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Thermal Comfort in Rural Habitats of Mountainous Areas (Case Study: Roodbar, Iran)

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Keywords

Thermal comfort, Mountainous habitats, Predicted mean vote, Predicted percentage of dissatisfaction.

Abstract

Cold and temperate, cold and semi-arid climate due to the short summer life, low relative humidity, distance from the sea and mostly the environment's temperature under the comfort zone, requires more clever design in solving the problem of heating supply rather than the other climates. The present study evaluates a case with such climate in the northern Iran. First, several parameters such as temperature, relative humidity, sun radiation status and wind condition in the understudy area have been provided using the climate consultant software in a table format. In June, July, August and September, the areas are placed in the comfort range while in the rest of the year from October to May they fall below the comfort level which need using the active and inactive heating equipment. Then using Design Builder software, the building modelling has been investigated and thermally analyzed from various aspects. In the following, the predicted percentage of dissatisfaction and predicted mean vote graphs have been plotted and assessed for the different seasons and months which gave the same results for the comfort range. Also, these figures show the physiological sensation in terms of an intense cold stress for the months December to March. However, for June to September, they show the moderate heat stress. Field surveys and questionnaires also confirm that these months were quite desirable for the residents and did not need any heating equipment. The results of Design Builder software have been compared with those recorded by the data logger during the same timeframe and close agreement has been achieved.

1. Introduction

Thermal comfort is one of the most important aspects of the user satisfaction and energy consumption in the buildings [1]. Fanger in 1972 [2] developed the most prominent indexes of thermal comfort so called the predicted mean vote (PMV) and predicted percentage of dissatisfaction (PPD) which have been applied in the international organization for standardization (ISO) 7730 (BSI, 2006) [3] and American society of heating, refrigerating and air-conditioning engineers (ASHRAE) standard 55 [4].

Since the general standards are not appropriate for all the climate conditions and many influential criteria are effective in the thermal comfort, a huge number of studies have been carried out in recent years by researchers in different climates and locations. In one of the latest studies which carried out in 2016, Manu et al. [5] performed a comprehensive investigation for proposing an India model for adaptive comfort (IMAC) according to the field surveys administered in 16 buildings in three seasons and five cities, representative of five Indian climate zones. Furthermore, using the instantaneous thermal comfort surveys, a total of 6330 responses were gathered from office buildings with naturally ventilated, mixed mode and air-conditioned systems. As a result, Indian offices' occupants were adapted to the naturally ventilated systems more than ASHRAE and EN models. Based on the proposed model (IMAC), the neutral temperature of the buildings varies from 19.6 to 28.5°C for 30-day outdoor mean air temperatures ranging from 12.5 to 31°C in the naturally ventilated case. This study presented a single adaptive model for the first time for mixed mode buildings together with the claim of its validity for both naturally ventilated and air-conditioned modes of operation in the building, with neutral temperature varying

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from 21.5 to 28.7°C and outdoor temperatures within the interval of 13–38.5°C. For buildings with air-conditioners, Fanger's static PMV model consistently overestimated the sensation on the warmer side of the 7-point sensation scale.

Bhattacharyya and Saha in 2014 conducted a study on the eastern areas of India [6]. They arrived at the fact that using the shading devices (with or without glazing) in the eastern India is desirable as people are suffering from the intense sunlight and higher humidity. Further to these, an investigation has been made in this study on the variety of raw materials for the manufacture of shading devices, the directions of the inputs, windows of buildings and their size.

Ioannou and Itard in 2014 [7], presented the results of a Monte-Carlo sensitivity analysis on the factors affecting the PMV comfort index. Their achievements clarified that the most influential parameters for the PMV are the metabolic activity and clothing, while, the thermostat is in the secondary significance level.

In a novel work by Hooi et al. [8], an adaptive thermal comfort equation has been developed for naturally ventilated buildings in hot–humid climates. In this research, the statistical meta-analysis of ASHRAE RP-884 database has been implemented covering several climatic zones. The data were precisely categorized into the three climate groups including hot-humid, hot-dry, moderate and analyzed separately. The obtained results revealed that the adaptive equations for hot-humid and hot-dry climates were analogous with approximate regression coefficients of 0.6, which were nearly twice those of ASHRAE, European standards 55 and EN15251, respectively. The novel equation which has been developed in this study can be applied to the tropical climates and hot-humid summer seasons of temperate climates.

Nguyen et al. [9] presented a detailed procedure for developing an adaptive comfort model applicable to the south-east Asia. The meta-analysis employed here was based upon many observations from the field surveys conducted on this region. This study illustrated the significant effect of the Griffiths constant on the foundation of the adaptive comfort equation and presented an appropriate value as well. The generated model is applicable to the naturally ventilated building under hot-humid conditions of this part of the continent. Furthermore, the capability of the extended PMV-PPD model for the hot and humid conditions was examined.

Implementing the ASHRAE RP-884 database, Farghal and Wagner [10] classified the naturally ventilated buildings into seven climatic zones among which significant differences were noted in thermal neutralities. In their analysis, only a mean neutral temperature has been used for each building and they did not include the raw database values. In addition, they accomplished field surveys in Cairo and presented a steeper adaptive comfort equation for hot-dry climate than those via the existing adaptive standards ([3, 4]) and avoided considering the other climatic zones.

Hens [11] comprehensively studied the thermal comfort in office buildings for two case studies. For both cases, the results of the comfort enquiry are compared with those obtained via the measurements. The enquiries provided numbers of dissatisfied at a PMV zero that were much higher than the curvature of the standard of PMV/PPD. However, the substituted measurements demonstrated that in one of the cases mentioned comfort complaints could be expected in summer.

Ahmed [12] investigated the thermal comfort status in the urban areas of the tropical environment of Dhaka, Bangladesh. His achievements were according to a survey conducted on a large number of randomly selected people from urban areas. He concluded that the ratio, internal and external environments must be taken into consideration. He also measured the temperature and humidity in July and August and for different areas of the city including those with low density of buildings and the rest with high density of residential and industrial constructions. According to this study, a microclimate comfort provision is related to the urban design (geometry, orientation of buildings, building materials, plant mass and water bodies) and energy saving.

In 2005, Wang [13] investigated the environmental warmth and thermal comfort in the residential houses located in the northern China during the winter 2000-2001. The questionnaires and information have been collected for 120 participants and the indoor climate analyzer has been implemented for recording the indoor temperature. The results clarified that men are less sensitive to the temperature changes than the women. Several other researches have been performed dealing with the thermal comfort problem around the globe such as the studies conducted by Dedear and Fountain [14], Cena and Dedear [15] and Xavier and Roberto [16] on tropical and temperate climate.

However, the number of field studies associated with very diverse climates of Iran is scarce. Heidari and Sharples [17] described the two filed studies on the thermal comfort in Ilam city, located in western Iran. The first study consisted of two short-term surveys carried out during two climatically extreme periods (a hot summer and a cold winter) in 1998. The second one consisted of a long-term survey for which the data have been gathered throughout the whole of 1999. Both studies have dealt with naturally ventilated buildings. This study further gives some comparative analysis between the findings from the short and long-term studies. The neutral temperatures for the hot season were estimated as 28.4 and 26.7°C from the short and long-term studies, respectively. These values for the cold season were calculated as 20.8 and 21.2°C from the short and long-term neutral temperatures, respectively. As revealed by the achievements of this study, people could achieve comfort at higher indoor air temperatures compared with the recommendations of international standards such as ISO 7730.

From the latest works concerning with the thermal comfort, one can cite the thermal comfort investigation in Vakil Bazaar in Shiraz using the PMV and PPD methods by Najafi and Najafi [18]. They collected the required data in a field manner. After examining the obtained results of PMV and PPD, they founded that the thermal comfort in the winter has been without any cold stress and thermal sensitivity from the aspect of the physiological stress degree and only less than 15% of the users were dissatisfied with this location.

Knowing that Iran is full of energy and fossil fuel resources which will come to an end as a result of the ever increasing consumption of these non-renewable resources. Despite Iran's rich energy resources, it is not possible to make a balance among the usage amount of all areas. In different regions such as the mountainous areas, there is a need to create large-scale transmission and distribution networks, which in some cases, in addition to spending a lot of money, will destroy forests, various plant and animal species. Therefore, the lack of minimum facilities for residents of such areas causes the forced migration to the edges of cities, evacuation and destruction of their settlements. The use of modern solar technology in the architecture of these settlements for providing the lighting and heat would be more expensive. In this regard, the present study concerns with investigating the thermal comfort territory by case studying the rural settlements located in the mountainous areas of the village of Baravard of Rudbar city in Guilan.

In order to assure the correct energy analysis in these settlements, the effective climatic conditions on the architecture of these settlements are initially investigated. To precisely recognize a climate and analyze it, there is a need for hourly or at least daily climatic data. In order to better perceive the climate conditions required in the design, one must consider various effective climatic parameters on the thermal behavior of the building. The tools have the required capability when they display the climatic factors in communication with each other and in relation to the desired thermal conditions. The most important of them include the air temperature, relative humidity, wind, psychrometric charts, solar and shade plots and temperature timetable graph [19].

