International Journal of Architectural Engineering & Urban Planning, Volume 32, Number 3, 2022
DOI: 10.22068/ijaup.624

Research Paper

Comparison of Vernacular and New Construction Materials and Methods in Sub-Mountainous Areas of Guilan in terms of Energy Savings

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Received: January 2021, **Revised:** December 2021, **Accepted:** March 2022, **Publish Online:** August 2022

Abstract
Energy saving is one of the significant issues in achieving sustainable development. This study compares the energy consumption of rural houses using local materials and new ones in Guilan province, in order to investigate the effects of using local materials and techniques on reducing the amount of energy consumption. The present research method is quantitative, in which observation and computer simulation are used. In this regard, the features of vernacular and new rural houses of sub-mountainous areas of Guilan are investigated. This case study focuses on two houses located in the foothills of Guilan. Design builder software is used to compare the amount of energy consumption of vernacular housing methods and the newer ones. The results of this study showed that the amount of energy required for heating is much higher than the energy needed for cooling in this region, so the main focus should be on reducing the amount of required energy for heating. Based on the results of the simulation, walls and roofs are more sensitive to heat exchange. Galipoosh roof have a reasonable function in terms of energy consumption, while Darvarchin wall wastes more energy than new materials.

Keywords: *Vernacular house, Local materials, Energy consumption, Sub-mountainous region.*

1. INTRODUCTION

Sustainability is indissolubly linked to vernacular architecture and the lessons this architecture of the past can teach us for the future. The concept of sustainability as it is presented is wide-reaching and encompasses not only environmental issues but also sociocultural and socioeconomic questions. The lessons we can learn from studying vernacular architecture in these three broad spheres are manifold and can help us not only to further the conservation and retrieval of this architecture already in existence, but to rethink new architecture in the light of what we have learned (Mileto et al., 2014). Redfield points out that in primitive societies, there is collective environmental knowledge and every aspect of tribal life is everybody's business (Redfield, 1956).

Home is the heart of human settlements in which people accomplish all of their daily activities according to cultural, social, economic, natural, and climatic contexts (Torkashvand & Raheb, 2014). Village House is a safe and reliable "inner place" against "external environment" with the extent of the wild nature. The formation of the vernacular house is affected by a variety of environmental factors of three surrounding environments which are formed in different species based on special regional and local materials of the area by natives of the area. On the other hand, the home may be defined as the totality of (building) elements involving components that separate the indoor of the building from the outdoor. They are made according to various criteria such as environmental, technological, socio-cultural, functional or aesthetic factors (Mofidi, 2005). This implies that everyone is capable of building his own dwelling and usually does. Trades are hardly differentiated, and the average family has all the available technical knowledge. Since the average

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member of the group builds his own house, he understands his needs and requirements perfectly; any problems that arise will affect him personally and be dealt with (Amos, 1969). In vernacular buildings that have been constructed to meet a specific need we may see evolve over decades, or even centuries, structures that have been modified and adjusted in form and detail until they satisfied the demands placed upon them (Oliver, 2007).

The climatically compatible design is one of the closest ways of getting the optimum use of renewable sources of energy since consideration of climatic conditions is the main concern in sustainability (Khotbehsara et al., 2018). Different climates require different architectural responses. To satisfy the various necessities, vernacular architectures that developed through the centuries have many original and interesting design practices and technologies (Singh et al., 2009). Most settlers, from the ancient to the pre-industrial era, discovered the influence of climate on comfortable habitats, and these become factors, which affected the way they planned their built environment (Mofidi, 2005). Local climatic and historical conditions including local materials shaped the formation of vernacular houses as well as the philosophical and cultural aspects. These houses are mostly built by local users and they have evolved over time (Torus, 2011). Many vernacular housing environments employ passive technology that was developed for such purposes as safety, hygiene, the health of comfort by use of the limited technical resources which were available in the days before modern technology existed (Murakami & Ikaga, 2008). The vernacular building construction technique and specifications are more based on knowledge achieved by trial and error rather than conventional practices. Vernacular architecture provides a good solution to climatic constraints, and there is more than one approach to solving the same climatic constraint (Rakoto-Joseph et al., 2009). These kinds of structures evolve over time to reflect the environmental, cultural, and historical contexts in which they exist (Coch, 1998).

Often, remarkably sophisticated results are achieved with relatively simple technologies. This is sometimes evident in buildings that have been constructed in order to serve a technological purpose. It is not only in the use of energy that we can learn about the employment of natural resources, for most forms of indigenous shelters have to be constructed from available materials. In different regions, we can see the intelligent and sensitive use of stone, mud, timber and grasses, even animal hides. Many different methods and techniques have been developed, sometimes extending the potential of the material to its optimum capacity to serve as a load-bearing or cladding element. Many societies have achieved an ecological balance that maintains, in a steady state, the relationship between the availability of a resource and its consumption of it (Oliver, 2007).

When people are forced by an economic or environmental decline to migrate from the rural regions to the cities, they rarely share in the urban prosperity but suffer as the most disadvantaged of the populace. Without their skills and knowledge, developed and passed on by successive generations within the vernacular context, few would be able to build a dwelling or simply survive within the peri-urban squatter settlements which constitute a high proportion of target cities. Problems of the continually expanding and scarcely sustainable cities, though rarely addressed, are largely the outcome of the neglect or ignorance of the impoverished rural regions of the world (Oliver, 2007). Unlike the current urban architecture that produces too much man-made waste because of indolence and more convenient use of goods, in the rural, productive life of the past relied on efficient use of anything that exists around us, and surplus goods is the main element to restore or build another product elsewhere (Khakpour, 2006). Vernacular architecture in countries throughout the world is threatened. Advances in technologies support and encourage mass customization and mass production can be freed from unconnected and repetitive housing (Torus, 2011). For contemporary designers, the principles of vernacular architecture, since established on the basis of natural conditions, were supported by trial and error over thousands of years. These principles could become significant decision-making constituents for present and future developments (Mofidi, 2005). However, it may not be appropriate to adopt these models as readymade solutions for modern architecture. Our advanced technical capability and cultural context prevent us from returning to these old-fashioned architectural forms. But we can learn a lesson from the approach of the builders who acknowledged the interdependence of human beings, buildings, and the physical environment (Coch, 1998).

