C) of energy saving in 18 years time.

The price of weather derivatives traded in the summer are based on an index made up of monthly CDD and HDD values. The settlement price for a weather futures contract is calculated by summing a month's CDD and HDD values and multiplying by $20.

$$\text{HDD monthly cost} = \text{HDD} \times 30\,(\text{days of month}) \times 20\,\text{US\$}$$

In Astara case study a difference of annual total of 169.92 °C calculated for energy saving in 18 years time. If we want to calculate cost as a rate of $20 similar to USA conditions, after converting Celsius to Fahrenheit, it would be about $6,117.12 as follow:

$$169.92 \times 9/5 = 305.856$$
$$305.856 \times \$20 = \$6,117.12$$

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