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Comparative study of the impact of heat transfer coefficient on the comfort conditions in the interior spaces of Iranian traditional houses (warm and dry climate of Yazd and cold and mountainous of Tabriz)

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Abstract
Paper undertakes software based numerical simulations in two different traditional houses in cold-dry climate of Tabriz and hot-arid climate of Yazd, The Eco Test software chosen for BIM simulations. Case study on real houses instead of hypothetical models can give more tangible results and choosing traditional houses can provide a good opportunity to compare both physical and thermal conditions, in which zones have more dense walls than contemporary typical building wall. With high thermal mass and more surface to volume ratio, investigating the effect of U-value on interior conditions are more accurate. Comparative case studies in two different climatic zones of Iran can give researchers the opportunity to compare the importance of total U-value in two severe climates in Iran. In addition, it can give the designers the insight that what design priorities must be considered in each climate. Results show that the U-value in a hot arid climate of Yazd has a more direct effect in controlling interior comfort conditions, like fluctuations of temperature and variations of summer and winter temperatures, as well as variations of temperature in a single day and total energy need and consumption in both hot months and cold months of the year.

Key words: *U-value, Thermal mass, Traditional Iranian houses, Cold-dry climate, Hot-arid climate, BIM Based Software Analysis*

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1.Introduction

The main purpose of this article is the comparative study of the effect of heat transfer coefficient on the comfort condition in the traditional buildings, in two different climates of hot and dry, cold and mountains of Iran. Heat transfer coefficient can be considered, as a related element with thermal mass, especially in a traditional house, because, using lightweight or thin materials with high heat transfer coefficient with technology and new materials is only possible for several years. By comparing homes that mainly are about 100 to 200 years, materials with more thermal mass, mainly have a lower heat transfer coefficient. Today, materials with high thermal capacity and less weight are produced and used in the construction industry and using materials with high thickness and weight, such as those in traditional houses, is not reasonable. Because, they create constructional high weight problems, and subsequently, high weight structures and using thick walls, such as their use in traditional houses, makes waste in useful space of the house. So, today, materials such as PCM (materials capable of phase change in different thermal and climatic conditions), with latent high-capacity heat and low weight and thickness, in recent years, are more widely produced and used [1-6]. Some of these studies discuss the effect of using materials with latent high thermal capacity to internal comfort conditions [7-9]. In addition, a wide variety of studies in the field of the effect of thermal mass effect on the comfort conditions and indoor air quality were found in the literature in this area [10-25]. Most of the studies that are in the field of climate design have been done in the climatic zones and different countries. For example, in connection with the subject of this research, there are many studies in the field of the effect of thermal mass and heat transfer coefficient and latent heat capacity, in a hot and dry climate [26-39]. However, in different climates and countries that are located in other climate zones, studies with different approaches can be found in the same field [40-44]. With different approaches, but in this same context of climatic design, studies in the field of climate, native design, traditional home design and evaluation of these examples can be found that examples of this research, which could also help researchers, are studied and brought in the resources section [45-51]. In the following table, the symbols and Latin terms summary that are used more in this research literature area, are given.

2. Methodology

2.1. Case Study

Two hot and dry climates, cold and mountainous climates are accounted for a large part of the center and the northwestern plains of Iran. Tabriz and Yazd that perhaps we can select the most important representative and cities for the two climates, As well as traditional homes can be found in the two cities which share many similarities in terms of physics, materials and design together. Given the major difference between the two climates, this issue seems contradictory. 33 traditional houses in Tabriz and Yazd were studied, and among them, two traditional houses of Ghodaki and Heidar Zadeh in Tabriz, Golshan and Mortaz in Yazd were selected. 4 zones as sample zones were analyzed of each one. The reasons for selecting these homes and zones were general appropriate orientation, the overall size of the houses and zones of the same size and the total area of the same windows' surface and many similar factors.