Iranian vernacular architecture achieved climate comfort conditions in interior spaces by using intelligent strategies adapted to the natural and social conditions of specific locations in which it exists. Different studies about Iranian vernacular architecture have revealed that bioclimatic is a critical parameter for achieving human comfort (Ghobadian, 1995). Variations of local climate, depending on altitude and proximity to the sea, have created a variety of bioclimatic design solutions which are specifically adapted to vernacular rural dwellings of specific regions. Besides the local climatic conditions, the topography in which the rural settlements have been developed changed the building form and led to various configurations which reflect the specific habits, needs, and way of living of the locals (Philokyprou et al., 2014). There are many lessons that can be learned from these houses where recent mass houses and apartment blocks are built numerously usually ignoring the environmental and cultural values and needs.

2. LITERATURE REVIEW

Sustainable development is a new concept with various perspectives in communities (Zolfani & Zavadskas, 2013). Due to the increasing pressure brought by recent global environmental problems, researchers and architects are embracing regionalism and the knowledge of traditional structures, arguing that these structures are energy efficient and highly sustainable. We observe clear evidence of the increasing interest in vernacular architecture among the research community (Nguyen et al., 2019)

The word 'vernacular' derives from the Latin "vernaculus", meaning 'native', so the definition 'native science of building' is really quite appropriate. In usage, however, 'vernacular' generally refers to the language or dialect of a people, while architecture is given a qualitative status. To bring some measure of neutrality into this term, Paul Oliver suggested 'shelter', which laid emphasis on the common motivation for the building of all the structures that man inhabits. He admits that it is not a satisfactory word, for it has associations of the rudimentary rather than the complex, the utilitarian rather than the aesthetically pleasing. In using the generally accepted phrase 'vernacular architecture', Oliver embraces all the types of building made by people in tribal, folk, peasant, and popular societies where an architect, or specialist designer, is not employed (Oliver, 2007).

Vernacular architecture presents basic and simple solutions for sustainable issues because it has significant environmental features that respond to sustainability such as low-energy techniques to provide human comfort (Halıcıoğlu, 2012).

In recent decades, many studies have been conducted in relation to vernacular architecture, often focusing on the environmental benefits which can be achieved from the recognition of vernacular architecture. These studies are conducted to investigate passive and bioclimatic design patterns of vernacular architecture to achieve a comfortable living environment, eco-friendly and energy-efficient architecture. A specific interest in the sustainability of vernacular architecture first emerged in the early 1980s, when a small number of studies that looked at the environmental performance of vernacular architecture were presented at the first PLEA (Passive and Low Energy Architecture) conference in Bermuda in 1982. These were followed, very soon after, by Hassan Fathy's Natural Energy and Vernacular Architecture (1986), which investigated the principles of vernacular climatic design in hot and arid countries. From the early 2000s onwards, significant growth in the interest in the sustainability of vernacular architecture is apparent, resulting in the publication of an ever-growing number of conference papers, journal articles, and books. One of the most prominent examples of these studies is the European Versus Project (2014) which encourages recognition of vernacular architecture. The main objectives of this project are to improve the recognition of vernacular habitats through the awareness of its values and qualities, focusing on both the heritage aspect and on what it could bring in terms of sustainability and disseminate principles, techniques, and solutions of the vernacular heritage in Europe so that they can be adapted to respond to real needs of European societies in terms of culture, identity, quality and environment (Correia et al., 2014). Its main objective is to gain knowledge from the fundamental principles of sustainability learned from the vernacular heritage and to explore new ways to apply these principles in modern sustainable architecture (Correia et al., 2014).

In Iran, also some studies have been conducted about vernacular architecture and its relation to sustainability. For example, Armagan (Gorji Mehelbani & Daneshvar, 2000), has investigated the values of vernacular architecture in relation to principles of sustainability.

One of the effective factors in the human life, health, and comfort is the climatic condition. A human being, directly and indirectly, has been affected by this condition (Ramezani et al., 2013). In Iran, various studies were done in the field of climate role in vernacular architecture. For example, Tahbaz (2003) in a chapter of "Climatic knowledge of architectural design" has studied vernacular architecture and its correspondence with different climatic regions of Iran (Gorji Mehelbani & Daneshvar, 2000). It described elements of the traditional architecture of Guilan and analyzed the impact of climate on the formation of these elements. So far, few studies have been done using the simulation method in order to investigate the thermal performance of local building methods and materials in Iran.

3. NATURAL ENVIRONMENT AND CLIMATE

According to Koppen's generally accepted classification of climate, temperate warm humid is abbreviated as C-type climate, is also called sub-tropical or Mediterranean, and is regarded as one of the main habitable climatic zones (Mofidi, 2005). In Iran, temperate and humid climate ranges from the plains along the Caspian Sea border to Northern foothills of Alborz. In these regions, moisture accumulates due to the short distance between the mountains and Sea. As a result, there are significant rainfalls. The spatial distribution of average annual rainfall in shoreline from west to east reduces while its time distribution is somewhat regular. Maximum rainfall happens in fall and the least rainfall happens in spring. In reviewing the temperature parameter, it is also observed that temperature is moderate and the temperature range is limited because of high relative humidity and a large number of cloudy days. This situation leads to warm summers and mild winters with rare frost (Falakian & Falakian, 2013).

Guilan province contains the northern foothills of the Alborz Mountains and the southern shores of the Caspian Sea. This province has an area of 13810/503 sq. km and is located between latitudes of about 36 degrees and maximum of 38 degrees and 27 minutes north and a longitude of 48 degrees and 32 minutes and a maximum of 50 degrees and 36 minutes east of the Greenwich meridian (www.gecomuseum.com. Guilan Rural Heritage Museum).

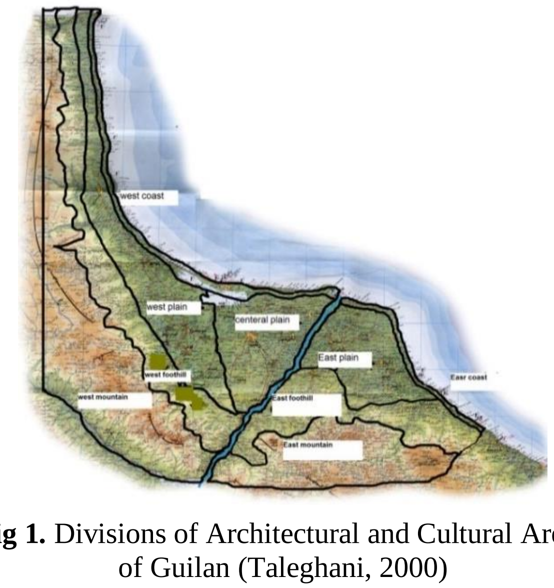

Fig 1. Divisions of Architectural and Cultural Areas of Guilan (Taleghani, 2000)

