Method of creating vernacular houses pictograms based on “climate – form” impact and relationship: houses’ pictograms; Part 1

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Abstract

The purpose of this paper is to present a method of creation of a pictogram system describing architectural form components of vernacular houses; those components acquire their form due to influences imposed by a particular climatic context. Many books and articles have been written on the topic but they suffer from one of the following disadvantages regarding the current goal: they are too comprehensive and specific or they are oriented towards particular philosophical or cultural thinking. The pictograms proposed in this research are on the other hand based on a global approach of many views of a specific problem such as form, scale, enveloping, openings and others.

The research method is based on the existing literature, important guidelines for creating pictograms in general, and a unique investigation of 87 vernacular houses. A template for the extracted data about their form, function, structure, composition and technology is used for this investigation. Following established methods, it is proposed to use (and respectively exclude) some of the climate influences which may or may not be relevant to certain house's features.

A set of pictogram rules has been created and based on them ten houses' pictograms from different climate zones and different continents were created as a test.

The pictogram method of studying vernacular houses provides an important global overview of the most essential house members generated in reaction to the climate. It allows for rough estimation and partial comparison in order to spread an indispensable foundation for future deeper research.

This research will ultimately lead to the creation of a world map of vernacular houses' pictograms as an electronic source, which is further explored in part 2 of this study.

Keywords: vernacular, traditional, house, hut, dwelling, pictogram, ideogram, sign, climate, zone, nature, form, impact, influence, relationship, map;

1 Introduction;

The purpose of this paper is to present a method of creation of pictogram system describing architectural form components of vernacular houses; those components acquire their form due to influences imposed as a result of climate elements' impacts. There has been no complex study to date which provides a system allowing a pictogram representation for all vernacular houses.

There are features of each building related to its main elements and members. Here, the characteristics of the vernacular houses' components (elements and members) deriving from the climate are studied in order to define a unique combination for each house's members. The importance of this is to classify the vernacular houses depending on the climate conditions that

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arise and to obtain a general view of two specific aspects: 1) How does a combination of components' features define the house's reference to the climate? and 2) What are the dependencies for defined houses' features around the globe due to different climate types?

This system of pictograms can provide scientists, practicing architects, and other professionals with the opportunity to compare vernacular houses in a "quick overview pattern" fashion. Thus, general observations can be made leading to general principles which conclusions can be drawn from, while delving deeply into either one house type or a region to obtain practical and concrete results.

The system of pictograms will be incorporated into a world map, for example, to create a *.kmz file [198] within Google Maps to provide a widely accessible resource.

Some of the building components (single or multi-storey houses, roof form, and incline) have been previously studied and shown on a map. However, there is no complex study to date providing a system which allows a pictogram representation for all vernacular houses.

What is proposed here is the first part of two parts of a full study, which will provide architects and other professionals with a world map presenting each of the houses summarized using pictograms deriving from their form and matched to their locations. This is the first and most straightforward step to find similarities, differences, and/or relationships within this architectural diversity. Furthermore, this first part presents an approach to extracting the direct dependence of "form component X" from "climate element Y" to enable the relationships between vernacular houses around the world to be shown by pictogram. The second part of the study will be focused on the creation of a world map following the principles outlined here.

Many articles and books have been written in the domain describing general dependencies of the form in response to climate [1,2,3,43,190,195].
Encyclopedia of Vernacular Architecture [1], a work of Vellinga, Oliver and Bridges, is the most comprehensive and detailed book in the domain of vernacular architecture. It is written from a philosophical point of view about the significance and importance of vernacular architecture in general. An idea of following cultural regions in order to acquire a good systematization of the building types was firstly presented here. Examples of different houses are given in each of the regions in terms of investigating plans and space, assembly and structures, vernacular materials (e.g. earth and clay, adobe blocks, fired bricks, cob, sun-dried bricks; straw, and thatch). An alternative idea of non-vernacular material use is proposed (e.g. cement, glass, plywood and corrugated iron) as a possible sustainable approach using vernacular principles and alternative building materials.
The main advantage of this book is its huge collection of examples collected with a multilateral approach. Vernacular houses are discussed in their cultural, formal, material, structural, technological, symbolic and many other aspects and nothing has been missed as is normally accepted for an encyclopedia. It was an irreplaceable source for this paper. A disadvantage of this publication is the lack of an established template for investigating the houses, since the importance was on the regions, materials and other categories which are listed following the house examples. It might be better to have a methodology for investigation providing a possibility to compare different houses, even regions of similar houses, building techniques etc. Even better could be a cross examination of similar groups, families and types of houses, focusing on their predominant and secondary properties.
This is one of the main reasons for creating the pictograms method, as it could fill some gaps and genuinely amplify existing knowledge.

Atlas of Vernacular Architecture [2] is the closest in meaning to this paper. In this text are presented world maps displaying climate; water, soil, vegetation resources, population, economy, language, and religion regions. There are also comparisons between vernacular houses based on form, plan, materials, technologies, etc. There are some specific investigations of roofs (pitched, hipped or

vaulted) and vertical order of the spaces in the houses depending on the cultural region. The overall contribution of the book is a cultural world map and its connections to all the mentioned categories, but it does not have classified and ordered information specifically about the "climate – house form" dependences, even though they are mentioned and explored. The atlas is a good keystone for any paper in the domain. Thus, it could provide the best framework for judging the pictograms effectiveness.

Victor Olgyay's book, *Design with climate: bioclimatic approach to architectural regionalism* [3] was first published in 1962. The focus in this book is on climate relevance to the human body rather than on house types and case studies. Nevertheless, the book is a fundamental work that classifies climate elements and proves its importance for building design.

The book, *Dwellings: the house across the world* [43], authored by Paul Oliver, presents chosen house types across the world in a context of habitation (nomad, sedentary), resources (built from the ground, resources that grow), climate and decoration. Several dependencies between houses and climate are mentioned and mostly focused on as phenomena, but there is not a systematic comparative study. The book points mainly to interesting scientific facts within house investigations. It is good to keep in mind the general framework of the study, together with the understanding that vernacular architecture is a product of climate, resources and human life.

Van Lengen's book *Barefoot architect* [190] is a comprehensive, holistic overview of house design and the building of green, and sustainable architecture in general. There are two important features of this reading matter. Firstly, the center of environmental design for the author is people. He combines Olgyay's [3] concept about the human's perception of the climate and a pure vernacular approach to techniques. Secondly, the book bestows on the readers a high level of simplicity within its diagrams, design methods, sketches and explanations. It shows that any design intent finally finishes with finding the right form of the elements of a building and their arrangement, order and composition. Precisely this approach could be indispensable for the pictogram method. Thus, this book will be actively used later in this paper, due to the systematized approach to the essence of vernacular architecture and its diagram simplicity.

Heating, cooling, and lighting as form-givers in architecture [195] gives a direct idea of climate based needs of habitation (heating, cooling and lighting) and house form (not necessarily vernacular). The advantages and disadvantages of some properties building form are systemized: compactness, inner courtyard, footprint, and orientation. Serious attention is placed on integrated design and there is a comprehensive explanation about the design process advantages of synthesizing the form holistically, rather than following the traditional "trial – error" sequence. Apart from the fact that conclusions in the writing are very specific, they give two indispensable ideas. First, vernacular houses provide the best principle solutions relevant to their form in terms of cooling, heating and lightning. Second, the design of the building form should be responsible for all the functional, structural, and environmental requirements in terms of the local climate. This means the pictogram method should follow this concept.

Natural energy and vernacular architecture [200] is a complex study that focuses on locally (Middle-East) available building materials and traditional building methods. It suggests an approach of combining traditional achievements and modern needs. The book uses Oliver's regional map and provides example diagrams and data, but the study is specific and focused on the Middle-East.

As a general overview of the above mentioned books, it could be synthesized that the climate impact on people is multi-layered and vast. In order to achieve biological, physical and psychological comfort, people have elaborated a wide range of techniques and methods for forming their houses to work with the climate, apart from the active air conditioning systems.

In addition, multiple and different studies have been conducted with focus on a single house type and its formal appearances in response to the climate [89,184,191].

Building form and environmental performance: archetypes, analysis and an arid climate [89] is a paper that mainly explores the building form in terms of urban design. However, a correlation between the findings of forms and the building members explored here were made. The idea of including the courtyard (Table 2, 2.d) and neighborhood shade buildings (Table 2, 6.d) templates come from this work.