2.2 Selecting the software to analyze climate

For the analysis of climatic comfort conditions, in both houses, the simulation software method was elected. The reason was the modeling and simulation of real similar circumstances in ECOTECT software that is proper software in the field of climate studies. This software has also been used in previous climate research [52-55] and has been able to analyze and report on various grounds, that their analysis could give useful conclusions to the researchers. Another reason for choosing software modeling was the hardship and complex

symbols		Abbreviations	
H transfer coefficient (W/ m2 K)	U	Response Factor	RF
Area (m2)	A	Total area of the whole surfaces (m2)	TSA
Volume (m3)	V	Total area of the window (m2)	TWA
thermal resistance (m2 K/W)	R	monthly day temperature (°C) (a unit used to determine the heating requirements of buildings, representing a fall of one degree below average temperatures)	MDD
Thermal conductivity W/m K	K	Day temperature in the warmest month (July)	HDD
Thermal receive W	Q	Day temperature in the coldest month (January)	CDD
The coefficient of determination (R2=1- SSres⁄SStot)	FG	Mass absorption, tissue (Qc + Qs) (W)	FG

manual calculations about the heat transfer coefficient of walls, etc., and entering climate calculations throughout the year, according to different materials and different conditions in the interior design of the houses.

2.3 Climate modeling and simulation methods

4 houses, two houses from Yazd and two houses from Tabriz were selected among 32 traditional houses, and had initial survey. These houses include Haidarzadeh house and Ghadoki in Tabriz, Golshan and Mortaz houses in Yazd. In any of these houses, 4 zones were selected as the thermal zones and other areas were modeled and were inactive. In every four houses, one of the spaces was modeled with large glass windows and one of the zones was modeled with small windows so that the impact of these factors can be seen in the results. In all zones, the walls were modeled in the form of a40 cm brick wall with an internal gypsum layer with the heat transfer coefficient of 1.95 (W / m2K). The windows were selected in the form of single-layer with a heat transfer coefficient of 5.10 (W / m2K). Furniture or thermal tools were not modeled inside so that only results of external conditions on the interior will be simulated. Specific heat or air conditioning system is also not defined. Presence hours in the area were defined due to residential use of these structures in all days of a week and 24 hours a day. Intervals thermal comfort, 18-26 ° C, was determined. Related conditions to other minor issues such as paint, glass, small executive details, and the same … were selected, so that only the impact of factors that were effective in the researchers' assumption can be seen.

It should be noted, every four houses, almost, had the same orientation and zones were selected in the same front direction. Standard weather file, related to the city of Yazd and Tabriz was defined for each house fits in the software and tests were performed for the entire year.

3. Results

3.1. The overall results obtained and the results selected for analysis

The centroid range of results was analyzed, including the effect of TSA/TWA, V/A and TSA.TWA on the MDD, etc. However, significant relations were observed only between some of them. The reason that here, CDD, primarily, is considered, is that, this matter shows the high amount of heat to achieve thermal comfort intervals, as the sum of the space, and since, in both cities, a major factor is raised in winter, can be an overall and a main