2. Methodology

In this article, firstly, using the climatic consultant software and based upon the ASHRAE standards, the city of Rudbar is analyzed in order to determine the thermal comfort conditions. By implementing the Design Builder 5.0 software concluding the climatic data of 1992-2002 which improved by US department of energy, the building's modeling was performed from a variety of aspects such as building's physics (building's materials), building's architecture, cooling and heating and lighting systems. It is worthwhile to mention that the available data in Design Builder software include the 10-year average leading to 2002. In order to plot the PMV and PPD graphs of different seasons, the effective parameters on the thermal comfort including the average relative humidity, radiant average temperature, effective temperature, activity and coverage amount and average wind speed were used.

Then, the results were compared with the data and statistics of the Guilan meteorological organization and finally we were able to determine in which seasons of the year, the area's climatic design falls in the area of thermal comfort and at what times it would be necessary to have heating systems along with the use of a design compatible with the climate.

3. Location and Climatic Zoning

Guilan province is limited to the Caspian Sea and the independent countries of Azerbaijan from the north, Zanjan, Qazvin provinces and the Alborz and Talesh Mountains from the south, Mazandaran province from the east and Ardabil province from the west and northwest. This province has an area of over 14000 square kilometers. The minimum distance from the Caspian Sea is about 3 kilometers (in Havigh) and the maximum one is about 50 kilometers (in Emam Zadeh Hashem). It extends from the northwest to the southeast, 235 km and its width ranges from 25 to 105 km. The Alborz and Talesh Mountains with an average height of 3000 m are drawn like a wall in the west and south of Guilan, and this area, other than the Manjil valley, has no other way to the Iranian plateau. The geographical location of this province is from 48°30′ to 50° 35′ east longitude and 35°36′ to 28°38′ north latitude [20].

Guilan province along the southern coasts of the Caspian Sea is the northernmost province of Iran which manifests a diverse architectural image full of mysteries and symbols in terms of its villages. The thing that made the architecture of this area special is the presence of the coast of the Caspian Sea, its remoteness and proximity to it, which has influenced the culture, social interactions, economics and livelihoods and architecture further to the climatic consequences.

The plain and coastal zones due to their proximity to the Caspian Sea and the significant role of humidity, rainfall and the low temperature difference between night and day and the relative moderation of the hot summer and cold winter, meet special variations and arrangements and as the distance increases, the humidity decreases as a consequence. The replacement for this is the greater temperature difference during the whole day and also the coldness in the higher regions which itself creates a new design for the architecture of the mountainous areas [21].

Frequent surveys have been conducted on the climatic zoning in Guilan province using the Koppen- De Martonne and revised De Martonne methods. These methods are based upon two parameters including the temperature and rainfall. In this regards the 30-year statistical data is considered (except the time frame 2010-2011 in which there was water lackage).

The topographic units' climates are categorized according to the plain and coastal areas (less than 100m), foothills (100-700m), mountainous (with average height of 700-1500m), high mountainous (1500-2500m) and very high mountainous (2500m and higher). Guilan province has 6 (very humid to dry) and 13 (very temperate humid to cold dry) different climates according to the De Martonne and revised De Martonne, respectively. However, based on the Koppen method, it has two different climates (humid and steppe). Very humid, very temperate humid and humid climates in the above mentioned process meet the largest outspread of 80%, 57% and 98%, respectively [22]. As would be observed from the results, the plain and coastal areas which have been ignored from the present study have the steady climate, while, the mountainous ones with medium height (foothill) have the highest climatic varieties in the southern parts of Guilan. In Table 1, the cities of Talesh and Rudbar are classified according to the zoning of De Martonne, Koppen and revised De Martonne methods [22].

Table 1. Classification of areas according to the different zoning methods [22]

Zone	Revised De Martonne	De Martonne	Koppen
Rudbar	Semidry temperate, Mediterranean Cold	Semidry	humid

4. Effective Parameters on the Thermal Comfort

Six parameters including the radiation temperature, humidity, air flow, air temperature, activity rate and clothes have a direct influence on the response of the human being to the thermal conditions. The temperature and humidity data are the most important ones [4]. Furthermore, wind flow itself lead to the heat exchange between the body and environment and affects the thermal comfort feeling [4].

Also, the type of coverage and activity of the inhabitants of these settlements are also effective. The active person who consumes more oxygen also generates more heat. Domain and Passore in 1967 calculated and presented the generated heat due to the different activities, for the first time [4]. Also, factors such as the amount of evaporation or radiation and airflow depend on the type of clothing. So the clothes can significantly reduce the cooling potential. The ASHRAE standard has presented different values for various clothing [4].

5. Results and Discussions

5.1. Temperature

Using the obtained temperature information, the temperature status graph (dry temperature) of Rudbar is plotted in Figure 1 for the 12 months of the year. The recorded upper and lower points define the maximum and minimum temperature values. These data have been deduced from the climatic file of the Energy Plus Weather (EPW) obtained from Metonorm Software.

From the interpretation of Figure 1 which presented in a comprehensive manner in Table 2, the average annual temperature shows that 4 months of the year, i.e., June, July, August and September fall in the thermal comfort zone and the remaining eight months of the year are below the comfort limits and require active and inactive heating systems (Table 2).

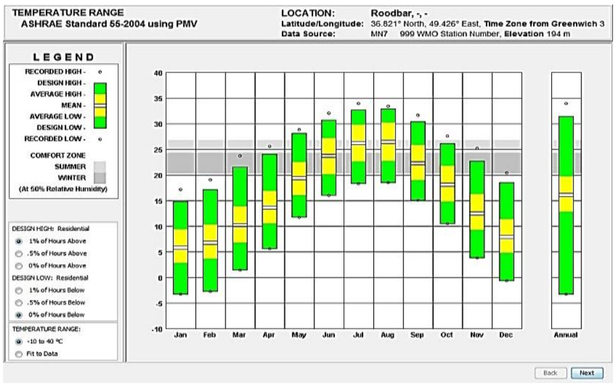


Figure 1. The dry temperature variation of Rudbar during the 12 months of the year

Table 2. Numerical values associated with the temperature of Rudbar, Guilan

Max &Min Temperature (Centigrade)	Comfort status	Month	Season
Min Temp: 11 Centigrade (in March) Max Temp:18 Centigrade (in May)	Average Temperature Below Comfort Zone	May Apr- Mar-	Spring
Min Temp: 18 Centigrade (in June) Max Temp: 27/5 Centigrade (in Aug)	Average Temperature in Comfort Zone	Aug - Jul -Jun	Summer
Temp: 23 Centigrade Min Temp: 13 Centigrade (in Nov) Max Temp: 18 Centigrade (in Oct)	Average Temperature in Comfort Zone during Sep Then Average Temperature Below Comfort Zone during Oct and Nov	Nov -Oct- Sep	Fall
Min Temp: 6 Centigrade (in Jan) Max Temp: 8 Centigrade (in Dec)	Average Temperature Below Comfort Zone	Feb -Jan- Dec	Winter
Result: 4 months from June-September are in comfort zone and the remaining 8 months are below this zone.			

5.2. Solar Radiation

In order to assess the amount of solar energy, the climate consultant software with the presentation of the radiation zone's curve, enables the estimation of the average total received radiant energy in the months of the year. Table 3 lists the maximum and minimum values of this energy during the different seasons. Figure 2 depicts the radiation zone including the direct, horizontal and total radiation from the surface of the objects.

In this analysis, the average radiation in the dry temperature is considered. As can be seen (Table 3), the lowest radiation amount is related to November, December and January, while, the maximum radiation is dedicated to June and July which is about 470-480 Wh/m2.

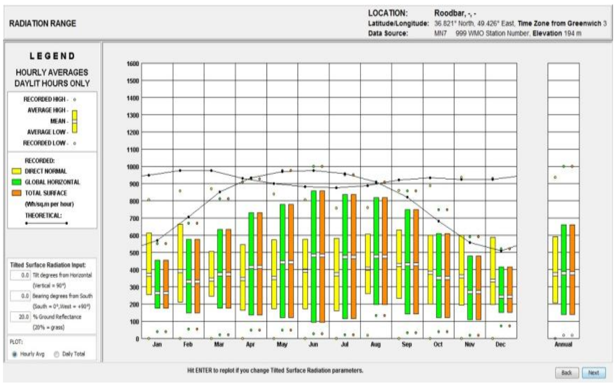


Figure 2. Rudbar's sunshine range diagram

Table 2. The minimum and maximum values of sunshine energy in Rudbar

Radiation status (Wh/m^2)	Month	Season
Min Average: 385 , Max Average: 450, Average: 420	Apr- Mar-May	Spring
Min Average 480, Max Average : 470, Average: 475	Aug - Jul -Jun	Summer
Min Average: 280, Max Average: 410, Average: 380	Nov -Oct- Sep	Fall
Min Average: 230, Max Average: 320, Average: 285	Feb -Jan- Dec	Winter

5.3. Relative Humidity

The relative humidity in 03:00 AM GMT equal to 06:30 AM Rudbar's local time is illustrated in Figure 3. As would be observed, in June, July and August, one is faced with the lowest amount of the relative humidity. The maximum and minimum values of the relative humidity is about 90 and 59 percent, respectively, which indicates high relative humidity during the whole year (Table 3).