It is essential to classify the climates to understand their impacts on vernacular architecture. Guilan consists of two parts: mountainous areas which surround Guilan as the border and separate it from other provinces and the plain areas which stretch as a strip at the edge of sea and between sea and mountain from Astara to Tonkabon (Torkashvand & Raheb, 2014). Based on geographic boundaries, and division of microclimates from the perspective of basic climate (mild and wet), they have been approximately divided into the four coastal areas, mountains, foothills and plains, which each of them will be divided into western and eastern areas and exclusively central in the plains area in terms of broad geographic reach (Taleghani, 2009). Highlands of Guilan encompass the plains regions as a crescent wall from east to west and Sefid Rud Valley is the only way to the outside (Azimi Dobakhshari, 2006). Mountainous regions are the second topographical unit of Guilan in terms of area of land. Due to their specific geographic features, these areas play an important role in the formation of the cities of Guilan (Fateh & Dariush, 2008). Specific geographic location in the northern half of the subtropical region, southwest coast of the Caspian Sea, northern slopes of the Alborz Mountain, and east slopes of Talesh Mountain have resulted in a temperate and humid climate in this province (Fateh & Dariush, 2008). According to Gobadian (1994), climate is one of the most effective parameters in forming vernacular houses. Generally, climatic specifications of this region are:

- Extreme precipitation entire year, especially in autumn and winter
- High humidity ratio, the entire year
- Low diurnal temperature changes
- Extensive distribution of vegetation

4. CHARACTERISTICS OF ELEMENTS OF VERNACULAR BUILDINGS IN GUILAN SUB-MOUNTAINOUS AREAS

Local vernacular architecture is a cycle encompassing "life pattern", "form pattern" and nature. Some of these vernacular heritages may have remained stable in the face of a changing world, but some of them are threatened by extinction (Khatibi, 2012). Therefore, it is important to study the sustainable solutions of vernacular architecture. Local construction practices apply in a way that little aboriginal knowledge is used and non-local material and labor (skilled and unskilled) have a small role in these buildings (Torkashvand & Raheb, 2014). Establishment of vernacular architecture, often has a similar pattern in the total settlement. But this homology does not necessarily mean similarity, and buildings are different despite the fact that they have been built on the same logic (Torkashvand & Raheb, 2014). Climate has played and should play a significant role in determining the overall architectural form and fabric of the future sustainable urban areas and livable living style. In other words, vernacular and sustainable architecture in all climatic regions are mainly born out of the environmental conditions (Mofidi, 2005). Adaptation to climate conditions in the vernacular architecture of Gilan is the main reason for using all these solutions to use the environmental potential for providing comfort for its occupants, which are the main purposes of sustainable development (Khatibi, 2012).

Looking at the role of climate in indigenous settlements of Guilan, which are formed based on the uniformitarianism principles for the environmental comfort of residents in the basic body, and stability and compromise with the natural factors, as a basic and immutable principle over time, has created various species in its context based on the needs and availability of basic infrastructure. Different methods and climatic elements are used in buildings to provide a comfortable living condition. Such buildings act as a living organism that is inherently sustainable responding to various bioclimatic changes with a minimum waste of energy (Khatibi, 2012). In fact, relying on local materials, and the possibility of construction in Guilan, which is caused by environmental conditions, not only has led to a different appearance of the buildings in the area, but due to the abundant use of wood and plant fibers in the building, and special properties of these materials, methods of construction in Guilan is distinct from other parts of Iran (Soltanzadeh & Ghaseminia, 2016). Each element and principle according to its culture and history is unique, however, many of their physical patterns are similar to each other, specifically patterns of elements and strategies influenced by the environment. The results from the above process are the pieces that will be put together to provide guidelines for architectural configuration in a temperate climate (Soltanzadeh & Ghaseminia, 2016).

The features of the province of Guilan are coastal regions, plains, foothills, and mountains. The construction details and designs of housing spaces differed from region to region. Different types of architecture were also found in the eastern, central, and western parts of both the mountainous areas and the plains. However, there are also similarities in the building materials, shape of roofs, and foundations that were used (Nazidizaji et al., 2014). Some of the most important attributes of Guilan, which impact the architecture of this region, are summarized as abundant rainfalls in all seasons especially autumn and winter and low-temperature differences between nights and days in all seasons (Khotbehsara et al., 2018). Guilan’s architecture is a green and extroverted kind, in direct contact with the outdoors (Naserian & Nikmarm, 2010). Some of the general characteristics of Guilan’s architecture include sloping roofs, light, open spaces in the fourth round of buildings (or sometimes two rounded roofs), vertical buildings (usually in two floors), and orientation to gain a great deal of sunlight and to avoid rainy winds. Moreover, there is no subterranean floor in this region. Over the years, high humidity, wet soil, and overwhelming rivers have prompted the local master builders to keep the floor high above the ground (Karbalaee, 2011). All buildings in Guilan province are built with a view to gaining airflow as a kind of a natural fan. House plans are vast numerous openings for the gentle breeze coming from the Caspian Sea (Fateh & Dariush, 2008). It is important for the vernacular architecture of Guilan to provide ventilation to reduce the humidity. Therefore, the construction of balconies in this rainy region is considered an important matter to prevent rain penetrations into the interior spaces, reduce the humidity, and the entrance of north-east winds to the interior spaces in summer. Thus, it is obvious why most of the balconies are located on the east side of this region (Khotbehsara et al., 2018).

Vernacular architecture of the plains and foothills of Guilan have differences due to different weather conditions, different kinds of living, and the types of available materials. These differences are in the type of materials and construction methods. The foothills of Guilan are divided into western and eastern parts, which despite the similarity in general characteristics, have some differences. Construction methods and materials used in rural houses of sub-montane regions of Guilan are explained as follows:

4.1. Foundation

Generally, the closer it gets to the sea from the foothills, the air humidity reduces, and the depth of the groundwater increases. And that's why the floor height of the ground floor of the buildings reduces from the plain areas to the mountainous regions (Ghobadian, 1995). Foundation of sub-montane rural houses often is strip foundation and base course. In this method, the ground is due to a depth of 50 to 60 cm and gets filled with stone and cement mortar or lime or mud (Torkashvand & Raheb, 2014).