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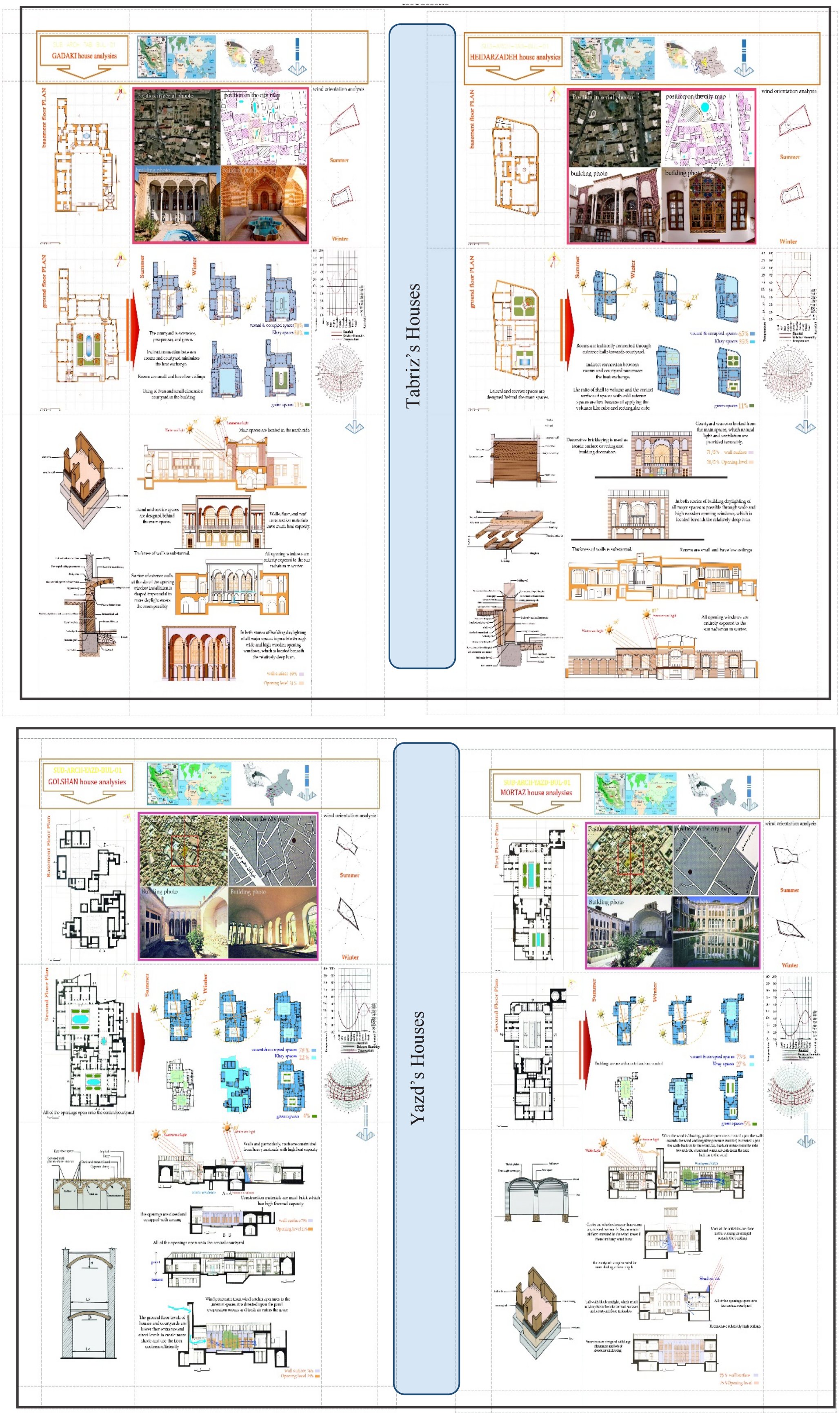

Pictures 1 and 2. Selected houses of Yazd, Tabriz and preliminary review and analysis of some physical features, architecture and thermal

		RF	U-value	V/A	TSA/TWA	CDD	HDD	V	A	TSA	TWA
Tabriz's Traditional Houses	Heydarzade	3.24	5.5	2.45	81.1	45316	6400	103	42	172	2.12
		3.53	5.2	2.38	60.4	46351	6400	71.5	30	127	2.52
		6.15	4	3.7	57.1	88000	3500	50	13.5	86	1.53
		3.79	4.7	4.66	20.3	66664	15666	212	53	247	14.7
	Ghadaki	RF	U-value	V/A	TSA/TWA	CDD	HDD	V	A	TSA	TWA
		2.32	7.3	3.84	38	78000	17500	315	82	349	9.16
		2.03	10.6	3.48	32.2	99000	20000	122	35	177	5.4
		2.36	8.68	3.82	43	90000	18000	172	45	243	5.6
		1.95	11.5	5.6	52	158000	32500	410	73	386	74