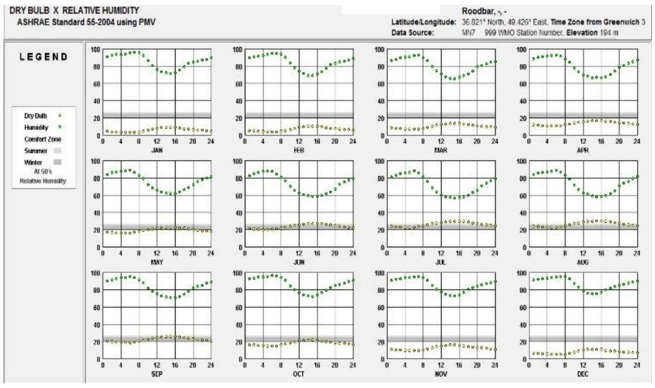


Figure 3. the relative humidity and wind flow ranges in Rudbar

Table 3. The minimum and maximum values of the relative humidity and wind flows in Rudbar

Season	Month	Relative Humidity (%) (3:00 AM GMT, 6:30 AM Local Time)	Wind (m/s)	Temp Wind 0-21 (°c)	Temp Wind 21-27 (°c)	Temp Wind 27-38 (°c)
Spring	Mar	Max: 95 , Min: 65	0–2	100%		
	Apr	Max: 95 , Min: 65	0–2	100%		
	May	Max: 90, Min: 60	4–6	100%		
Summer	Jun	Max: 90 , Min: 59	2–4	75%	25%	
	Jul	Max: 90, Min: 58	2–4		100%	
	Aug	Max: 90 , Min: 59	2–4		100%	
Fall	Sep	Max: 95 , Min: 70	2–4	25%	75%	
	Oct	Max: 95 , Min: 75	2–4	100%		
	Nov	Max: 95 , Min: 75	4–6	100%		
Winter	Dec	Max: 95 , Min: 79	0–2	100%		
	Jan	Max: 95 , Min: 75	0–2	100%		
	Feb	Max: 95 , Min: 77	0–2	100%		

5.4. Wind Velocity

According to the wind wheel graph, it is possible to determine the velocity, direction, temperature and also the wind frequency. The status of the wind flow is separately given by Figure 4 for various seasons of the year. As illustrated by this figure, the wind velocity is 4-6 m/s during May and November. Wind wheel is a unique technique presenting the wind data by implementing the climate consultant software which shows the different winds affecting each other on the plane (see Figure 5). The brown outer ring stands for percentage of the winds per hour blowing from each direction. The next ring is the blue one in which the height and color of the radials indicate the average temperature of the winds blowing from each direction. The pale blue color stands for the comfort zone. The next ring shows the average humidity in which the pale green color points out to the comfort zone. The three triangles located in the inner circles illustrate the minimum, average and maximum wind intensities in each direction, respectively. In this case, the strongest wind blows from the east, south, and southwest, with a speed of 10 mph.

Figure 6 presents the dry bulb temperature of Rudbar in different months of the year. When the sunrise and sunset happens in every month and in this latitude, it is determined by the yellow curve. The annual dry temperature indicates that in all months except in June and September, the temperature entirely falls between 0 and 21° C. However, during July and August, the temperature range is from 21 to 27° C.

Figure 7 depicts the psychrometric charts associated with 16 different cases of building design strategies in Rudbar which shown in different colors depending on the zones (different regions) of this city. From the analysis of the psychometric diagrams, one can find the 16 approaches presented in Table 4 for the design of rural human settlements. Table 5 deals with investigating the climatic factors of summer and winter seasons in Rudbar and their analysis.

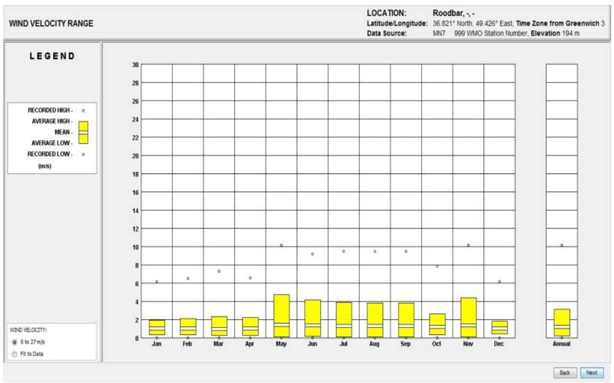


Figure 4. The wind speed range in Rudbar

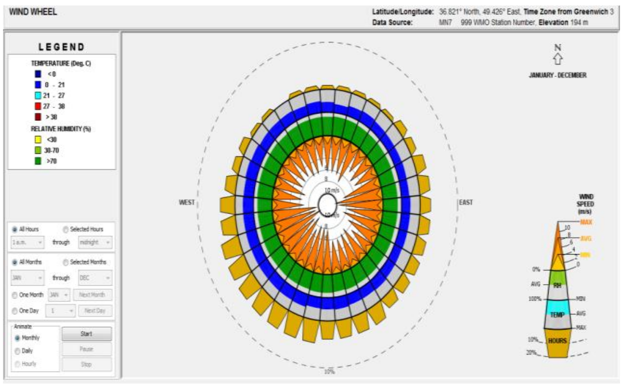


Figure 5. Wind wheel diagram representing the speed, direction, temperature and frequency of the wind