4.2. Wall

There are two types of vertical surfaces in Guilan architecture, according to how open or close the houses are. One type is found in the central core, which is rigid, and the other is a permeable surface in the outer envelope of the building. The outer vertical surfaces control the influence of the external environment within the building. Interior walls divide the building's internal spaces. Each of these surfaces has special characteristics (Pirnia & Memarian, 1998). The walls of the core are formed of round timber sections covered with a coating made from local materials, usually a mixture of clay, water, and straw. This was finished off with a coat of whitewash made with water, lime, and a little salt. This finish was used for the main façade of the building as well as the guest rooms and hall. These walls are classified as either Davarchin (Zagme) or Nefar (Zegal) depending on how they are constructed (Nazidizaji et al., 2014). In the sub-montane and mountainous regions of Guilan province, different types of walls can be seen in terms of materials and procedures. The types of walls are chosen based on climate, materials, and techniques which are available. These methods are explained below:

- Zagme (Darvarchin) wall: This structure is used in mountains and forests. In "Risi" wall logs are placed on each other and intervals between them are filled with mud. This structure needs lots of wood and doesn't have enough efficiency. It's too heavy, its performance is very hard and provides few opportunities for openings (Torkashvand & Raheb, 2014).
- Zegal wall: These walls are composed of wooden frames formed from vertical and horizontal beams, and tree branches spaced 10 to 15 cm which are fastened diagonally to the inner and outer surfaces of the main beams. The space between the two sidewalls is filled with thatch and then a layer of plaster and rice hulls and finally, lime plastering is pulled on it (Ghobadian, 1995).

4.3. Roof

The form of vernacular roofs in this region often is a Hip roof (four sides slope downwards to the walls). With regard to the structural behavior of the building, the roof structure is often independent of the internal partition walls (Nazidizaji et al., 2014). A common type of roof has four sloping surfaces which are more effective for rainfall runoff, as well as preventing water from getting inside the house. The roofs differ in terms of the skeleton and their final covering. The sloping roof is supported by a timber structure consisting of timber beams and posts. The small distances between columns, as well as the use of timber beams and columns, resulted in the characteristic proportions of this architecture. The simplest type of sloped roof is seen in primitive structures. Antenna-like columns standing on horizontal beams support the roof. Slanting rafters, whose top ends are joined to the ridge, are placed on top of the horizontal beams. The ridge is supported on top of these rafters. A more advanced type of roof has a combination of vertical posts with several parallel trusses. When the roof structure has a double-slope, two further posts are added on either side of the central column (Nazidizaji et al., 2014).

The final covering of roofs in mountainous and sub-montane areas and closed areas to the jungle is generally a "Late Sar roof" composed of wooden pieces arranged on wooden truss (Ghobadian, 1995). One of the disadvantages of this roof is the loss of heat from the space between pieces of wood, which can be removed by the use of thermal insulation of the internal side of the roof. Another disadvantage of this type of roof can be pointed to the rotting of wood coating. In other countries, a protective coating against moisture is used to prevent the decay of wooden pieces. The Gâli roofs are fairly steep since this region has heavy snowfalls every 20-30 years. Simple forms of steep roofs prevent snow from accumulating in the corners and prevent water from melted snow from seeping into the building. The steep roof usually extends down to the ground on one or two sides of the building to keep out rainwater that could be driven into the building by the wind, and these sides of the building have no windows. The roof covering is usually made with straw (Veli, a local plant fiber) and rice stalks. After the four rafters are in place, bundles of straw or thick branches are laid about 20 cm apart. All the connections are made with Verees, using rice stalks. As a final cover, bundles of rice stalks, or Gâli in rural homes, are placed on the *Jar* to form a thatched roof. The bundles of Gâli are tied like a besom, and placed between the *Z* gâls, overlapping one another like roof tiles or Rice stalks (Nazidizaji et al., 2014).

In most recent houses, roofs are made of terracotta. One of the advantages of the terracotta roof is its durability. It can last for many years and retain its beauty and strength. Having two layers of terracotta on each other and a relatively thick layer of the straw bunch, it is a good heat and sound insulation. One of the disadvantages of terracotta is its high price. In addition, due to the lack of connection between terracotta and truss, the effects of lateral forces such as earthquakes and wind replace the tiles (Falakian & Falakian, 2013).

Fig 2. Shingled Roof in Kanrood Village (Source: Authors)

Fig 3. The Terracotta Roof in Garesoo Village (Source: Authors)

5. NEW MATERIALS AND CONSTRUCTION METHODS IN SUB-MOUNTAINOUS AREAS

In recent decades, construction methods and materials have changed. Torkashvand and Raheb have divided the rural housing construction practices and materials used in rural houses of Guilan province into three major groups: indigenous, eclectic, and modern (Torkashvand & Raheb, 2014). The eclectic method of construction includes buildings that are extensions of vernacular constructions. In fact, these buildings are combinations of traditional and new methods and materials. Eclectic architecture in Guilan villages is being replaced by new methods and materials. Feathers of new rural houses in sub-montane areas are explained below:

1. Roof: In the new house of Guilan often tin plates are used on wooden trusses.
2. Wall: brick and clay blocks are used to construct the new building walls.
3. Foundation: Foundations are made of reinforced concrete.

Fig 4. A New Rural House in a Village around Rasht, (Source: Authors)

Table 1. Elements of the New Rural Houses in Sub-mountainous Areas of Guilan, (Source: Authors)

Elements	characteristics
Foundation	Reinforced concrete
Roof	Sloping roof on wooden truss structure and covered by tin plates.
wall	Made of cement block and the outer layer of the south facade is covered by stone.
porch	Porch often is located on one side of the building and usually in the recess.
Spatial organization	Rectangular plan, kitchen, living room, and sewing workroom are on the ground floor, and the master bedroom is located on the first floor.

6. CASE STUDY

Generally, vernacular construction techniques in each region have a similar pattern. Due to the pace of construction in this area, few buildings remained intact. In this study, two vernacular houses are selected in the west and east foothills of Guilan. These houses have a long history and employ vernacular construction methods and materials. Information on the houses is taken from the Rural Heritage Museum of Guilan. The architectural features of vernacular houses are explained in Table 1.