Table 2. Tabriz houses and some important physical and climatic features

		RF	U-value	V/A	TSA/TWA	CDD	HDD	V	A	TSA	TWA
Yazd's Traditional Houses	Golshan	3.73	5.15	3.7	31	41111	31000	260	72	311	9.9
		3.83	5.48	3.64	26.97	34000	32000	248	68	321	11.95
		4.78	4.9	3.74	46.25	37000	28000	101	27.5	148	3.24
		3.48	7.93	3.8	40	47000	39000	120	32	196	4.8
	Mortaz	RF	U-value	V/A	TSA/TWA	CDD	HDD	V	A	TSA	TWA
		2.52	14.7	5.53	29.4	103000	63000	127	23	166	9.9
		2.41	10.83	6	26.7	79000	53000	330	55	321	12.9
		3.07	9.75	5.7	38.8	74000	50000	325	57	388	10.9
		4.91	4.07	2.55	31	24500	18000	69	27	121	3.9

Table 3. Yazd houses and some important physical and climatic features

raw factor in determining the inside comfort conditions. In addition, it should be noted that, space cooling in summer is not a very important and necessary factor in Tabriz, but in Yazd, due to very hot summers, this factor could be an important parameter in the thermal comfort or overall thermal of a space, so HDD was analyzed also in second place. Response Factor is a parameter that Ecotech provides for a zone and show the accountability degree of that space in its space, and its impact on many results could be seen. Therefore, the comparative analysis was performed between two factors of the heat transfer coefficient and response coefficient.

2.3. The results of the heat transfer coefficient and the monthly day degrees analysis

Tables 2 and 3 show the sum of the physical conditions and spatial characteristics of each two houses. Some parameters, such as TSA, TWA, V, A and some proportions and relationships, such as TSA / TWA, V / A have been extracted from the comparison and analysis of relationships between variables that can effect on the internal comfort conditions. Between these variables, the researchers observed a correlation among heat transfer coefficient and monthly day degrees in both cities. In particular, this relation is stronger between day temperatures in the coldest month of the year, which means January, that this issue can be seen in Figures 3 and 4. The relation between the day temperature of the cold months, in each two houses and the eight Tabriz selected zones with a heat transfer coefficient is with a factor of approximation R2 = 0.833. While this approximation coefficient for Yazd houses zones is equal to R2 = 0.965. This equation is controlled for the day degrees of the warmer months of the year in both cities that as it can be seen in Figures 5 and 6, the approximation coefficient of equation accuracy was reduced, but, still, the nominal relation can be defined between these two.

In each pair of graphs, there is a direct relation with higher accuracy approximation coefficient between heat transfer coefficient

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and maximum monthly Day temperature in Yazd to Tabriz. Another series of comparative analysis, which was carried out to examine the relation between heat transfer coefficient and the response coefficient of each thermal zone, which for each zone, independently, it is provided by the software. By comparing the results, it was observed that, with a higher response rate in each zone, the temperature fluctuations, on certain days, such as the hottest, or coldest, most windy or most cloudy days are fewer and in receiving and loss diagrams of static energy, it shows more stable results. Finally, by examining the relation between heat transfer coefficient and response coefficient, as seen in Figures 7 and 8, a closer relation between heat transfer coefficient and response coefficient can be seen in the houses of Yazd.