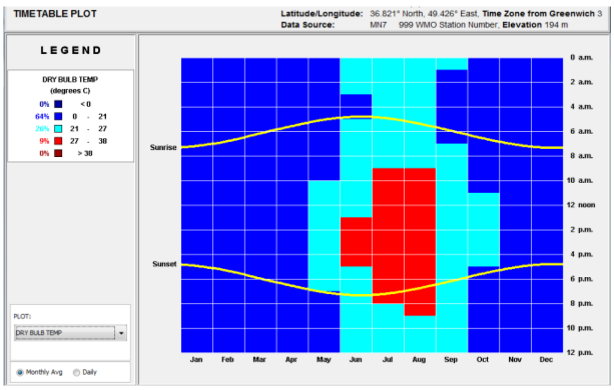


Figure 6. Rudbar's dry bulb temperature during the different months of the year

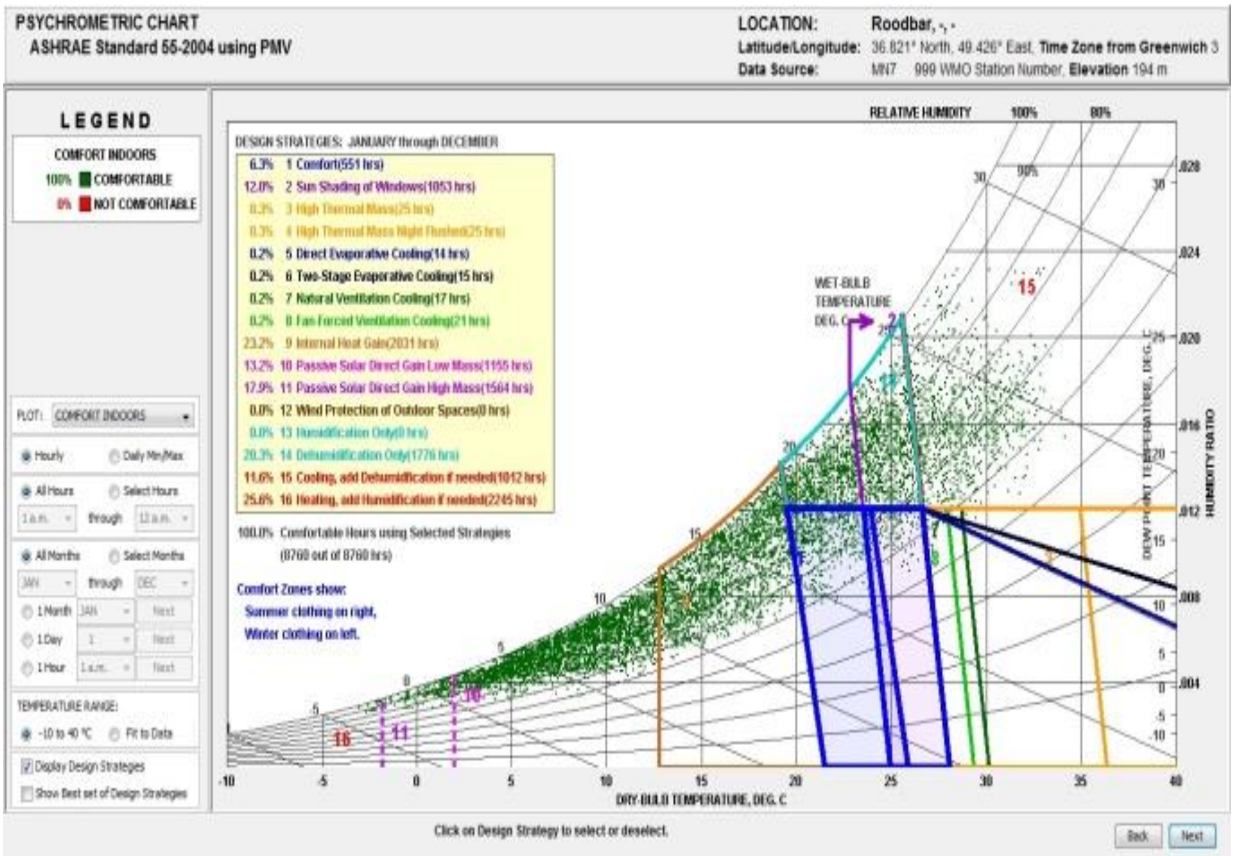


Figure 7. Psychrometric charts associated with 16 different cases of building design strategies in Rudbar

Table 4. Results obtained via investigating the design approaches and their effect on the comfort level using the psychrometric charts (Rudbar)

Climatic approaches	Percent	Hours	Analysis
1- Comfort zone	3.6	551	
2- Sun Shading zone	12	1053	Since the shadow alone cannot guarantee the provision of the comfort conditions, the number of its hours cannot be increased to the total number of hours of the comfort area.
3- High Termal mass zone	3.0	25	With this strategy, the temperature fluctuations of the indoor space are reduced. Particularly in the hot and cold areas, there is a cooling strategy that is not discussed in this study.
4- High Termal mass with Night Flushing Zone	3.0	25	To make this cooling strategy useful, forced ventilation must be initially performed using the natural ventilation or fan so that cool air to be provided for the entire building. Then, the air inlets must be closed when the air is warm. Despite the increasing night-time cooling technique, it does not include larger zones rather than case number 3.
5- Direct Evaporation Cooling	2.0	14	Especially in the dry and hot areas, it is a kind of cooling strategy as it yields an increment in the humidity further to the cooling which is ignored from the present investigation.
6- Two stage Evaporating Cool zone	2.0	15	This is a modification of the case number 5. First, water is used for cooling the outer part of the heat exchanger by which the inlet air is suctioned to the second stage and the direct evaporative cooling is happened.
7- Natural ventilation cooling zone	2.0	17	It is suitable for the hot and humid regions where the humidity is not high. Ventilation is the only way of inducing the cool sense and it cannot reduce the dry temperature. During the day, the natural ventilation for the dry and hot areas must be minimum as the inner surface and air temperature increases due to the entry of outside's hot air to the inside. On the other hand, because of the low humidity, even with a low-speed airflow, there is the possibility of body cooling through the evaporation of the body's perspiration. This low-speed airflow is due to the temperature difference among the surfaces and outside air permeation from the window seams which has not been addressed in the present study [23].
8- Fan-Forced Ventilation cooling zone	2.0	21	It is appropriate for hot and humid regions with no remarkable humidity. It is effective for velocities less than 0.2 and induces the temperature reduction to 8.3°C [23]. This has not been addressed in the present study.
9- Internal Heating zone	2.23	2031	It is approximately the result of the heat received from the activity of people, light producing equipment and also home appliances. The equilibrium point temperature is the temperature of the outside air by which one can only reach to the comfort level by implementing the efficiency of the internal heat.
10- Passive solar Direct Gain low mass zone	2.13	1155	It should be noted that the occurrence condition is to prevent the direct solar energy delivery when it is not necessary. Due to the low mass, there is a possibility of rapid warming up for the space. The approximate withdrawal time is about 3 hours for this material.

11- Passive solar Direct Gain High mass zone	9.17	1564	Care must be taken that the occurrence condition is to prevent the direct solar energy delivery when it is not necessary. The approximate withdrawal time is about 12 hours for this material.
12- Wind protection zone	0.0	0	Since the cold outside air is unpleasant, this strategy is not applicable here (this strategy requires wind breakers such as walls or plants to protect the entrances, balcony and other usable outdoor spaces).
13- Humidification zone	0.0	0	The above strategy is not applicable here because this strategy can only be used when the dry temperature is in the comfort range and humidity is less than this range. The humidity is provided by transpiration, cleaning and cooking. The humidifier is not required because the moisture absorbent machine also results in a reduction in the dry temperature by humidity production, which is unwanted
14-Dehumidification zone	3.20	1776	It is applicable due to the high average of relative humidity. The moisture reduction device also reduces the dry temperature which requires heat energy.
15- Cooling zone with humidity control needed	6.11	1012	When the previous strategies are not responsive to providing the comfort conditions and the need for cooling is felt. Usually, the actual hours that conventional air conditioning is needed is more than what is shown. It seems that sometimes the rest of the zones may require air conditioning, such as hours of normal ventilation in which there is not enough wind or in high thermal mass when its heat is not fully emptied out at night.
16- Heating zone with humidity control needed	6.25	2245	When the previous strategies are not responsive to providing the comfort conditions and the need for warming is felt. Usually, the actual hours that conventional air conditioning is needed is more than what is shown. It seems that sometimes in the rest of the zones the need for normal warming may be existed, such as hours in which there is not enough solar radiations in order to absorb the direct passive solar energy.
17- Using all of the above-mentioned items			In some cases, the other factors are focused and the total percentage are higher than 100 percent.

Table 5. The climatic factors investigation of Rudbar in summer and winter seasons

Analysis	Problematic Parameters in Summer and Winter time in Roudbar	Month	Season
The maximum and minimum received radiation in the summer is high and very noticeable. The minimum temperature is about 18°C which is near the comfort zone, but, the maximum humidity is high. Due to the high air temperature and great amount of solar radiation delivered. Also the warm wind blowing as a breezier with the temperature limit of 21-27°C which can be more pleasurable by using architectural windows.	Min Temp: 18 (°c) in June Max Temp: 27/5 (°c) in Aug Max Average Radiation: 480 Min Average Radiation: 470 Average Radiation: 475 Max relative Humidity in Jul: 90 % Max relative Humidity in Jul: 58% Average Radiation: 470 – 480 wh/sq.m per hour Wind Speed: 2-4	Jun Jul Aug	Summer
The maximum and minimum rates of radiation received in winter is very low. However, the minimum temperature is about 6° C and does not far below zero. Humidity is usually high which is suitable to decrease coldness feeling. Wind blows calmly within a temperature range of 0-21° C.	Min Temp: 6° C in June Max Temp: 8° C in Aug Max Average Radiation :320 Min Average Radiation :230 285: Average Radiation Max relative Humidity In Jul٩5% Max relative Humidity In Jul : 75% 230-320Average Radiation:- :wh/sq.m per hour Wind Speed: 2-0	Dec Jan Feb	Winter

5.4. Case Study

The understudy area which is located in Baravad village near Vishan (Khorgam, Rudbar) was surveyed first, the ground as well as the first floor plan drawn and the energy consumption was then simulated using Design Builder software.

Rudbar's climate data were considered as the default for the software and the seasonal PMV diagrams (winter, spring, autumn and summer) were plotted and analyzed. The obtained results illustrate that in spring and summer, the thermal behavior of native housing is appropriate. However, but by the end of summer and the beginning of autumn to early spring, it becomes inappropriate and heating is needed.

In order to validate the achievements of the software within a month from June 10 to August 11, 2017, a data logger has been used to record the indoor information of the living room. Temperature and relative humidity diagrams were recorded and compared with those deduced via the software and very close agreement has been achieved proving the validity of the software. Finally, the PMV diagrams obtained via the data logger and the software have been plotted in the period from June 10 to August 11, 2017. A comparison of these two diagrams, revealed the same results.

The thermal performance investigation of the above building clarifies that in terms of providing thermal comfort, it has a good performance in spring and summer, while, faces with issues in autumn and winter. Furthermore, the monthly and annual interior loads (kWh) received from the parameters of equipment, lighting, solar radiation, and people, indicate that the heat load in the spring and summer is appropriate but autumn and winter's load must be supplied. The amount of solar radiation absorbed in different months of the need for using new technologies such as photovoltaic and solar collectors in cold weather is verified.