Climatic effect in the formation of vernacular houses in the Eastern Black Sea region [184] is a paper directed at a "difficult" region not only for its climate conditions but also culturally. This creates a vast diversity of house types around the whole Black Sea region. The authors explore the effects of climatic factors, such as rain, wind, humidity and sunlight, on vernacular houses in terms of plans, external walls, roofs and the exterior of buildings.

Building envelope design as a passive cooling technique [191] is a paper pointing to the envelope design as a mean of achieving comfort and energy saving. The effect of climate on building form and members of the building envelope are mentioned, and these are two crucially important notions for the present paper. The theoretical part of the paper is very useful for the creation of the pictograms' method. Furthermore, the author implemented this knowledge in case studies which are firstly very specific to the region and secondly, with the intention of supporting a future sustainable design process and not only ascertainment of vernacular house existence. Additionally, this paper was chosen for active use and analysis further on.

Ancient vernacular architecture: characteristics categorization and energy performance evaluation [153] combines world cultural and climate zones mapping in order to identify unique regions of ancient vernacular houses. It can be arguable whether language groups are undoubted criterion for houses' cultural heritage (world cultural zones). Another point is that, such a complex study must not make any omissions regarding the usage of materials. However, there is an order of some important categories like envelope construction, roof materials, ceiling structure, room structure, building shape, building story, infiltration, relationship to the ground, and shading. This order is perhaps appropriate for energy performance study, but not well systemized for achieving house' form members deriving from climate. The paper is considered significant for the relationship between climate and form in general.

These studies have been largely focused on a specific regional context pointing to a concrete aspect (place, specific climate conditions, cultural issues, etc.), however, the information about houses is not structured in a global way that allows for ease of comparison.

Here is presented a scheme describing the methodology of research and the research sequence. It starts first with literature overview and collecting some information about what have been done in the area. The next step is to consider some pictograms' creating rules, depending on their properties and specificity and extract the investigating, registering and analyzing the houses' form properties. Based on the accepted literature, some houses' features are considered as depending on the climate and some are neglected. Further, some pictograms' specific properties are established and shown. The pictograms are applied to 10 types of houses from the set of 87 while constantly rendering count for the rules of creation and the houses themselves. Some lapses are fixed and the rules are improved. This gives us the method.
The test houses are chosen from different continents and different climate areas in order to cover as much as possible practical cases and decrease the possibility of potential omissions.

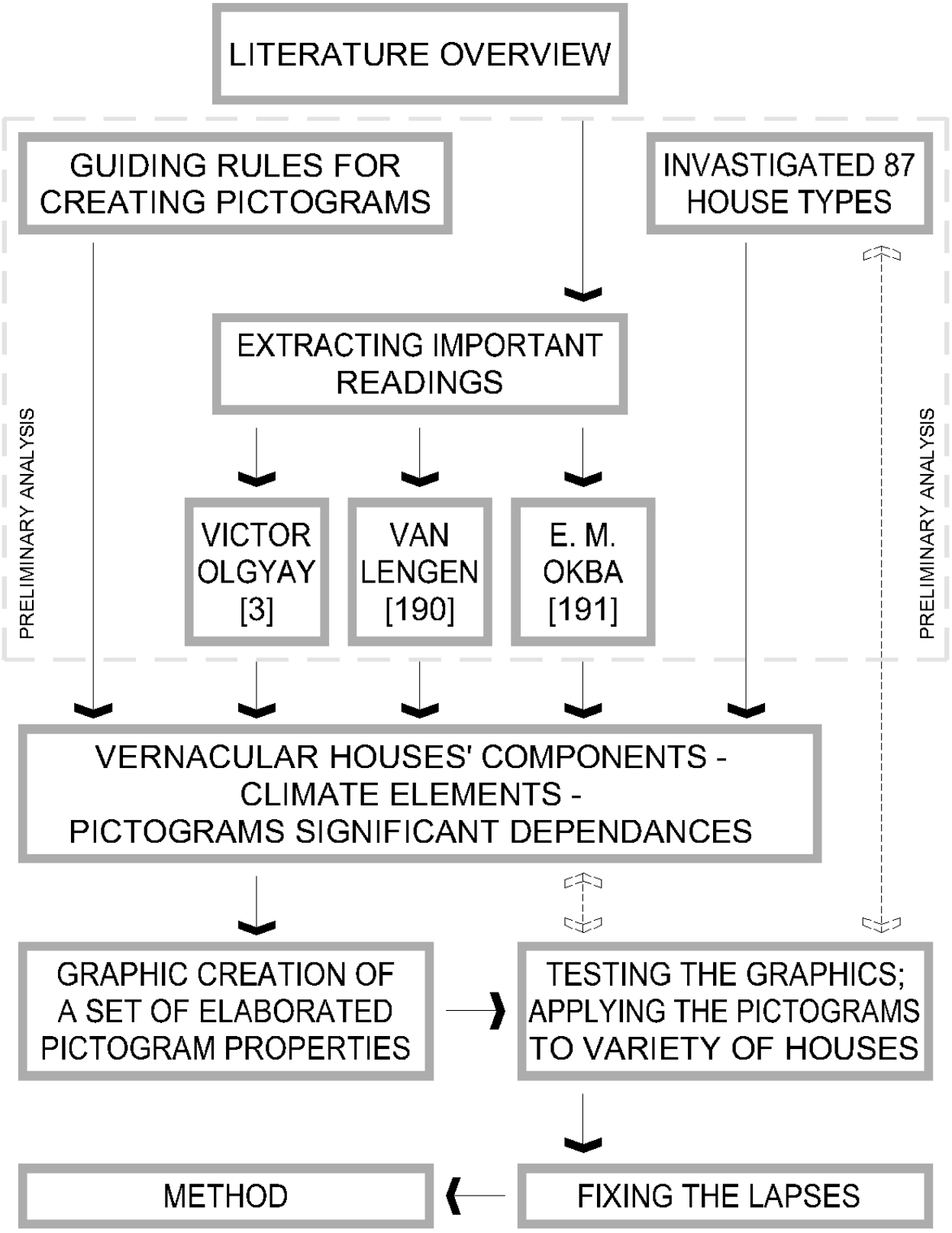


Figure. 1. **Methodology of research. The sequence for collecting information, distinguishing elements and connections, creating pictograms and testing the result.**

2 Pictograms

The nature of a pictogram is to show something – a picture of a notion, an idea or a concept in a direct and immediately perceptual way. A pictogram is an ideogram, which is

a graphic symbol that represents an idea or concept, independent of any particular language, and specific words or phrases [196]. That means it should be clear, meaningful, compact, readable and simple and it is necessary to exclude some house features of the future pictograms' design in order to support their quality.

We can exclude some geometric elements from pictograms that are:

- Too detailed; (in order for the pictogram to be readable)
- Are practically invisible for the accepted scale; (in order the pictogram to be readable)
- External to the design of the house itself; (in order the pictogram to be compact)
- Individual cases with specific details; (in order for the pictogram to be simple) – it takes into consideration the principle form but not the exceptions.

Some additional clarifications:

- Pictograms are presented in scale compared to a human size; (in order for the pictogram to be clear)
- There is a trend for pictograms to represent the real form if possible and do not complicate the appearance. (in order for the pictogram to be meaningful)
- Each set of pictograms (see **Error! Reference source not found. Error! Reference source not found.**) shows a single "climate element - house component". When describing a house these are combined in a pictogram (see **Error! Reference source not found. Error! Reference source not found.**)
- Pictograms represent the average house type's form as much as possible, but in general they are more schemes than real projections; (in order for the pictogram to be readable and compact)

3 Investigated house types

This house types were chosen predominantly as representative examples of different climates. Having in mind that houses from different places but very similar climates have different architecture, it is possible to point out the exact "climate – form" dependence and to exclude the socio-cultural and resource prerequisites for the purpose of this study. The house types are investigated by always adhering to a "form, function, structure, composition and technology" template in order for different houses to be comparable with each other.