Fig 5. Tarabi House, West Foothills, KishRoodbar, Fouman (Source: the Guilan Rural Heritage Museum)

Fig 6. Behzadi House, East Foothills, Chalkasar, Roodbar (Source: the Guilan Rural Heritage Museum)

Table 2. Characteristics of the Sample Vernacular Houses in Submontane Areas of Guilan (Source: Authors)

features	Tarabi house	Behzadi house
Region	West foothill (Fouman)	East foothill(Roodbar)
Building height	8.3m	About 7m
Wall	Darvrchin(zagmei)	Darvrchin(zagmei)
Roof	Galipoosh	Late(wooden pieces made of beech with dimensions of 20 x 40)
Floor	wooden	wooden
Foundation	Channel to a depth of 20 to 40 cm, fills with a layer of stone and a layer of mortar	aligning the ground with stones
And implementation of the barn walls on it		
Orientation	to the southeast	the East (with the rotation of 10 degrees to the north)

7. MATERIALS AND METHODS

Considering climatic comfort in architectural and building design is the subject matter of many studies that clarifies its significance (Shakor, 2011). The building envelopes are the first defense lines against outdoor climatic parameters. This research compares the thermal performance of vernacular building envelopes with new ones in terms of the amount of energy consumption in rural houses. The aim of this study is to investigate the thermal performance of vernacular building envelopes in order to utilizatize vernacular patterns to achieve climatic comfort and optimal thermal performance in architectural design. The main questions of the study are how is the thermal performance of vernacular building shells in comparison with new ones and what lessons can be learned from local materials and construction techniques?

The method of the present research is quantitative. In order to compare shells of vernacular and new buildings, energy consumption and thermal energy exchange of rural buildings using local and new materials are assessed.

Buildings are simulated on two levels; initially, selected buildings with existing materials are simulated and in the next step, building materials are changed into new materials, and the two buildings are simulated again. Design builder software is used to study the amount of energy consumption, and according to the Energy Plus analysis engine, the zonal method is used to solve the energy equations. To simulate the energy consumption of samples, climatic parameters of areas of study have been used. These parameters include temperature, solar radiation, relative humidity, wind speed and direction, height from the sea, etc. which include all days and hours of the year.

The area of study is the sub-mountainous regions of Guilan province of Iran. In this regard, architectural specifications of vernacular rural houses in the areas of the study are explained. Then, features of new rural houses in the area of study are assessed.

In order to achieve the aim of the research, two samples of rural houses located in sub-montane areas of Guilan are selected and the thermal function of these houses is simulated using design builder software. The two selected houses are samples of a few remaining examples of vernacular traditions that have been studied by the Rural Heritage Museum of Guilan. The selected samples are common types of vernacular housing in sub-montane areas.

8. DATA ANALYSIS

The results of thermal simulations are presented in the charts below. Based on the results of simulations, the heat exchange of different parts of the building was determined. In the charts, negative numbers indicate heat loss from the building and positive numbers are indicatives of heat gain.

During the day, building shells gain energy, but they lose indoor energy at night. The sum of receipts and losses of energy in each building shell is a specific number and positive or negative signs show the resultant energy gain and loss in the shell.

In these charts, red spots indicate the maximum energy gain and blue spots show the maximum energy loss during a year. The closer positive and negative numbers are to zero, the more desirable are the results.

9. RESULTS AND DISCUSSION

9.1. Simulation Results of Tarabi House

Tarabi house consists of two rooms. One room is located on the first floor and the other one is on the top floor (Mousavi& Chehreara, 2016: 40). The ground floor includes a winter room and barn and the top floor is used as living space in summer. According to the simulation results, the overall energy consumption of the building during the year by the use of local materials is 71.57 KWh lower than that of new materials. The building extremely needs energy for heating, while there is little need for cooling energy. By changing local materials into new ones, energy loss increases from all shells, especially in the metal roof (Chart 1). According to Chart 2, by changing the materials of vertical shells, we have little change in energy consumption.

Table 3. Physical Features of Materials of Tarabi and Behzadi House

Elements	materials	Thickness (m)	Specific Heat (J/kg.k)	Density (kg/m^3)	Thermal conductivity (w/m.k)
Darvarchin wall	mud plaster	0.05	2085	1500	1.5
	timber	0.15	2390	700	0.19
	lime plaster	0.05	1000	1000	0.65
	plaster	0.02	1000	1000	0.4
Ground floor wall	timber	0.15	2390	700	0.19
Foundation	rubble	0.3	180	2050	0.52
Floor	oak wood	0.2	2390	700	0.19
Roof	tiny branches	0.1	1300	290	0.055
	large branches	0.3	1200	650	0.14
	Oak branches		2390	700	0.19
Window	Single glazed clear glass	0.06	1.1	2700	5.9
Door	oak wood	0.05	2390.00	700	0.19

Source: Library of Design Builder Software (ASHRAE Standard Materials)

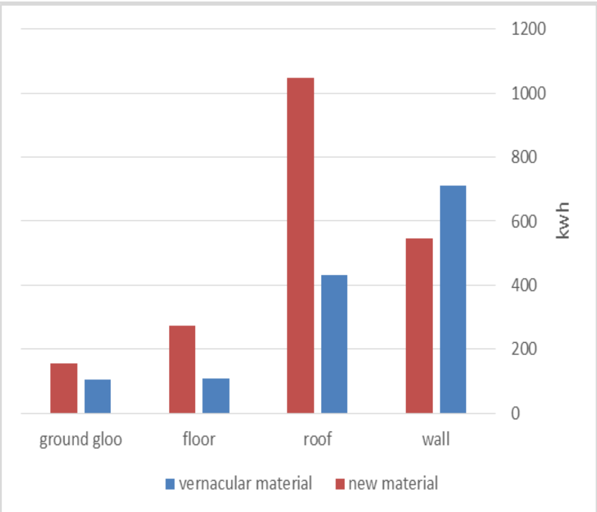

Chart 1. Comparison between Annual Thermal Energy Exchanges of different Shells in Tarabi House

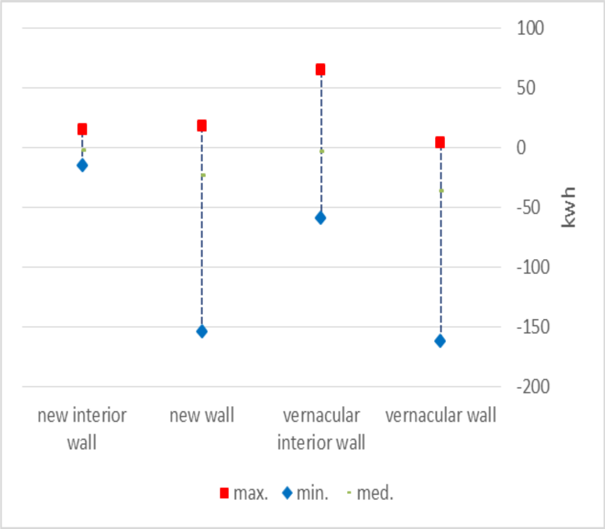

Chart 2. Annual Exchange of Thermal Energy of Tarabi House within Vertical Surfaces