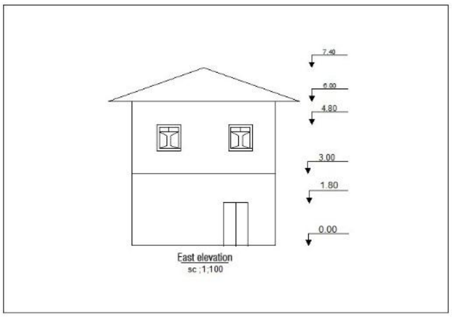
Table 6. The understudy building's specifications in Baravard village

Building Specifications	• Use: livestock-residential • Floors: 2 • Location: Dowsaledeh, Rudbar	• Architecture: Building elongation: elongation in the east-west axis (building area: 63 square meters) • A 28 square meter balcony in the ground floor and a 35 square meter balcony in the first floor. • Building materials: mostly mud as the building shell with wooden window frame and doors. • The roof of the building is made of wood and is steeped.
Modeling is performed for different months and also annually for the entire building and each floor.	• Users: 1 • Heating temperature: 21-12 degrees Celsius • Cooling temperature: 25-50 degrees Celsius	• The amount of light required in spaces: 100 lux • Setting artificial illumination using light of day received by spaces • Unwanted air replace: 1.03 change per hour • Modeling of buildings, was performed taking into account existing partitions without using curtains (interior awnings)

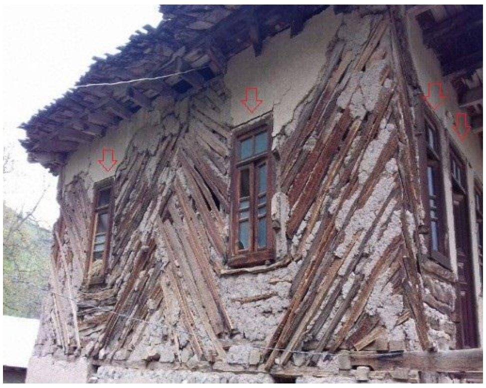
a) South elevation of building

b) East elevation of building

c) South elevation of drawing



d) East elevation of drawing



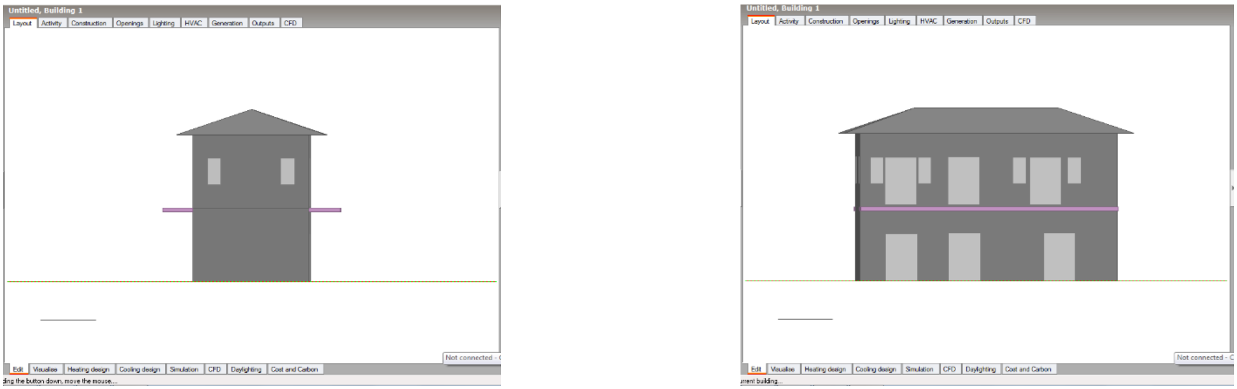
e) West elevation of building

f) North elevation of building

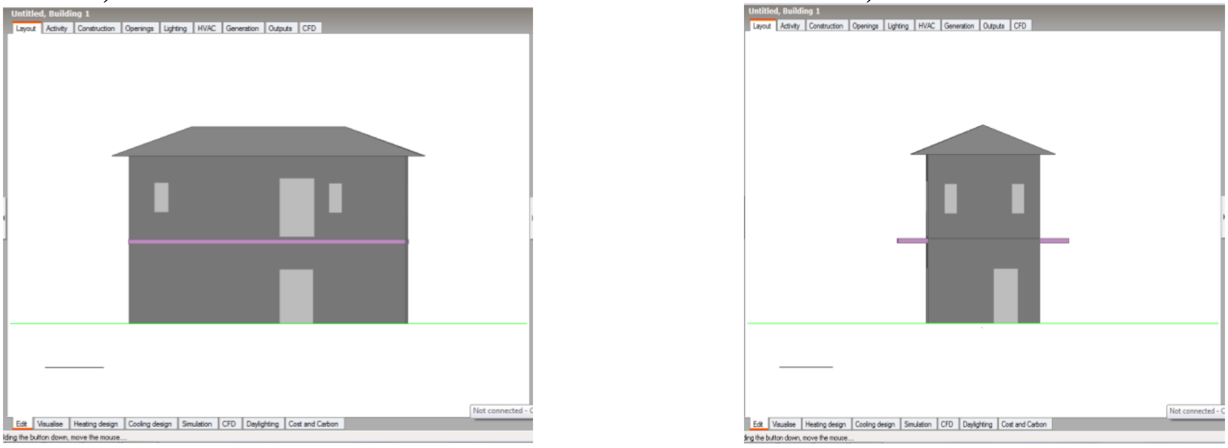
g) West elevation of drawing　　　h) North elevation of drawing

Note: The openings are shown in the figures. The ground floor doors are led to the corral.

Figure 8. The studied rural-Mountainous residences



a) South elevation Simulation　　　b) West elevation Simulation

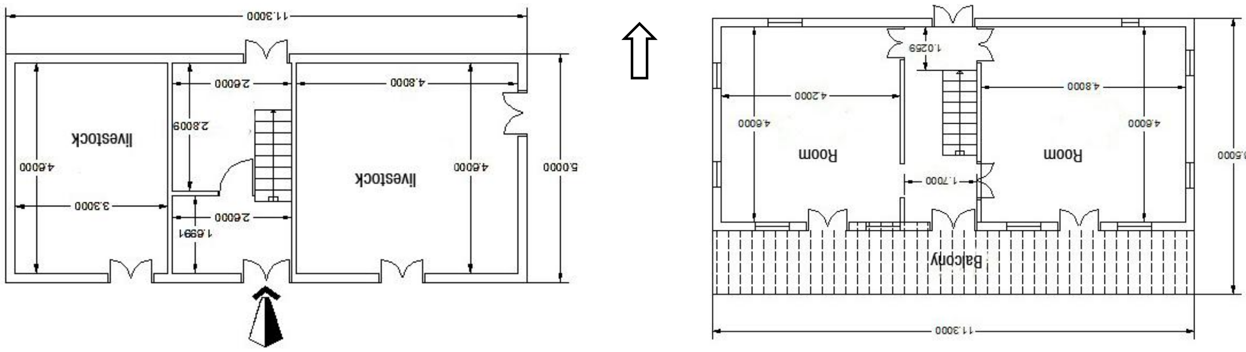


c) First Level is Residential, North elevation　　　d) East elevation, Ground floor is non residential

Figure 9. Simulation of the house (Baravard, Rudbar)

Figure 10. Location of the data logger

N



First Floor Drawing

Ground Floor Drawing

Figure 11. The architectural plan of building

The data logger is located on the first floor showed in Figure 10. West side room where the residents (an old woman and 13-year-old grandson) perform daytime activities on their own, and spend the night at rest. The East side room is for guests and is less used. The kitchen as well as the restroom service is also outside of the building. The major and multi propose room is West side room.