Table. 1. **Examined set of vernacular houses**

Climate types	Representing examples
1. Wet equatorial	Bahay Kubo. Asia, southeast, Philippines [188,189,199] Bubungan Tinggi. Asia, southeast, Indonesia [12,13] *Bungha. Asia, Indian peninsula, west. [14,15]* Kuna house. Central America, Panama [98,99] Musgum. Africa, central; [115] Oca Mune/Takuxipan/Timakoto /Tiriyo/. South America, north [122-126] Oca Paima/Karapapufa /Tiriyo/. South America, north [122-126] Oca Tampataraka/Taotinto /Tiriyo/. South America, north [122-126] Oca Kuna Oucuntaka /Tiriyo/. South America, north [122-126] Oca Xavante. South America, north [122-126] Oca Antiga /Karaja/. South America, north [122-126] Oca Heto (Tapera) /Karaja/. South America, north [122-126] Maloca Tampataraka. South America, north [122-126] Maloca Xinguana (Pah) /Yawalapiti/. South America, north [122-126] Maloca Takana /Tapirape/. South America, north [122-126]

	Maloca Tukano. South America, north [122-126] Maloca Marubo. South America, north [122-126] Omo Sebuah. Asia, south [128-130] Rumah Batak /Karo/ Asia, southeast, Indonesia [130,143,144] Rumah Batak /Toba/ Asia, southeast, Indonesia [145,146] Rumah Gadang /Minangkabau/. Asia, Southeast, Indonesia. [130,144] Rumah Joglo. Asia, southeast, Indonesia [145-147] Rumah Melayu. Asia, south [148-150] Rumah Radakng (Rumah Pandjang, Uma, Rumah Iban, Rumah Panjabi, Asia longhouse) /Dayak/. Asia, southeast, Indonesia [144,151,152] Rumah Tongkonan /Toraja/. Asia, southeast, Indonesia [49,72,153-155] Uma Mbatangu (Sumbanese house) Asia, south [177,178]
2. Tropical savanna	*Bure. Oceania, north, (Fiji) [16,17]* Bushman hut (San Bushmen Hut) Africa, southwest [23-25] Dorze. Africa, east [39,40] *Kanak. Oceania, east [84-86]* Khmer house. Asia, south [93,94] Manyatta. Africa, east [108-111] *Maloca Shabono. South America, north [122-127]* *Maloca Srobo /Yucuna, Uitoto/. South America, north [122-126]* *Nyumba (Bomba) Africa, south [117-121]* *Rondavel. Africa; Asia, south [137-139]* Tatta Somba. Africa, central [156-159] *Toda. Asia, south [49,164,165]* Tukul. Africa, *south* [37,176]
3. Humid subtropical	Fujian Tulou. Asia, southeast. [48-49] IQhugwane. Africa, south [70, 74, 75] Radoev K. (2016) Personal conversation with Nyasha Vengesay (local citizen and architect). Long Gou Lang. Asia, south, China, Hainan Radoev K. (2017) Personal conversation with Wang Zhi Lin (王芝林) managers in Li village and Wang Qiu Xia (王秋霞) a member of Li society. Translation by Hong Qian (洪倩) 24.12.2017
4. Semi desert	Berber adobe house. Africa, north [10,11] Cavate. (Cliff Dwellings) North America, southwest; Asia, west; Africa, north [26-28] *Darbazi. Asia, west, Azerbaijan [33-36]* El-Molo hut. Africa, east [43-45] *Glhatun. Asia, west, Armenia [33, 36, 50-54] Radoev K. (2016) Personal conversation with Azatuhi Sagasian (local citizen and architect).* Karadam. Asia, west, Georgia [33,36,87] Radoev K. (2016) Personal conversation with Azatuhi Sagasian (local citizen and architect).
5. Desert	Dogon house. Africa, west [37,38] Earth lodge. North America, west; Europe, east; Asia, west [41,42] Himba Hut /Himba/. Africa, southwest [67-69] *Hogan /Navajo/. North America, southwest; Asia, west [70,71]* Jacal (Hohokam house). America, southwest [81-83] Khaima (Bedouin, Berber tent) Africa, North [37,73,88-92] *Pueblo. North America, southwest. [71,132]* Troglodyte dwelling. Africa, north [37,168-170] Tuareg shelter. Africa, north [37,173]

	Tuareg tent. Africa, north [36,174,175]
6. Mediterranean	Kushta. Europe, southeast; Asia, west [100-102] Kümbet. Asia, southwest [95-97] Ksar. Africa, north. [103-105] Masia. Europe, west [112-114] Trullo. Europe, south [171,172]
7. West coast marine	Clochan. Europe, west. [31,32] *Wattle & Daub hut. North America, south; Europe, west and south; Africa, west; Asia, west [49,180]*
8. Humid mid latitude	Burdei. Europe, east [18-22] Ev. Europe, east [20-22, 46, 47] Radoev K. (2016) Personal conversation with Diana Osotova (local citizen and architect). Hanok. Asia, east [57-63] *Izba. Asia, central and north. [76-80] Radoev K. (2016) Personal conversation with Karlo Lukanov (participant in a local building project).* Plank house. North America, northwest. [71,131] Teepee. North America, central. [71,160-163]] Wigwam. (Wickiup) North America, northeast [181, 182]
9. Continental Sub-arctic	Balagan. Asia, north [4-7] Ballok. Asia, north [8,9] *Chum. Europe, northeast; Asia, northwest [29,30]* Goahti. North America, north [55,56] Torfbær. Europe, northwest [166,167] Urasa. Asia, north. [5,6,179] *Yaranga. Asia, north [29,183]* Yurt. Asia, central [50,70,184-187]
10. Tundra / Ice cap	Igloo. Asia, north; North America, north [29,50,71-73] *Nivkh. Asia, north [116]* Qarmaq. (Valkaran in Asia) North America, north. Iceland. Asia, north. [71,133] Quinzhee. North America. North; [134-136] *Sami. Europe, north. [56]*
11. High altitude	Ruka /Mapuche/ South America, west [140-142] *Hallenhaus. (Fachhallenhaus, Low German house, Low Saxon house) Europe, northwest [64,66]*

This set of vernacular houses has been studied by considering their location on the different continents as much as it was possible. The study was undertaken using a template with the essential properties of the vernacular house like form, space, structure, technology, etc. This pattern was developed because, in order to have comparable data, it was necessary to examine the houses within the same property categories. Nevertheless, the study uses those components of the building form relevant to the climate influences. Since the subjects of the study are these vernacular houses' climate-formed components, it must be clear and stated that they are comparable.

The houses types have been selected from 11 climate zones referring to the accepted by ASHRAE (The American Society of Heating, Refrigerating and Air-conditioning Engineers) map [193], due to its suitability for architectural purposes. The houses are not evenly distributed within these zones. This fact derives from their diversity and the location of the zones. The arrangement of the house types in a particular order in Table. 1 Examined set of vernacular houses is conditional. Some of them (marked with italics) belong to more than one zone or appear at the border of two zones.

The examination of the houses includes general study of the form. Of course, it is not possible to have suitable knowledge of the form if an examination of the function and the structural, compositional, and technological features is excluded. In some cases, a deep investigation for the

structure was performed. (e.g. Bahay Kubo, Bubungan Tinggi, Darbazi, El-Molo hut, Ev, Igloo, IQhugwane, Joglo, Khaima, Rondavel, Rumah Batak, Tatta Somba, Troglodyte House). While it is clear that the climate-form relationship is related to all these categories of houses, detailed studies of them are helpful but not indispensable in this case.
It must not be forgotten, that the houses' form is not only explicitly dependent on the climate and a single unambiguous cause - the climate - cannot be attributed to the form's nature [192]. Each architectural form can be assigned three general groups of factors - climate, socio-cultural and recourses [193], which are interweaved and overlapping in a barely explicable way. However, there are some significant obvious dependencies between form and climate that the study will adhere to.