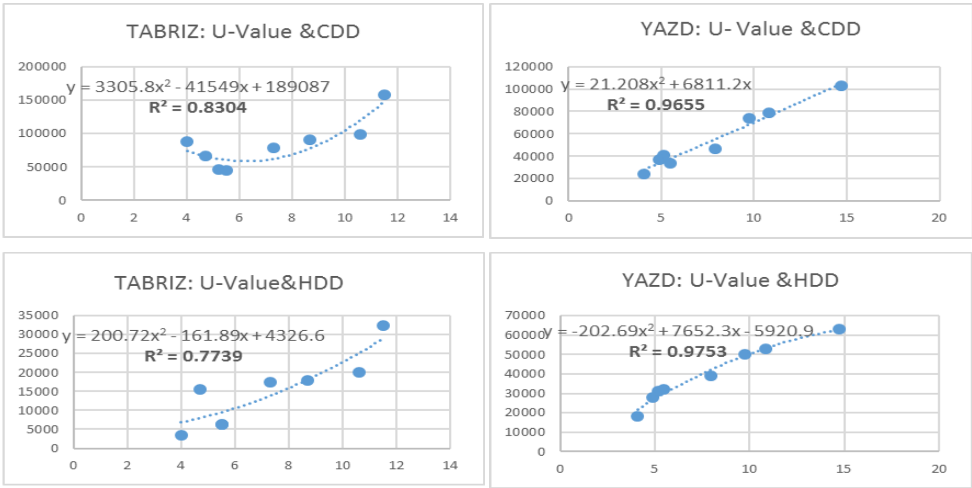
The plot shows less variance between heat transfer coefficient and response coefficient in the zone of Yazd and it can be concluded that the coefficient of heat transfer is a better factor to predict the internal comfort conditions, in hot and dry climates, such as Yazd, compared to the cold and mountainous climates such as Tabriz.

4. Results and discussion

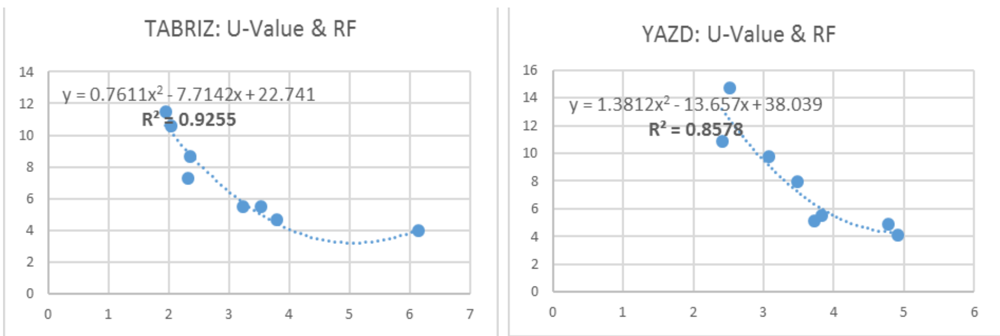
In both cities and the region, the results showed that, regardless of how much heat transfer coefficient of the space is less, the need for heating or cooling energy in summer and winter, would be less. Since the houses are traditional and most of their materials are brick and brick walls, we can say there is a relation between the coefficient of heat transfer and the total thermal mass of the space. There was a powerful relation between heat transfer coefficient and its impact on the monthly day degrees in Yazd. It means the houses of Yazd will receive more and more direct effect of heat transfer coefficient. As a result, a higher relation was observed between this factor and response factor in Yazd, compared to Tabriz, although in Tabriz, with a higher accuracy factor of anticipation, a relation between heat transfer coefficient and response coefficient of space can be seen. The high response factor of space showed more stable temperature in the charts, in total, according to the two relations, the impact of the heat transfer coefficient on the greater temperature stability, less need for heating and cooling in both of the seasons can be concluded and observed. In addition, as a useful indicator of evaluating the amount of energy required for heating and cooling, discrimination diagrams of receiving and loss of structures static are also analyzed. As in Figures 9 to 12 are clear, in all the houses of two cities , with a high overall response coefficient of the house, the received and wasted energy on heating and cooling are less, energy exchange fluctuations are reduced and the overall cycle of energy consumption, in general, is less. However, given the fact that the overall heat transfer coefficient of a space was a function of the type of materials, which are considered fixed, therefore, the ratio of the area with the glass, rather than brick had a direct impact on the area and among the houses of Yazd, the more windows area, its impact could be observed directly on the overall heat transfer coefficient, the monthly day degrees and the response factor of space.