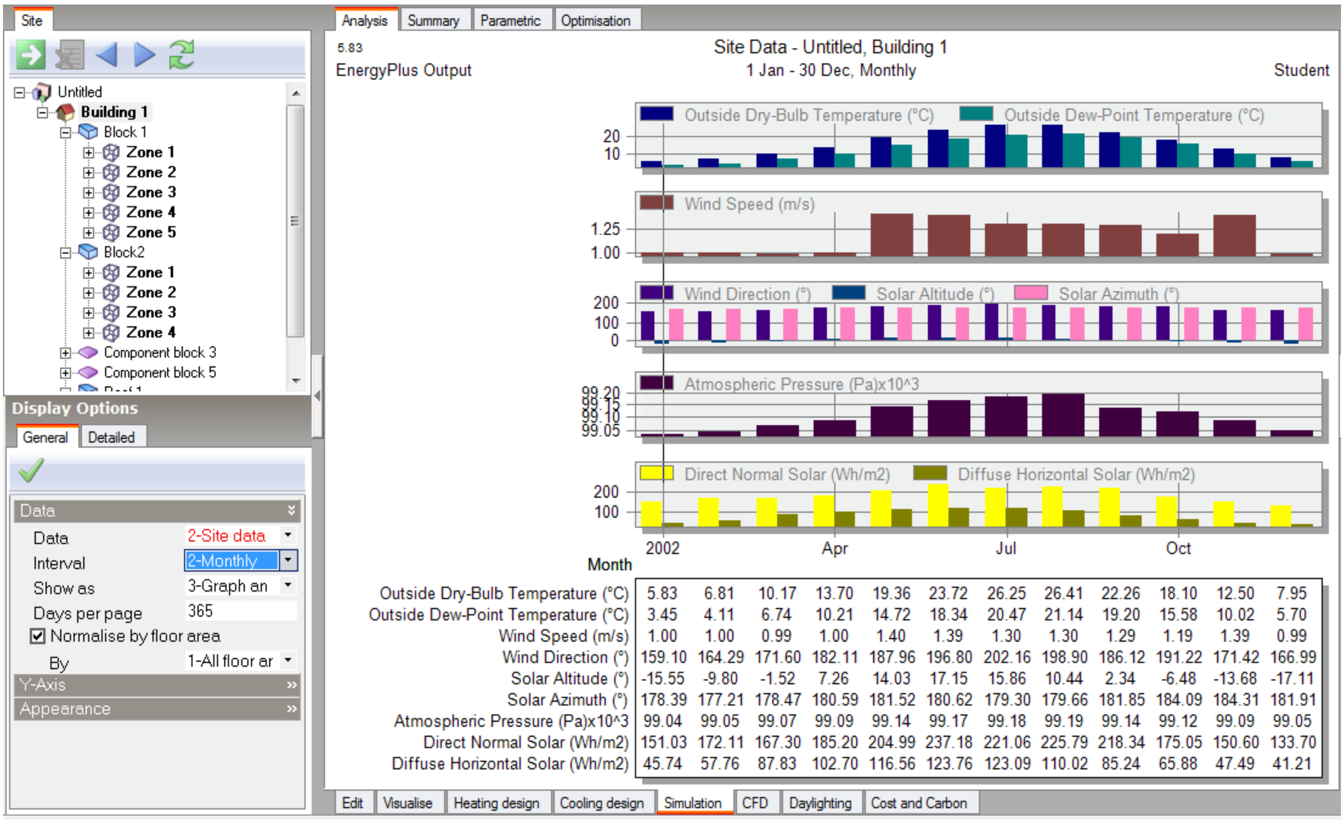


Figure 12. The climatic chart of Rudbar in on-site Design Builder software

The climatic chart of Rudbar (Figure 12) in on-site DesignBuilder software verifies its complete agreement with the climatic data available in the climatic consultant one. Precisely evaluating Figure 13, one would be able to determine the average humidity-temperature which can be implemented for plotting the PMV charts associated with the understudy construction as considered in Table 7.

The reason for the relative difference between the relative humidity and temperature obtained by the data logger and Design Builder indicates that

- The presence of the building shell has a role in this difference; and
- The current atmospheric conditions of the earth prove tangible changes in relative humidity relative to the 15-year average used in the EPW file of the software.

According to Table 8 presented by Matzarakis et al., in 2001 [24], threshold value of PMV, thermal sensitivity and physiological stress degree can be evaluated.

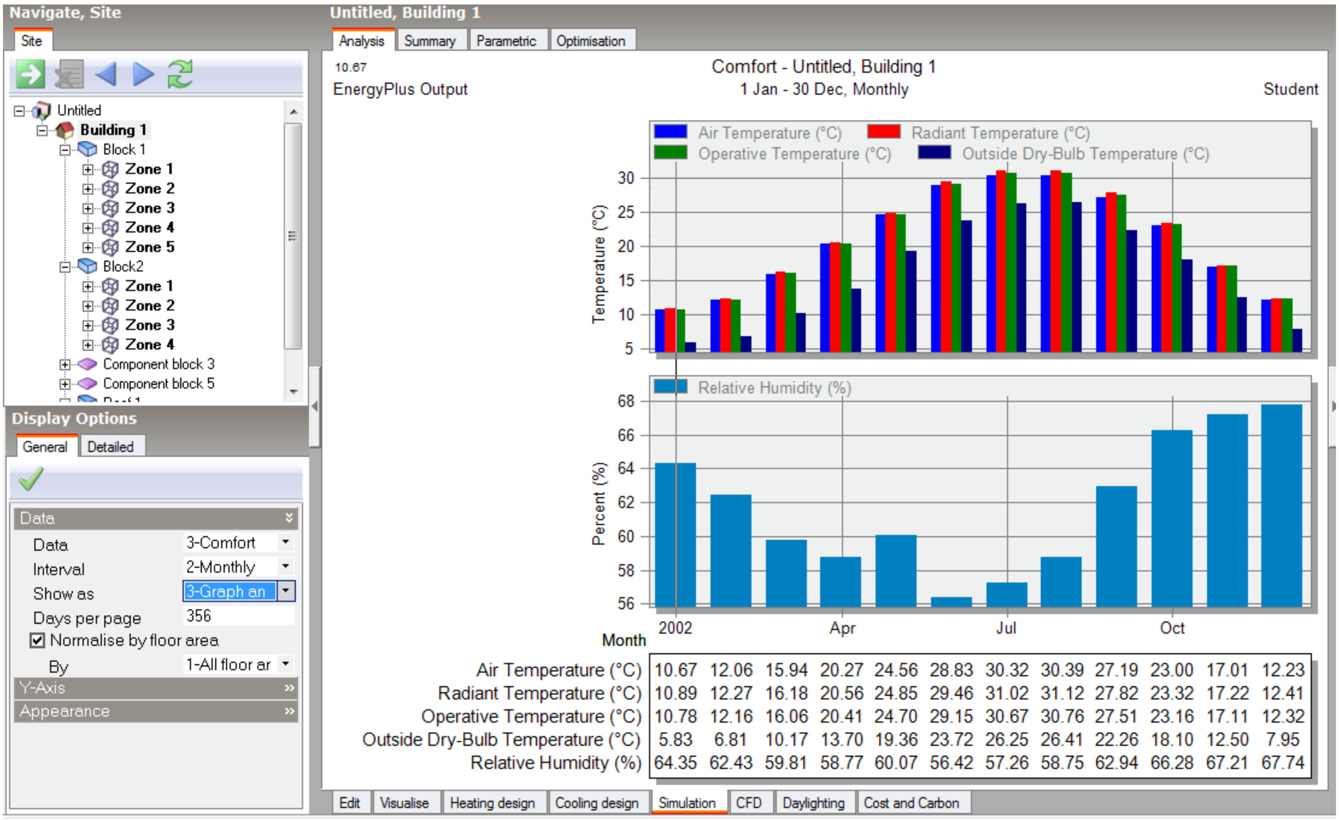


Figure 13. The comfort zone chart in Design Builder software on the understudy construction

Table 7. Necessary variables for plotting the PMV charts of the construction

Activity	Temp.	Temp for average Radiation	Wind Average m/s	Relative Humidity 3 Greenwich 6:30 Local Time	Season	Inputs for drawing seasonal PMV in Building (Roudbar)
1	15.94	16.18	0/99	59.81	Mar	Spring
1	20.27	20.56	1	58.77	Apr	Spring
1	24.56	24.85	1/40	60.07	May	Spring
1	28.83	29.46	1/39	56.42	Jun	Summer
1	30.32	31.02	1/30	57.26	Jul	Summer
1	30.39	31.12	1/30	58.75	Aug	Summer
1	27.19	27.82	1/29	62.94	Sep	Fall
1	23	23.32	1/19	66.28	Oct	Fall
1	17.01	17.22	1/39	67.21	Nov	Fall
1	12.23	12.41	0/99	67.74	Dec	Winter
1	10.67	10.89	1	64.35	Jan	Winter
1	12.06	12.27	1	62.43	Feb	Winter

Table 8. Matzarakis' physiological stress [23]

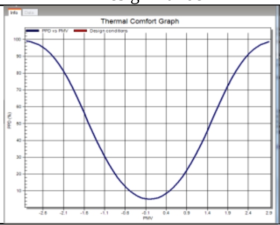
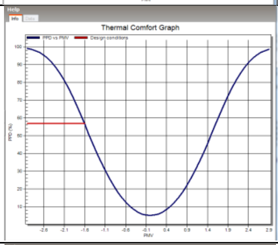
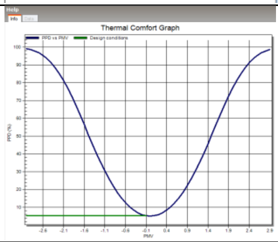
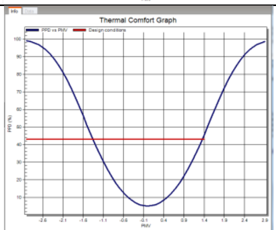
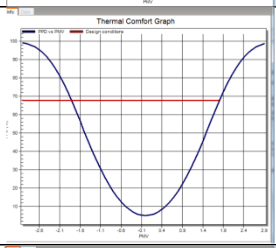
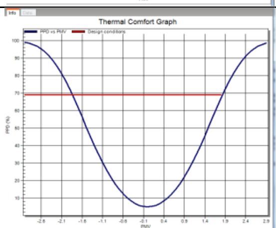
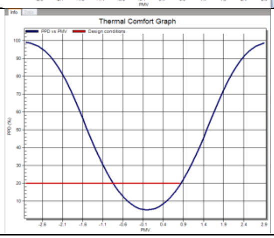
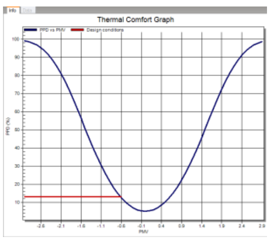
Physiological stress degree	Thermal sensitivity	PMV
Intense cold stress	cold	-3.5
Average cold stress	cool	-2.5
Slight cold stress	slightly cool	-1
Without cold stress	comfort	-0.5
Slight heat stress	slightly warm	0.5
Average heat stress	warm	1.5
Intense heat stress	Very warm	2.5
Very intense heat stress	hot	3.5

As a result of comparing the information obtained via PMV graph of different seasons and the climatic consultant software's graph, one arrives at the fact that the design of rural residential houses can add the two months of October and November to the desirable seasons in terms of thermal comfort.