4 Climate elements

According to Victor Olgyay [3, p.11], the climate elements relevant to architecture are temperature, relative humidity, sun radiation and wind effects. The five major elements of the climate are the atmosphere, the hydrosphere (e.g. oceans, lakes, and rivers), the cryosphere (e.g. ice, snow, glaciers), the land surface / lithosphere, and biosphere (e.g. vegetation) [197]. Rain, natural disasters (e.g. floods, typhoons, earthquakes, volcanos, and tsunami) and water and air currents are form-generating elements according to the analysis of the set of vernacular houses (Table. 1 Examined set of vernacular houses). The most significant forces are rain and wind. Volcanos have a substantial role of supporting soil in some regions, but they are not, however, a global factor, and also volcanoes and earthquakes do not affect the houses' form but mostly influence the foundations. Considering this information, the following climate elements should be regarded as relevant for pictogram creation:

1. Temperature;
2. Relative humidity;
3. Sun radiation;
4. Wind;
5. Rain;

Houses' components

According to Van Lengen [190] the design approaches and building components depending on the climate are:

1. Build on a high or sheltered place; (controlling air circulation)
2. High roof; (controlling air circulation)
3. Cross ventilation; (controlling air circulation)
4. Inner courtyard; (controlling air circulation)
5. Wind catchers; (controlling air circulation)
6. Loose lattice structures; (controlling air circulation)
7. Oval or edged building forms; (controlling wind velocity)
8. Wall thickness; (envelope accumulating capacity corresponding to the level of temperature differences)
9. Building materials; (accumulating capacity corresponding to the level of temperature differences)
10. Roof slope; (depending on the precipitation and need for ventilation)
11. Openings size and orientation; (controlling solar radiation penetration and the need for ventilation)
12. Distance between houses; (controlling solar radiation penetration and the need for ventilation)
13. Buffer spaces around the house and the environment; (Verandas for sun and rain protection)
14. House position according to ground level; (controlling the ventilation and temperature differences)
15. Solar orientation; (controlling the temperature by the size of the exposed surfaces)
16. Interior courtyards; (controlling cold/hot air movement)

17. Overhangs / eaves; (controlling the temperature by the size of the exposed surfaces and the rain impact on the walls)
18. Fireplace position; (controlling heat distribution inside the house)
19. Vegetation presence and position; (Protection from the sun and wind)

Several of these formal approaches could be excluded from the initial set because of the preliminary qualifications accepted in 2 and additional clarification explained as follow:

For point 1:
Build on a high or sheltered place; (controlling air circulation) not applicable because this is a particular approach used to describe a single house design but not a global house type environment.

For point 19:
Vegetation presence and position; (Protection from the sun and the winds) not applicable because this is a specific approach used to describe a single house design but not the global state of a house type environment.

According to Okba [191] importance should be brought to:

1. Walls and roofs
   a. Shape, form and orientation;
   b. Shading;
   c. Bright colors;
   d. Thermal insulation;
   e. Thermal mass construction;
   f. Solar control on the building exterior;
2. Windows, doors and openings
   a. Form, size and location;
   b. Negative impact of door opening;
   c. Protection through insulation;
   d. Shading devices for openings;
   e. Ventilation;
   f. Overhangs or deciduous plant materials to shade windows;
   g. Select the proper glazing to reduce heat;
   h. Windows and doors with air-tight frames Windows, Doors and Openings – not applicable for the pictogram;
   i. "Stack effect" ventilation;
3. Construction details
   a. Construction materials and details that reduce heat transfer;
   b. Insulating materials to resist heat;
   c. Details that eliminate or minimize thermal bridges Construction Details;
   d. Details that minimize opportunities for air infiltration;
4. Ground surface
   a. Earth berms and sod roof to reduce heat transmission and radiant loads
   b. Existing and new landscape and other elements ground surfaces;
   c. Reduced paved areas to lessen heat buildup around the building;

The appearance of most house form components according to Okba are the same as Van Lengen's, but in a more detailed form. Several of them can be excluded from the pictogram designation for the following reasons:

1f. Solar control on the building exterior (meaning ambient environment); - not applicable because this is a particular approach used to describe a single house's surrounds design but

not the global state of a house type's environment. It should not be a part of the form or the pictograms.
2b. Negative impact of door openings; – not applicable because it's not a part of the house's form.
2f. Deciduous plant materials to shade windows; – not applicable because the material is not a part of the form. It should not be a part of the pictograms. Otherwise, any shading devices are included in the pictograms.
2g. Select the proper glazing to reduce heat; – not applicable because the glazing is not considered as a part of the form. This could, however, be good advice for a new design of a green house. Another question is whether the glazing should be considered as a vernacular element…
3a. Details that reduce heat transfer; – not applicable because the details are not considered as a part of the pictograms. This could be good advice for a new design of a green house. The details should not be a part of the overall form.
3c. Details that eliminate or minimize thermal bridges; – not applicable because the details are not considered as a part of the pictograms. This could be good advice for a new design of a green house. The details should not be a part of the overall form.
3d. Details that minimize opportunities for air infiltration; - not applicable because the details are not considered as a part of the pictograms. This could be good advice for a new design of a green house. The details should not be a part of the overall form.
4b. Existing and new landscape and other ground surface elements; - not applicable because this is a particular approach used to describe a single house's surrounds design but not the global state of a house type's environment. It should not be a part of the form and the pictograms.
4c. Reduced paved areas to lessen heat buildup around a building; - not applicable because this is a particular approach used to describe a single house's surrounds design but not the global state of a house type's environment. It should not be a part of the form and the pictograms.

For the design of the pictograms, it is necessary to adopt some distinguishing features of vernacular houses, which should be considered as components. It is not appropriate to describe "nowadays design recommendations" in the pictograms based on these features. It is clear also that Okba does not treat the problem in the context of existing vernacular houses. His complex investigation gives a contemporary approach to designing houses extracted from some established vernacular techniques. Thus, the previously mentioned house components can be pointed out in the pictograms but not the particular details in each case.

According to the observation of the 87 examples of vernacular houses, attention could be placed on one more factor not mentioned in these studies; compactness of the house - to get an idea of the S/V ratio of each house type., This was, however, mentioned in one of the literature sources [195]. Compactness is strongly connected to elements like temperature loss, radiation, winds, etc.

4.1 Dependencies

Some observations about houses' members imply several clear signs they are meaningfully connected through their form to climate elements. The concrete examples are shown in Table. 2. Components of the houses – examples – climate elements.

Table. 2. **Components of the houses – examples – climate elements**

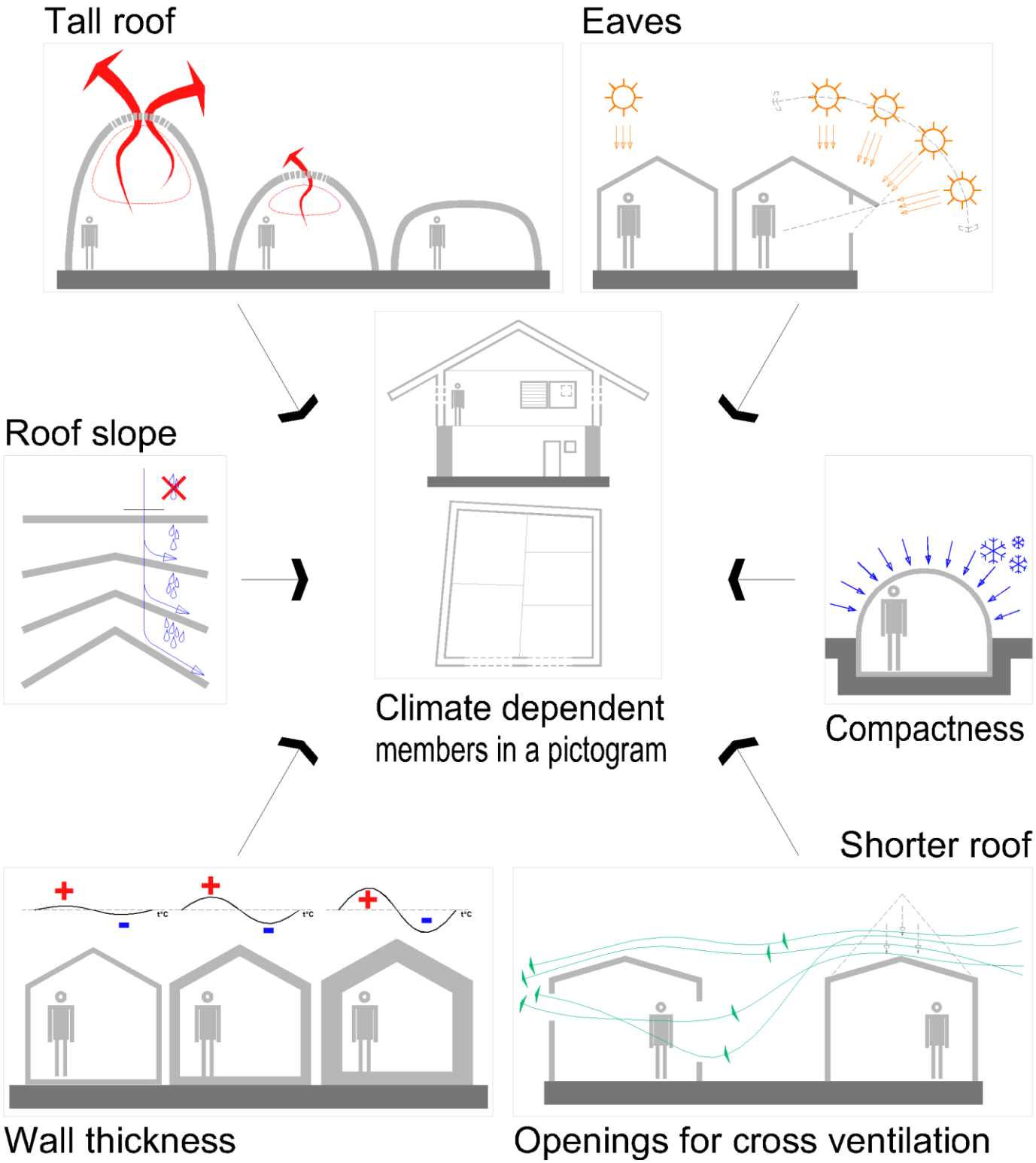
Components of the building	**Vernacular house example**	**Climate element / reason for the member form appearance**
Tall roof	Rumah Batak; Rumah Bubungan Tinggi;	High level of humidity and temperature