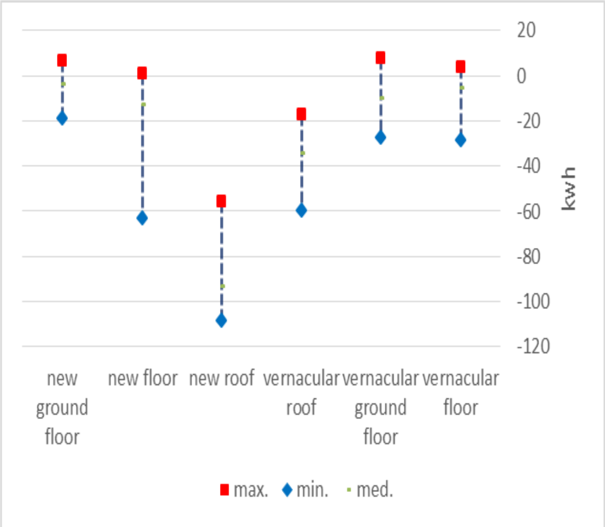

Chart 3. Annual Exchange of Thermal Energy within Horizontal Surfaces of Tarabi House

Horizontal shells are more sensitive to heat exchange. Horizontal shells including floors between stories, ground floor, and ceiling using new and local materials have significant differences in energy consumption. The roof with new materials wastes more energy than the other one with horizontal elements (Chart 3).

Heating and cooling are only needed in one room of Tarabi House. On the other hand, keeping animals such as cows and poultry on the ground floor generates heat. These two factors influence the amount of energy consumption in the house.

9.2. Simulation Results of Behzadi House

Behzadi House was built in 1315. It has a height of about 7 meters and has been built into two stories. The main activity of this family has been farming and wheat. The family lives in upstairs. Simulation of the thermal behavior of Behzadi house gives different results. According to the results, the overall energy consumption of the building during the year with indigenous materials is approximately 5 kilowatt-hours more than with new materials.

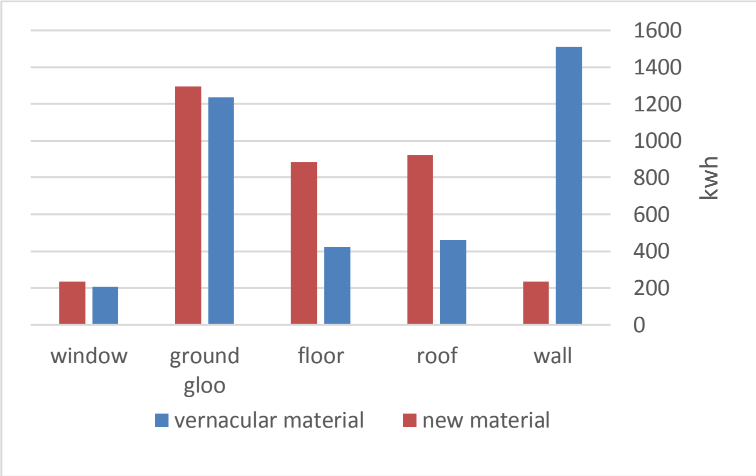

Chart 4. Comparison between Annual Thermal Energy Exchanges of different Shells in Behzadi House

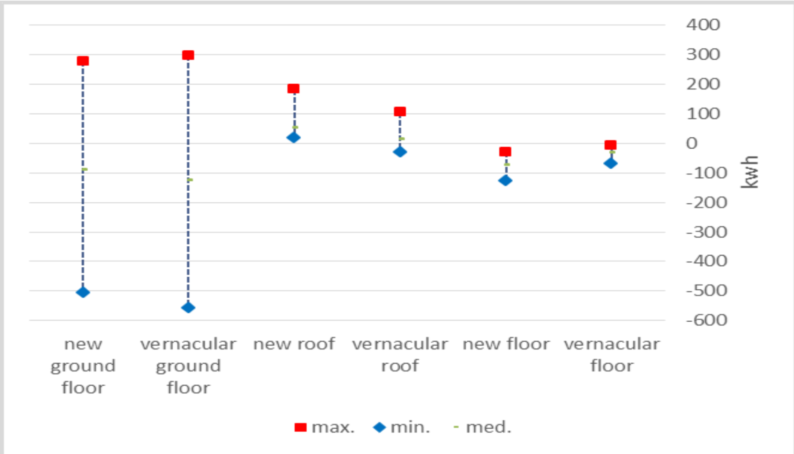

Chart 5. Annual Exchange of Thermal Energy of Behzadi House within Horizontal Surfaces

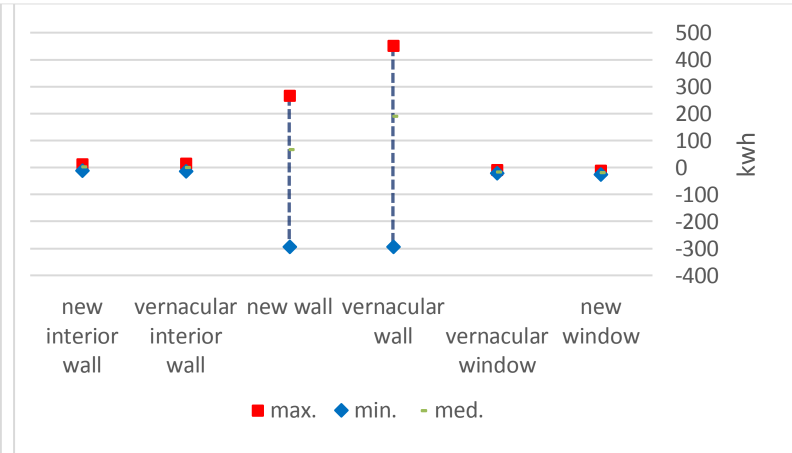

Chart 6. Annual Exchange of Thermal Energy within Vertical Surfaces of Behzadi House

This building needs a lot of energy for heating, while much energy for cooling is not required. By changing local materials to new materials, the energy loss of all shells rises, but the case is different for walls. The construction method of wooden walls of this building increases the heat exchange much more than new materials (Chart 5). According to Chart 6, the horizontal skins of the building do not show much difference after changing the materials. Energy loss in the wall with local materials is more than 200 kilowatt-hours than new materials.