The comfort zone is related to the climatic factors especially temperature and relative humidity and comfort range refers to the relative humidity and temperature in which at least 80 percent of people feel satisfied [25].

In a study conducted on the comfort range, Givoni [25] illustrated that the bioclimatic welfare is in direct relation with the temperature and relative humidity.

Table 9. Comprehensive analysis of PMV charts results and their related physiologic stress

Level of physiologic stress	Thermal Sensitivity	Graph In Design Builder	Operative Temp.	PPD	PMV	Month	Inputs for drawing seasonal PMV in Building
Intense cold stress	Cold		16/01	99/33	-3/06	Mar	Spring
Slight cold stress	slightly cool		20/36	56/94	-1/61	Apr	Spring
Without cold stress	comfort		65.24	5.36	-0.13	May	Spring
Average heat stress	warm		29.02	43.15	1.36	Jun	Summer
Average heat stress	warm		30/31	67/66	1/81	Jul	Summer
Average heat stress	warm		30/34	68/94	1/84	Aug	Summer
Average heat stress	warm		27/38	19/92	0/84	Sep	Fall
Without cold stress	comfort		23/10	13/13	-0/62	Oct	Fall

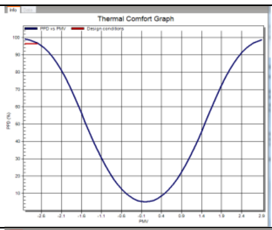
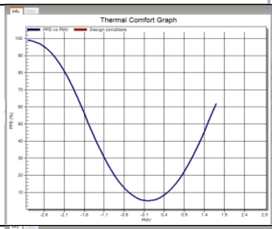
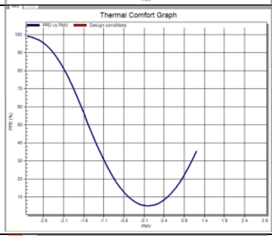
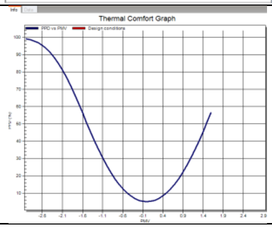
Average cold stress	cool		17/07	96/34	-2/67	Nov	Fall
Intense cold stress	cold		12/28	100	-4/28	Dec	Winter
Intense cold stress	cold		10/74	100	-4/8	Jan	Winter
Intense cold stress	cold		12/12	100	-4/36	Feb	Winter

Figure 14 consists the relative humidity and temperature data associated with a two-week timeframe from May 31-June 15, 2002, in the comfort range on a monthly basis. Also, Figure 15 shows the recorded data related to the relative humidity and temperature via the data logger by Design Builder software during the above mentioned timeframe in the comfort range on a daily basis.

Figure 16 depicts the relative humidity and temperature data of the same timeframe which have been exported in Excel datasheet format from Design Builder software (Data have been collected in half an hour intervals.). Zone one in the Design Builder software is the same as the main living room and sleeping area of the inhabitants and the location where the data logger is located.

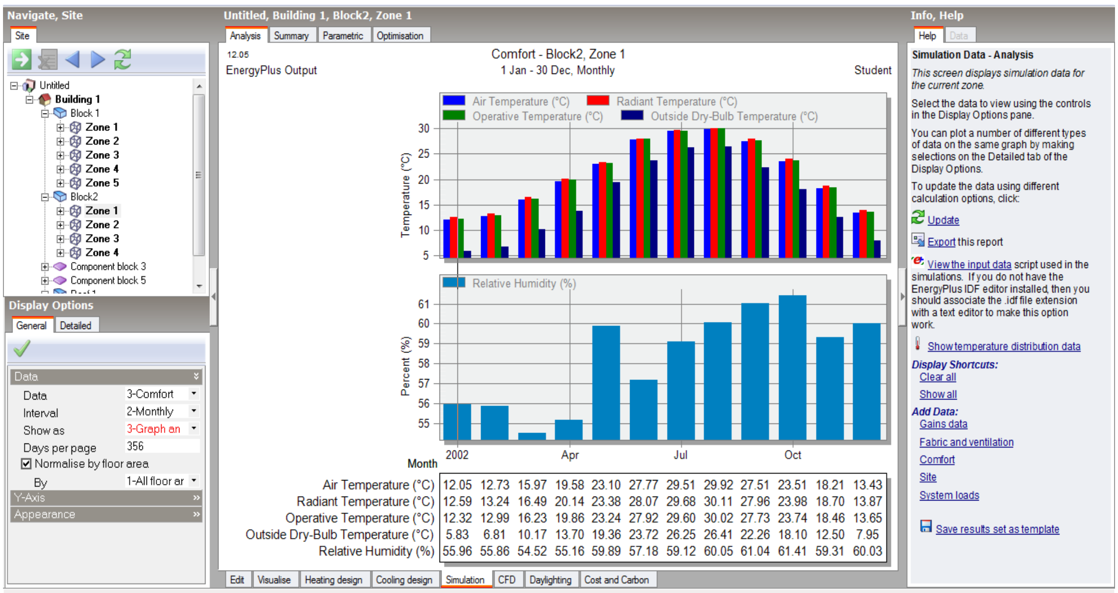


Figure 14. The relative humidity and temperature data associated with a two-week timeframe from May 31-June 15, 2002

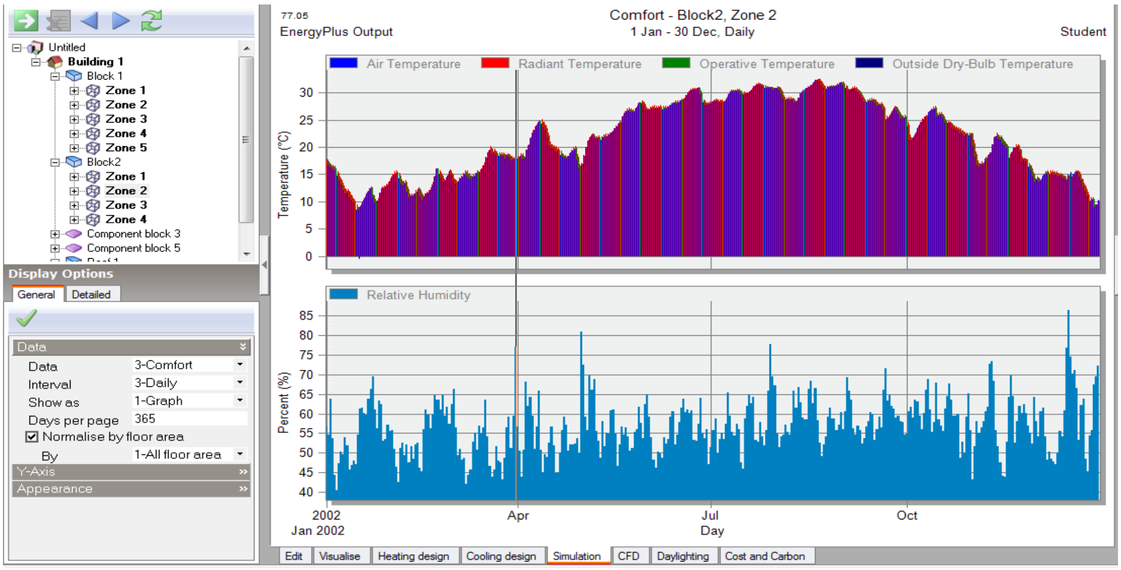


Figure 15. The recorded data related to the relative humidity and temperature via the data logger by Design Builder