Roof slope	Maloca Marubo; Kanak	High level of precipitation
Walls thickness of the building envelope	Ev; Bordei; Izba	Temperature differences
Longer eaves	Hallenhaus; Kushta;	High amount of rainfalls and snow
Compactness	Igloo; Khaima;	Low temperatures
Passive ventilation form	Rumah Melayu; Bahay Kubo;	High temperatures
Shorter eaves; low pitched roofs	Dogon House; Hogan; Khaima;	Strong winds

They could be also explored as preliminary patterns of pictograms

Figure. 2. **Observation of the climate dependent members of the houses.**

A general view over each of the houses is able to give an instant idea of their very specific components formed by the climate. These components were extracted from the observation of 87 examples (Figure. 2) and additionally confirmed by other sources (the reference sources) pointing out the climate-form relation. [190,191]

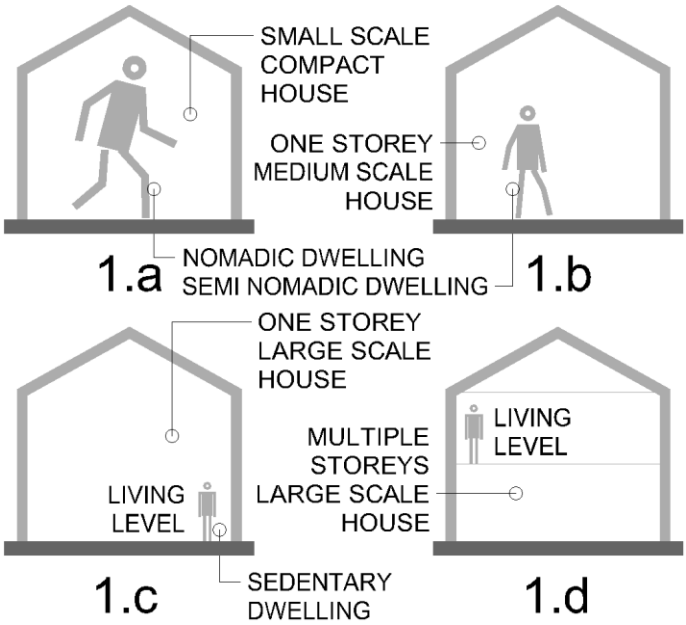


4.2 Results

Based on the analysis of these two sets and the set of studied houses, the next 10 aspects were chosen to describe the form of the house's components:

1. Scale and type of habitation; - important because of the quantity of the enclosed air, its ability to be heated and/or cooled and the number of floors in the envelope of the enclosed air. Sedentary or nomadic life is caused mainly by harsh appearances of the climate.
2. Plan, section, form, compactness; - important because of the quantity of the enclosed air, its ability to be heated and/or cooled. General form dependent on human habitation from inside and the climate from outside is crucial.
3. Orientation and plan shape; - important because of the sun's radiation and wind effects.
4. Roof slope; - important because of the rain and snow, and air circulation.
5. Wall thickness and thermal mass of the structure; - important because of the thermal accumulation capacity of the building.
6. Shading by the eaves; - important because of its sun protection ability and sun permeability.
7. Vertical position of the house; - important because of the ability to save energy under grade (earth pits) and to avoid floods (stilt houses).
8. Insulation and air permeability; - important because of the ventilation and air conditioning inside the house.
9. Air circulation; - important because of the ventilation and temperature control inside the house.
10. Openings; - important because of the ventilation and temperature control, and the sun penetration inside the house.

Table. 3. **Pictograms graphics creation and description**

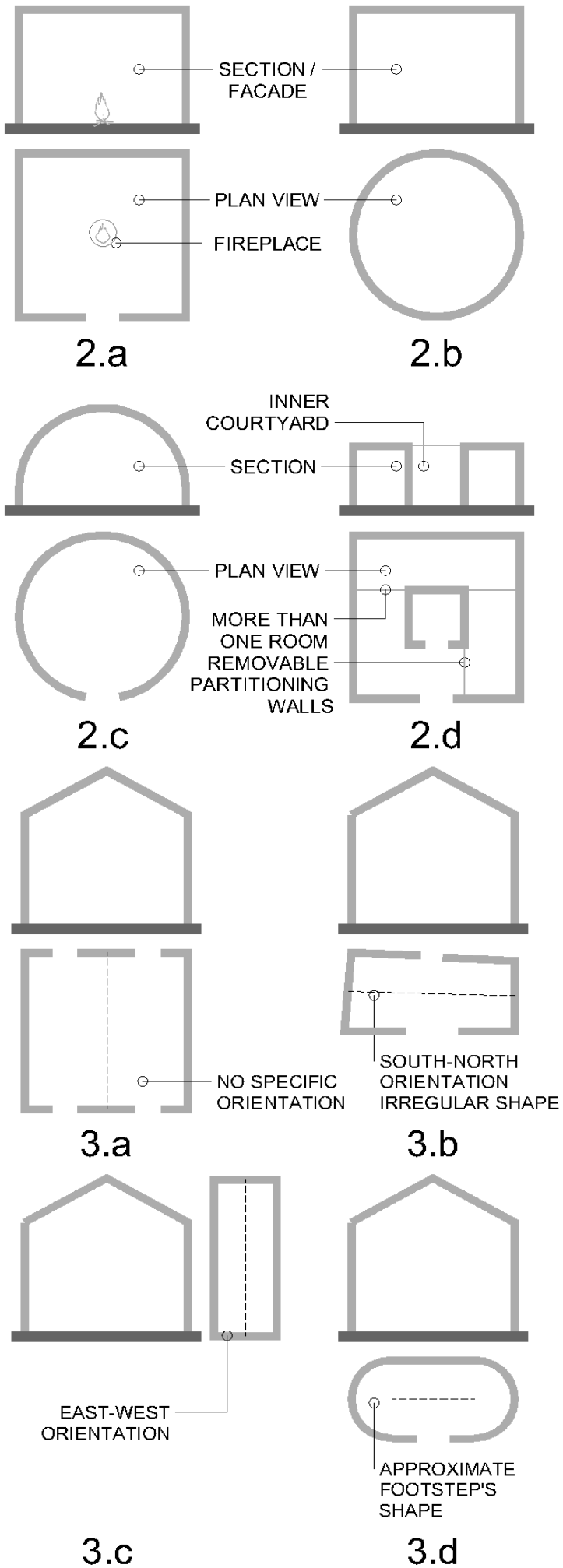
Description	**Pictograms**
1. Scale and type of habitation Since the intention here is to present each house with a small compact pictogram, great importance should be placed on the scale of the house; whether it is a hut, a single-family dwelling or a unit housing the whole kin network. In order to get an overall idea about the whole building and its size this description is needed. The human size describes the scale, type of habitation (sedentary, semi nomad or nomad) and the living level if the house has more than one floor. **2.** Plan, section, form, compactness This part of the pictograms consists of obvious information about the footprint on the ground and overall form. The depicturing "section/facade" style is mostly "section" with some	

façade elements but always from the most informative and significant side of the building.
The S/V ratio of the living space (the ratio between the surface area of the outer envelope of the building and the volume enclosed inside) is also visible on these pictograms. It is important to show a rough idea of the compactness of the house since it represents its overall form and hence its energy performance [194]. Attributes also shown in these 2.x pictograms are courtyard, fireplace and removable partitioning walls.