10. VALIDATION

To explore the thermal behavior of buildings, simulations should be established on a strong basis. In order to verify the accuracy of simulation software, the simulated results should be measured with acceptable criteria. In order to validate the software, a field study is used to select the appropriate test. The selected building is a house around Fouman which is located in the area of study. This house is built with new materials and construction methods. Gas and electricity are the main sources of providing heat in this building.

Therefore, by collecting gas and electricity bills of the building, the monthly energy consumption of the building is estimated. In the next step, sample building was simulated by the design builder modeling and simulation software with Fouman weather data. Charts 7 and 8 compare the simulation results and show the energy consumption in gas and electricity bills.

By comparing the simulation results and the electric bills, there is an average of 0.47% error in calculations. By comparing the numbers reported in the bills and the calculated electricity consumption, an average of 1.25% difference can be seen. Based on Table 4, there is an average of 1 percent error in the calculations of simulation software, which is within the acceptable range.

Fig 7. Rural House Kordabad, Fouman, (Source: Authors)

Table 4. The Difference between the Simulation Results and the Total Reported Energy Consumption

month	total report	total software result	difference	error percent
Jan	3381.256	3468.727	87.47	2.59
Feb	3302.265	2951.823	350.44	10.61
Mar	1918.326	2667.77	749.44	39.07
April	2001.327	2139.419	138.09	6.90
May	2368.265	2285.874	82.39	3.48
Jun	2761.231	2688.889	72.34	2.62
Jul	3382.265	3238.355	143.91	4.25
Aug	3144.326	3219.074	74.75	2.38
Sep	2279.256	2390.372	111.12	4.88
Oct	2154.156	2210.732	56.58	2.63
Now	2527.265	2334.019	193.25	7.65
Dec	3168.194	3117.276	50.92	1.61
	32388.13	32712.33	324.20	1.00
			error percent	1%

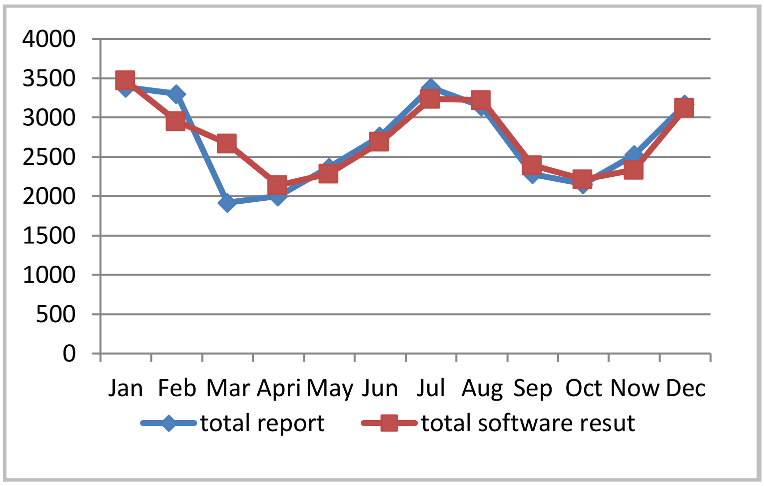

Chart 7. Gas Consumption Validation Test

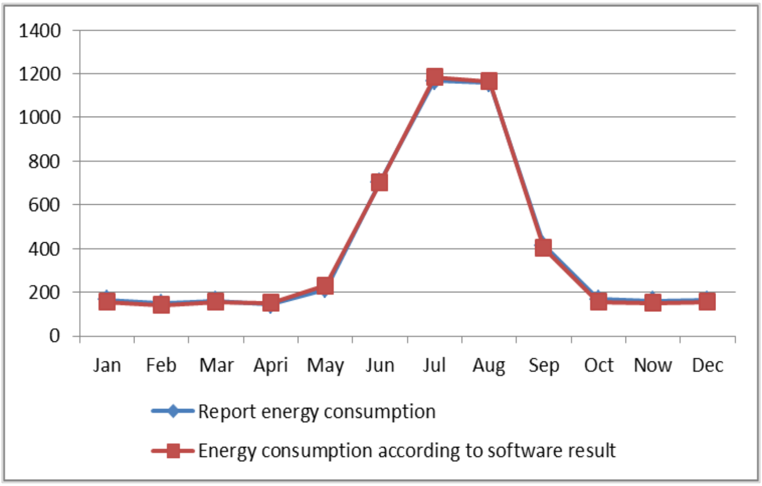

Chart 8. Electricity Consumption Validation Test

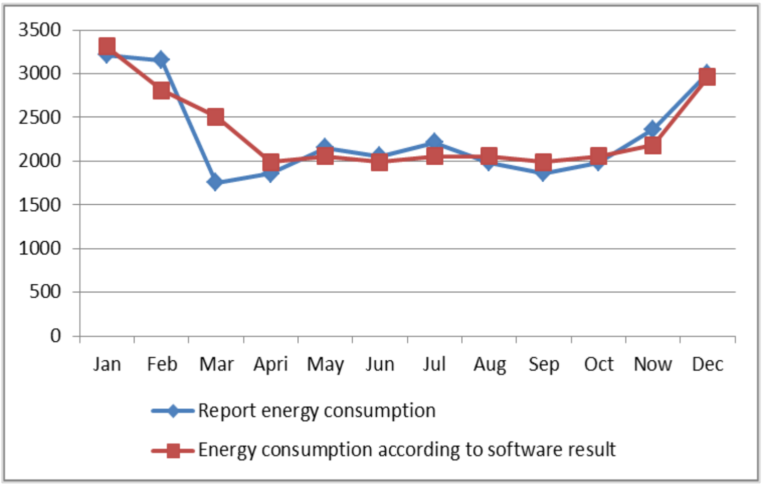

Chart 9. Comparison between Bill Reports and Software Results (Source: Authors)

11. CONCLUSION

Due to the temperate and humid climate of Guilan province, the amount of energy required for heating is much higher than the energy needed for cooling in this region. The simulation results also confirm this deduction. So, the main focus should be on reducing the amount of required energy for heating.

This study aims to compare the impact of vernacular and new materials on the amount of energy consumption. Parametric studies are used to prove that:

1- Darvarchin wall which is built of timbers doesn't have an appropriate function in terms of energy exchange. Wood has low thermal inertia, so the energy exchange through the Darvarchin wall is more than walls made of new materials.