Conclusion

In Tabriz, there is no relation with high accuracy prediction coefficient between the amount and area of the window and factors such as the total heat transfer coefficient and response factor of space. Perhaps this can be interpreted so that, windows had more impact on the interior comfort conditions in Yazd compared with Tabriz. They are not the only affecting factor in the internal conditions in Tabriz, so, for finding other factors, as well as more detailed analysis of the relation between the conditions and physical characteristics and comparative analysis of various factors, more studies and analysis can be performed. It is also possible to check and observe separately, in each city, factors such as TWA, TSA and V/ A, etc., that have a direct effect on the heat transfer coefficient, in more case studies on the overall heat



▲ Figures 3 and 4 (above), 5 and 6 (bottom): the relation between heat transfer coefficient and CDD, HDD: Both charts in both cities indicate the existence of a relation between heat transfer coefficient and the maximum monthly Day temperature hot and cold in each of the 8 zone of the cities.



▲ Pictures 7 and 8. The relation between heat transfer coefficient and response coefficient, in the houses of Yazd and Tabriz

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transfer coefficient, and finally, their impact on internal comfort conditions.

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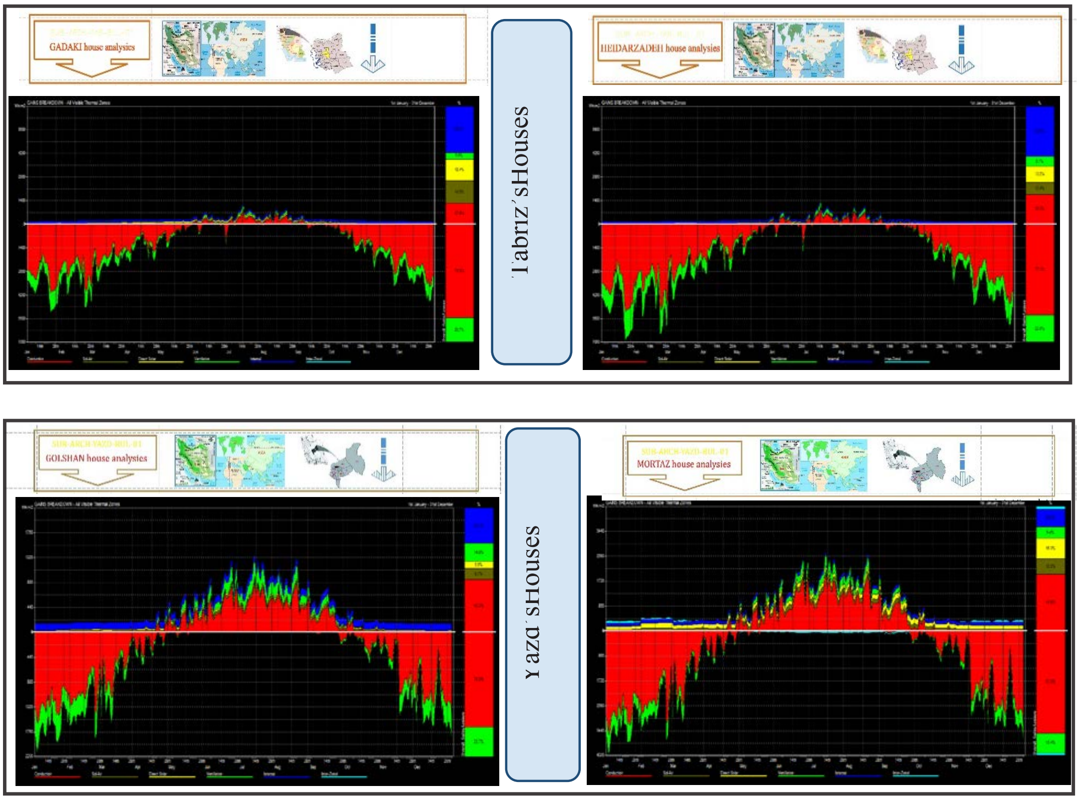

▲ Pictures 9 and 10 (above) and 11 and 12 (bottom): show the results of static energy denotative receive at homes in Tabriz and Yazd, with different climate features that, the more overall response factor of space is, it creates the better Thermal response of temperature, reduce volatility in energy waste and ultimately, the lower energy consumption on an annual cycle and thermal conditions and a better comfort.

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