3. Orientation and plan shape

This set of pictograms shows the orientation of the house and the exact exposure of the facades to the sun, since it depends mainly on the footprint on the ground. In addition, a rough approximation of the plan shape will be shown as a base for the final form. The footprint is always shown with north towards the top and any important openings are displayed.
3.b shows an irregular layout even though the idea of the shape is preserved.
3.c pictogram's plan view is put laterally to the section in a way signifying the house has east-west orientation. They don't have the same scale. The only reason for this is the endeavor to keep the pictogram compact.
A dashed line implies the roof configuration as well.

4. Roof slope



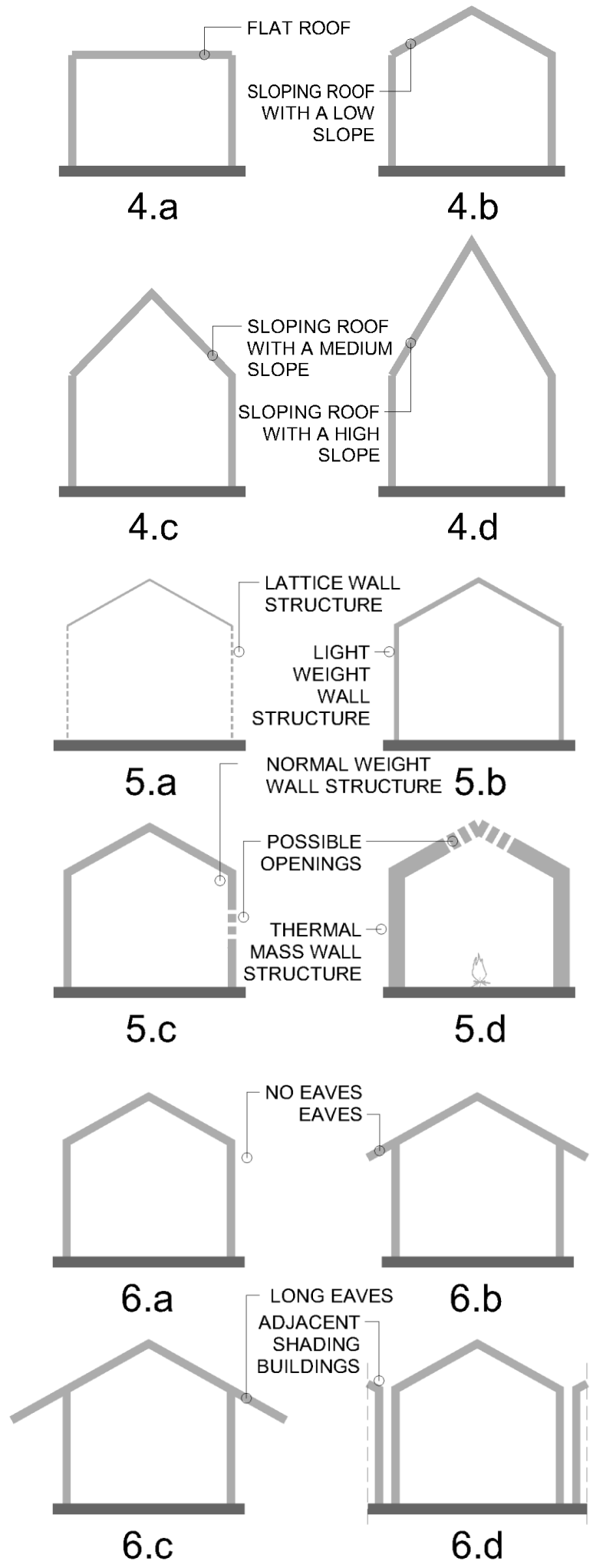
Slope of the roof (in order to facilitate the explanation and save space, the plans are temporary excluded in the next sets of pictograms) Flat roof (4.a), sloping roof with a low (4.b), medium (4.c), or high (4.d) pitch are shown in this set. In the pictograms here is shown a general approximation of the slope, however on the final pictograms, the roofs will be shown with their real inclines as much as is possible.

5. Wall thickness and thermal mass of the structure

Wall thickness is critically important to the thermal accumulation quality of a wall. However, depending on observations from the examples in Table. 1, when a vernacular house with thick walls is built usually the purpose is to achieve a heavy structure with a big thermal mass, There is no case of thick lattice walls. The walls are usually light and thin when air circulation is needed and thus, no heavy materials are used. The pictograms show four levels of thickness and a way to express reticulation when lighter walls are needed. Although it is not of importance to wall thermal mass, there is a need to show the openings employed to let out smoke or supply light, air and solar radiation.

6. Shading by the eaves

Shading a house is mainly achieved with its eaves. (6a, 6b, 6c) Any additional elements like surrounding plants or ground surfaces (terrain slope differences)



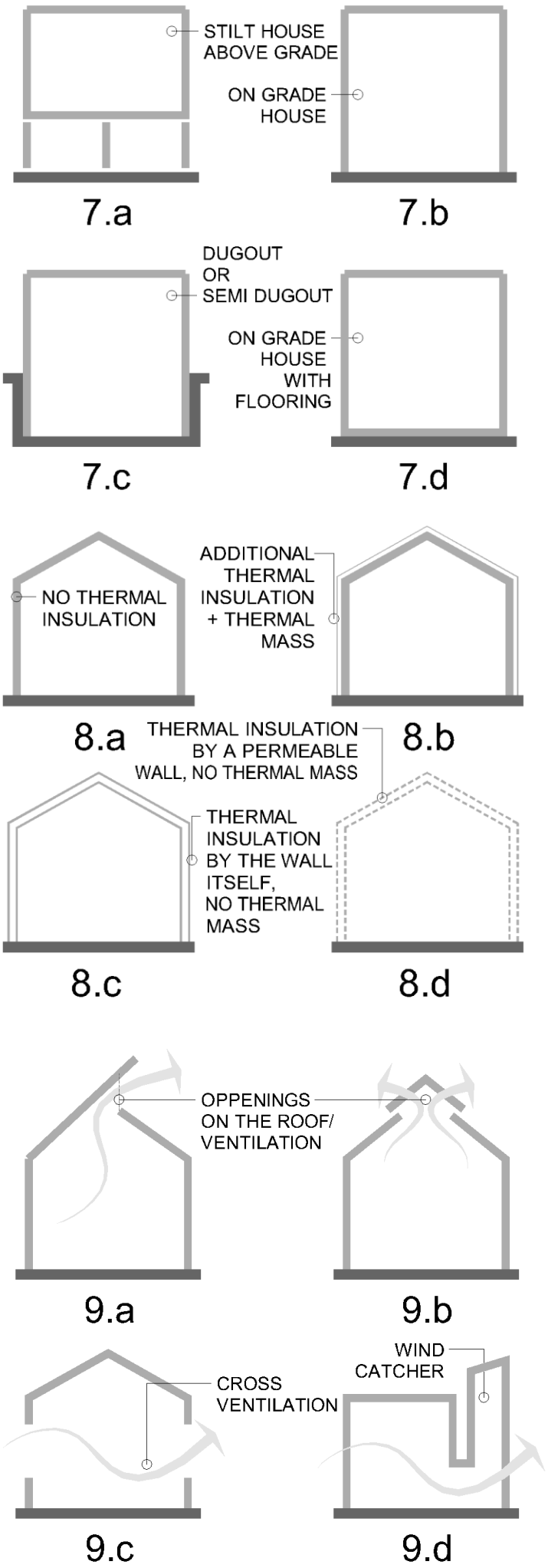
are not applicable for pictograms. Shading in some specific cases provided by neighboring buildings should be noted as an urban design approach. (6.d)

7. Vertical position of the house

The houses' position is usually above grade (7a), on grade (7b) or partially under grade (7c). It is connected to its heat exchanging ability but also to some protection techniques (storms, torrential rains) which are a part of the climate prerequisites as well. 7.d means additional flooring is constructed for some purpose and the house doesn't use the bare ground itself.