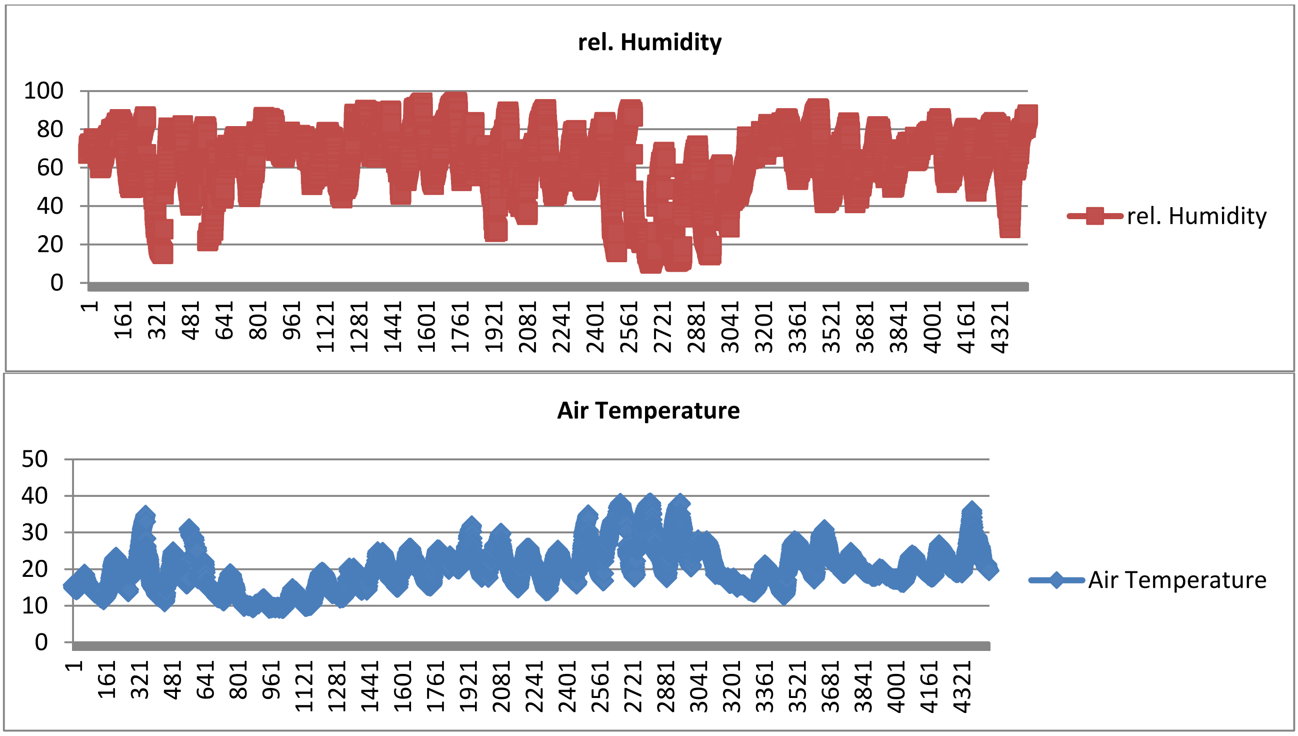


Figure 16. The relative humidity and temperature data (May 31-June 15, 2002)

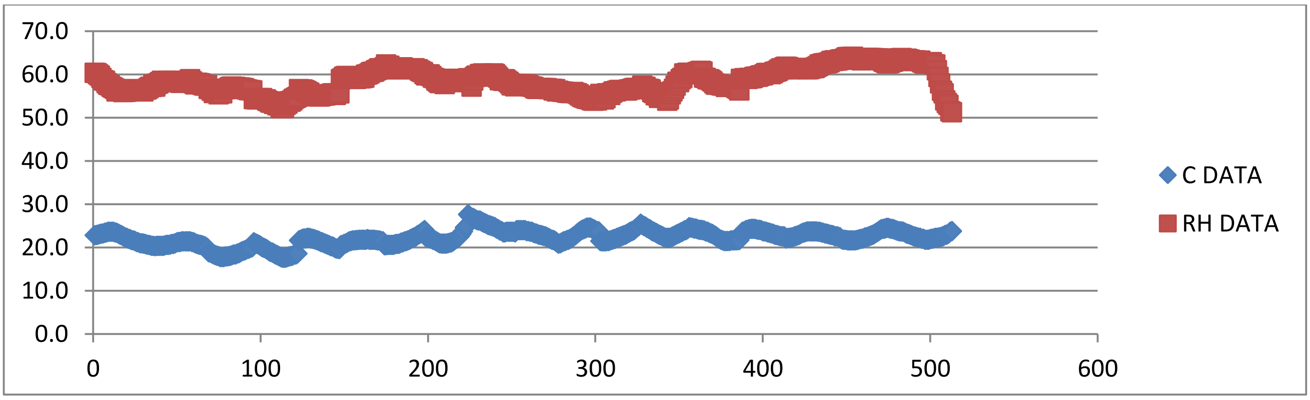


Figure 17. The relative humidity and temperature data recorded (May 31 to June 15, 2017) by a data logger

Figure 17 shows the relative humidity and temperature data recorded in a two-week period from May 31 to June 15, 2017 by a data logger in the zone of the main living room and sleeping of residents and exported as an Excel file. As it is clear from Figures 16 and 17 (2002 by Design Builder Software and 2017 by data logger), there is a little difference between these two sets of data. To validate the data recorded by data logger, the information of Guilan meteorological organization were referred to at the same time interval which were consistent with the provided data.

The relative humidity (red line: Series2) and temperature (blue line: Series1) charts of Rudbar are plotted in Figure 18 for the two-week time interval from May31-June 15, 2017, according to the information of Guilan meteorological organization. According to Table 9, the understudy time domain is located in the range of physiological stress degree of no cold stress (satisfied) and with average heat stress (warm) which indicates that there is no need for heating and cooling equipment in these times of the year.

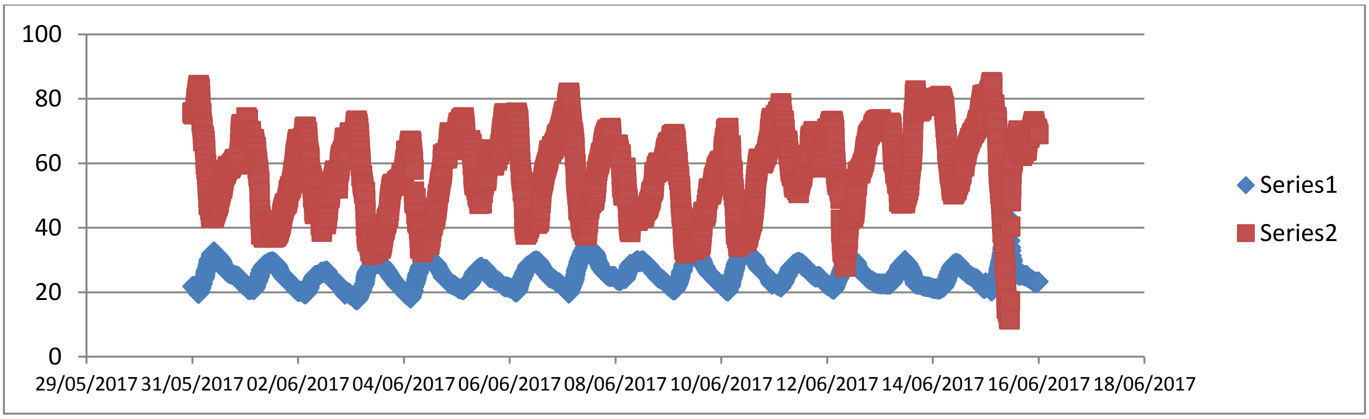


Figure 18. Relative humidity (Series 2) and temperature (blue line) charts of Rudbar (May31-June 15, 2017), according to the information of Guilan meteorological organization

The slight difference between the relative humidity and temperature data of the Design Builder software and those recorded via the data logger clarifies that, firstly, the presence of the building's shell is effective and secondly, the current atmospheric conditions of the earth indicate the tangible changes in the relative humidity compared to the 15-year average used in the EPW file of the DesinBuilder software.

By comparing the resultant diagrams, it can be concluded that in the whole year from April to November, Guilan's native house is well-suited to the condition and there is no need for a heating or cooling system, then from December to March, we need a heating system.

6. Conclusion

In order to properly analyze the energy in rural settlements of mountainous areas, the prevailing typology and the climate conditions affecting the architecture of these settlements were first examined. The dominant typology, two floors, has a southern northern portico with maximum openings in the north and south, made from indigenous materials of mud and clay. Also, the sloping roofs with livestock usage in the ground floor and residential usage in the first floor in inclusive. Using the climatic consultant software, the parameters such as temperature, relative humidity, sunshine and wind status were examined and tabulated. Then, by implementing the DesignBuilder software, building simulation were investigated and thermally analyzed from various aspects such as building physics (materials), architecture, cooling and heating systems, lighting systems, etc. Finally, by interpreting the PMV and PPD charts in different seasons, it was found that the months of June, July, August and Septamper are in comfort range and December, January, February, and March meet the intense cold stress requiring the use of active and inactive heating equipment. Field research, questionnaire, information and statistics of the meteorological organization of Guilan province are also fully consistent with the obtained results.

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