2- The thermal performance of tin plate roofs which are implemented in most of the new houses, is very poor. Especially in summer, tin plates absorb heat rapidly and this heat is transferred to indoor space and increases energy consumption.

3- The heat loss from the Galipoosh roof which covers vernacular roofs is substantially less than the roofs covered with tin plates that are implemented in new homes. This is due to air between the rice stalks that acts as thermal insulation.

4- Thermal performance of wooden roof (Late Sar) is better than a tin roof.

5- The greatest energy loss in the two houses takes place through the walls, which are associated with uncontrolled space (outside). In Behzadi House, the area of walls between the controlled and uncontrolled space is more than Tarabi house. So walls have a greater impact on the amount of heat exchange.

Generally, vernacular methods and local materials studied in this research (except walls) had better thermal function than new materials. The results of this study can be used to improve the current architecture of Guilan.

REFERENCES

Amos, R. (1969). House Form and Culture. *Englewood Cliffs (NJ)*.

Azimi Dobakhshari, N. (2006). *Natural geography of Guilan*. Fahange Ilia.

Coch, H. (1998). —Bioclimatism in vernacular architecture. *Renewable and sustainable energy reviews*, *2*(1-2), 67-87.

Correia, M., Dipasquale, L., & Mecca, S. (2014). Versus: heritage for tomorrow: vernacular knowledge for sustainable architecture. *Versus*, 1-286.

Falakian, N., & Falakian, A. (2013). A Study on Climatic Design in Traditional Architecture of Temperate and Humid Climate. *International Research Journal of Applied and Basic Sciences*, *5*(10), 1318-1322.

Fateh, M., & Dariush, B. (2008). Rural architecture. *Elmo danesh press*.

Ghobadian, V. (1995). Climatic analysis of the traditional Iranian buildings, Tehran. In: Tehran University press, p13.

Gorji Mehelbani, Y., & Daneshvar, K. (2000). The impact of climate on the formation of elements of traditional architecture of Guilan. *Armanshahr*, 135-145.

Halıcıoğlu, F. (2012). Analysis of Vernacular Architecture in Terms of Sustainable Considerations: The Case of Sirince Village in Western Turkey, Alam Cipta. *International Journal of Sustainable Tropical Design Research and Practice*, *5*(2), 39-54.

Karbalaee, F. (2011). *Human and architectural settlements: a case study of Guilan, Iran"* The Asian conference on arts and humanities official conference proceedings.

Khakpour, M. (2006). Construction of Shekili Houses.

Khatibi, S. (2012). Vernacular architecture values. *International Journal of Architecture and Urban Development*, *2*(4), 39-42.

Khotbehsara, E. M., Purshaban, F., Nasab, S. N., Daemei, A. B., Yakhdani, P. E., & Vali, R. (2018). Traditional climate responsible solutions in iranian ancient architecture in humid region. *Civil engineering Journal*, *4*(10), 2502-2512.

Mileto, C., Vegas, F., Soriano, L. G., & Cristini, V. (2014). *Earthen Architecture: Past, Present and Future*. CRC press.

Mofidi, S. (2005). Responsive and sustainable architectural strategies for temperate regions.

Murakami, S., & Ikaga, T. (2008). Evaluating environmental performance of vernacular architecture through CASBEE. *Institute for Building Environment and Energy Conservation. http://ibec. or. jp/CASBEE/english/document/Vernacular_Architecture_brochure. pdf*.

Naserian, F., & Nikmarm, P. (2010). Rural dwellings' comparison in Iran different climate. First international conference on rural settlements: housing and fabric, Tehran, Iran.

Nazidizaji, S., Tomé, A., & Regateiro, F. (2014). The architecture and construction processes of the vernacular Shikili Houses in Gilān, northern Iran. *Construction History*, 63-82.

Nguyen, A. T., Truong, N. S. H., Rockwood, D., & Le, A. D. T. (2019). Studies on sustainable features of vernacular architecture in different regions across the world: A comprehensive synthesis and evaluation. *Frontiers of Architectural Research*, *8*(4), 535-548.

Oliver, P. (2007). *Built to meet needs: Cultural issues in vernacular architecture*. Routledge.

Philokyprou, M., Savvides, A., Michael, A., & Malaktou, E. (2014). Examination and assessment of the environmental characteristics of vernacular rural settlements. Three case studies in Cyprus. *SB14*, 1-8.

Pirnia, M. K., & Memarian, G. (1998). Investigating About Traditional Architecture of Iran. *University of Science and Technology Publication*.

Rakoto-Joseph, O., Garde, F., David, M., Adelard, L., & Randriamanantany, Z. (2009). Development of climatic zones and passive solar design in Madagascar. *Energy Conversion and Management*, *50*(4), 1004-1010.

Ramezani, B., Yehkohan, F. M., & Shafaghati, M. (2013). Assessing and feasibility of climatic comfort in Bandare Anzali by effective temperature model and evans. *International Journal of Agriculture and Crop Sciences (IJACS)*, *6*(12), 825-832.

Redfield, R. (1956). Peasant society and culture: an anthropological approach to civilization.

Singh, M. K., Mahapatra, S., & Atreya, S. (2009). Bioclimatism and vernacular architecture of north-east India. *Building and Environment*, *44*(5), 878-888.

Soltanzadeh, H., & Ghaseminia, M. (2016). Climatic Building Envelope Employed in Vernacular Residential Architecture in Golestan-Iran.

Taleghani, M. (2000). Amini house, Tehran. *Rosanne Peress.*

Taleghani, M. (2009). «Guilan» rural architectural heritage publication. *Farhangestan-e Honar*, *1*.

Torkashvand, A., & Raheb, G. (2014). Typology of rural houses of Guilan province. *Housing Foundation of Islamic Revolution*.

Torus, B. (2011). Learning from vernacular Turkish House: Designing mass-customized houses in Mardin.

www.gecomuseum.com. Guilan Rural Heritage Museum.

Zolfani, S. H., & Zavadskas, E. K. (2013). Sustainable development of rural areas' building structures based on local climate. *Procedia Engineering*, *57*, 1295-1301.

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HOW TO CITE THIS ARTICLE

Zohari, S., Azemati, S. (2022). Comparison of Vernacular and New Construction Materials and Methods in Sub-Mountainous Areas of Guilan in terms of Energy Savings. *Int. J. Architect. Eng. Urban Plan,* 32(3): 1-15, https://doi.org/10.22068/ijaup.624

URL: http://ijaup.iust.ac.ir