8. Insulation and permeability

There are four different ways to describe the behavior of the outer wall. When there is no thermal insulation (8.a) the wall shall be shown as one of the 5.a, b, c, d pictograms which describes its natural ability to retain energy. (houses Clochan, Earth lodge and Troglodyte) The 8.b pictogram will be used to show cases when additional layer(s) of insulation are added. (house Kushta) In this case, there is a combination of insulation and accumulation to some extent. The third case is a wall having an insulation ability itself (houses Manyatta and Yurt) and no accumulation at all. The fourth case is a combination of a permeable wall structure



and it having insulation ability.

9. Air circulation

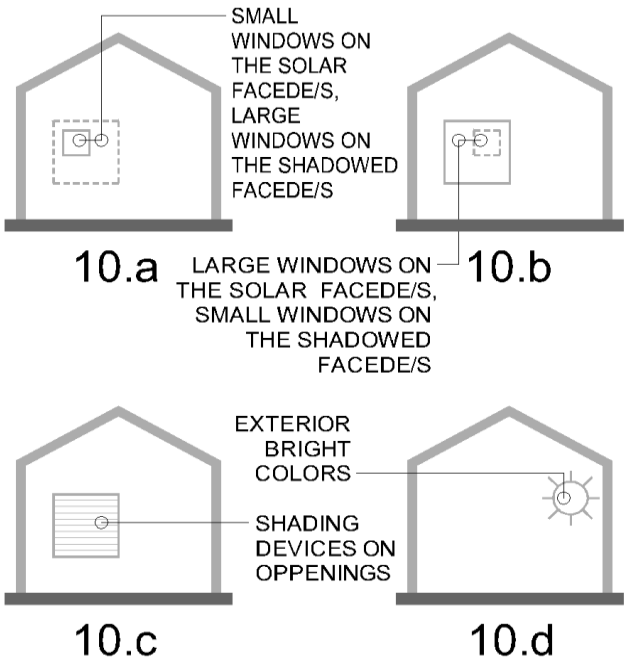
One of the most important approaches for a hot climate (humid or arid) is the air circulation shown in three different ways in 9.a, 9.b and 9.c. The natural way to induce this circulation is by the house form itself. Pictogram 9.d shows air movement arranged within an external form to show the presence of wind catchers (towers) in a hot arid climate.

10. Openings

Pictogram 10.a describes some cases with a hot climate requiring small windows on the solar facades and large windows on the shadowed ones (houses Bubungan Tinggi and Rumah Batak). 10.b shows the opposite. This is the case when solar radiation is necessary to raise the temperatures in the interior. (houses Ev, Hallenhaus and Izba).

Shadowing devices will be included on the openings when available (10.c)

Higher levels of solar radiation sometimes refer to a white (or at least) bright color of the façades depicted in 10.d.



The result is creation of a set of pictograms describing significant form components of vernacular houses depending on the local climate. They were shown and described in ***Error! Reference source not found. Error! Reference source not found.***. The pictograms could be used for presenting, studying, and comparing houses and determining regions with similar house types.

The main elements of the pictograms derive from the vernacular house components. These components are formed by the climate. This was investigated in all the 87 vernacular house examples and confirmed with some external sources [190,191]. It can be accepted as a second result that the set of pictograms is a universal expression of the houses' form in response to the climate in any locations around the world.

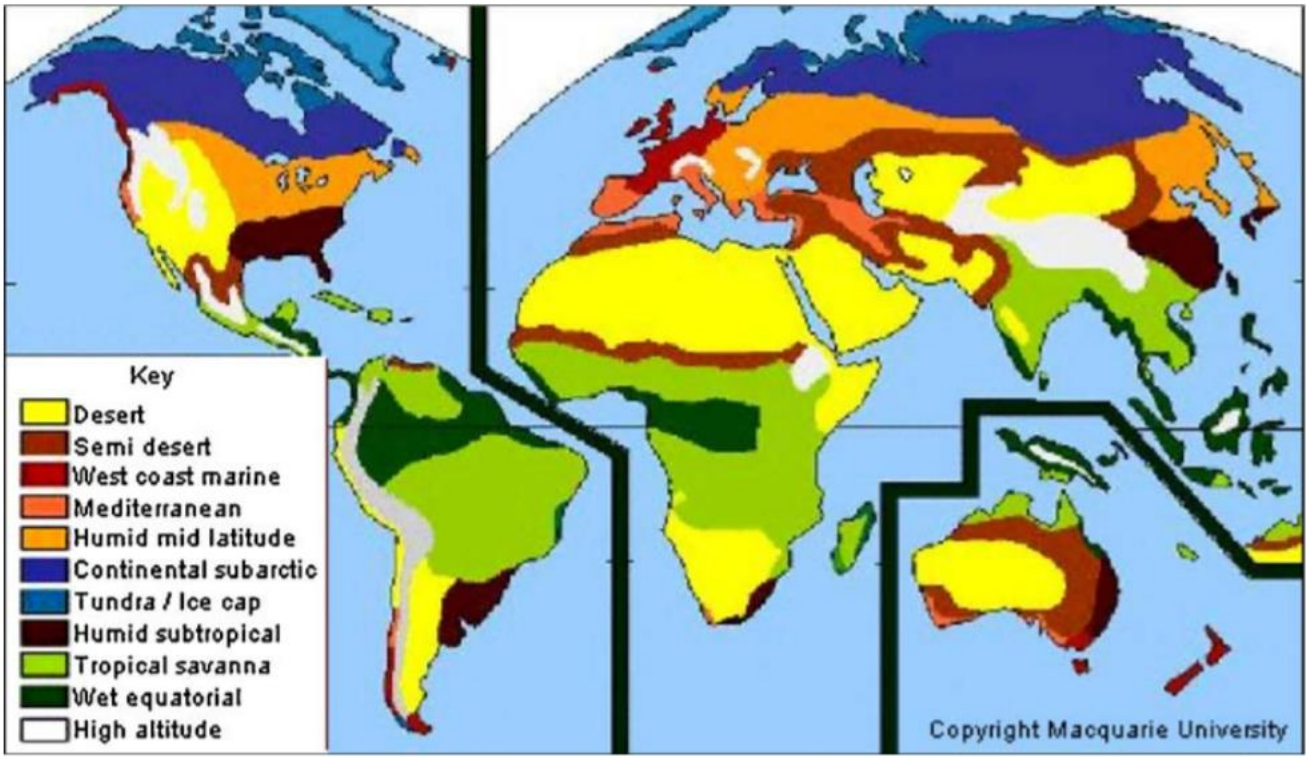
An obvious drawback of the pictogram's approach to presenting the climate-form relationship is the lack of detail. Although they tend to be accurate, it is not in their nature to be precise.

Another disadvantage of this presentation type is that there is not any weight given to some particular cases and thus lack particularities over individual case studies of specific situations.

5 Discussion;

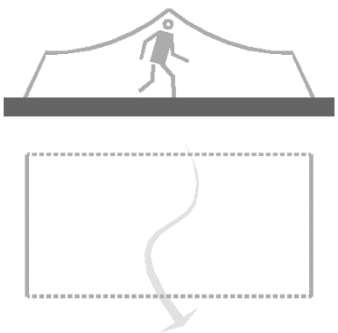
It is necessary to test several houses' examples by depicting them with pictograms following the rules established in Table. 3. Pictograms graphics creation and description. What could be some unexpected difficulties or obstacles? It would be more scientifically grounded to choose examples from different continents because together with the climate, the building form is usually impacted from cultural and material prerequisites. Thus, the result can be justified based on examples that are more diverse. Furthermore, it will be suitable that examples from different climate zones are chosen. These zones could be the ones accepted by ASHRAE (The American Society of Heating, Refrigerating and Air-conditioning Engineers) [193] because of their suitability of application for architectural purposes. (Figure. 3 A world climates' map coherent with the needs of architecture.)

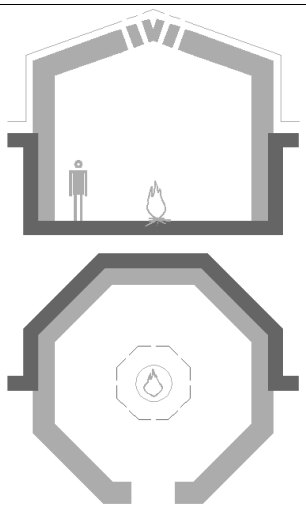
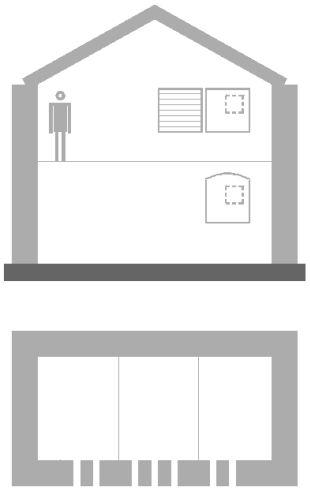
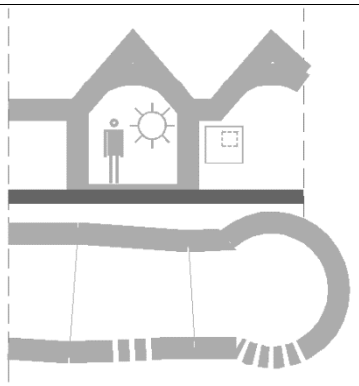
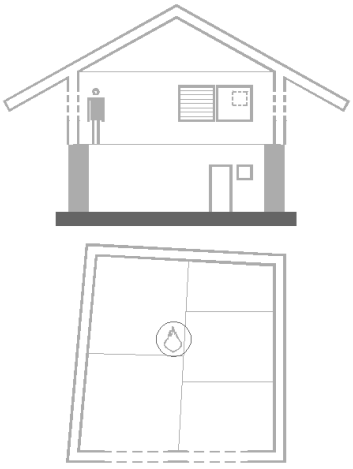
Figure. 3. **A world climates' map coherent with the needs of architecture.**

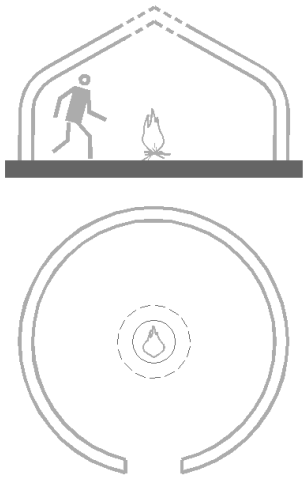
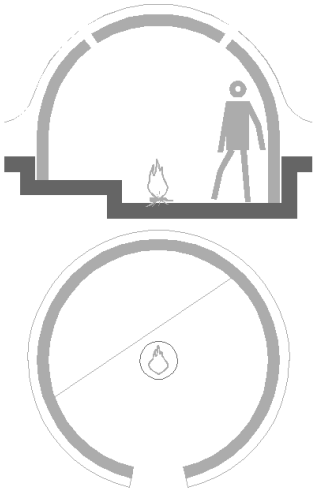
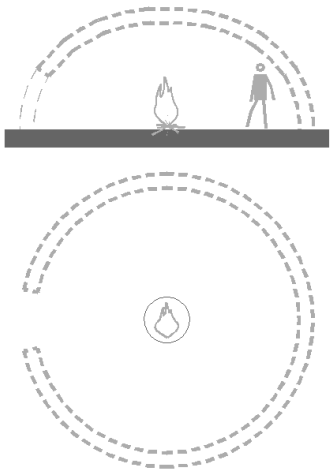


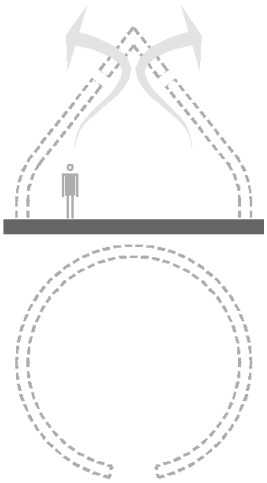
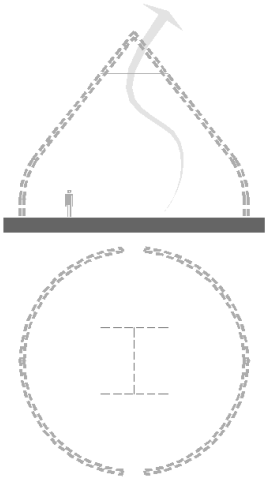
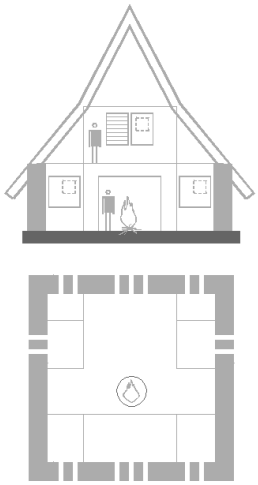
Considering all of this, the proposed examples are:

Table. 4. **Pictogram test examples**

House's properties	Place and climate	Pictogram
Khaima (house # 33) - for desert climate; Nomad; • Thin but relatively accumulating walls; • Optional openings on the large sides; • Small amount of enclosed air; • North-south orientation;	Africa Desert areas; • High diurnal differences; • Little resources; • Harsh desert storms; • No rains;	

Darbazi house (house # 13) – for semi desert climate; Sedentary; • Thick accumulating walls; • Semi-earth pit; • Fire in the middle; • Almost no openings; • Low pitched roof;	Asia Caucasus; • Significant diurnal differences; • Significant temperature summer-winter differences • High snowfalls;	
Masia (house # 41) West coast marine climate; Sedentary; • Thick accumulating walls; • Two stories; • Low pitched roof; • Openings on the south façades;	Europe West; • Mild winter; • Mild humidity; • Low amount of rains;	
Trullo (house # 78) Mediterranean climate; • Thick accumulating walls; Sedentary; • High pitched roof; • Openings on the south façades; • Small amount of enclosed air;	Europe Mediterranean; • Mild winter; • Mild humidity; • Low amount of rains;	
Kushta (house # 37) - Humid mid latitude climate; Sedentary; • Thick accumulating walls at the ground floor; lighter at the second; • Two stories; • Fire in the middle; • Openings on the south façades; • Middle pitched roof;	Europe/Asia Balkans • Cold winter; • Significant summer-winter temperature differences; • Snowfalls	

Yurt (house # 87) – Continental subarctic climate; Nomad; • Thin insolating walls; • Fire in the middle; • No openings; • Middle pitched roof;	Asia Continental • Cold winter; • Significant summer-winter temperature differences; • Huge diurnal differences; • Low amount of resources; • Strong winds; • No rains, low amount of snow;	
Igloo (house # 27) – Tundra/Ice caps climate; Semi-Nomad; Thick insolating and well accumulating walls; • Fire in the middle; • No openings; • Compact form;	North America North; • Short and cool summer; • Significant summer-winter temperature differences; • Low amount of resources; • Strong winds; • No rain, significant amount of snow;	
IQhugwane (house # 28) - Humid subtropical climate; Semi-nomad; • Poorly insolating, permeable walls; • Fire in the middle; • No openings; • Compact form;	Africa South • Mild winter; • Sensible temperature differences; • Predominately plant resources; • Insect defense needed; Middle amount of rain; Almost no snow;	

Kanak (house # 31) – Tropical savanna climate; Sedentary; • Poorly insolating, permeable walls; • No openings; • High roof for ventilation;	Oceania. New Caledonia • Tropical climate; • Predominately plant resources; • High Humidity; • Insect defense needed; • Storms and typhoons; • Rain;	
Casa Marubo (house # 57) - Wet equatorial climate; Sedentary; • Poorly insolating, permeable walls; • No openings; • High roof for ventilation; • Larger scale;	South America. North • Equatorial climate; • High humidity • Predominately plant resources; • High levels of rain;	
Hallenhaus (house # 24) – High altitude climate; Sedentary; • Thick accumulating walls at the ground floor; lighter at the second and third; • Two or more stories; • Fire in the middle; • Openings on the south façades; • High pitched roof;	Europe Middle • Cold winter; • Significant summer-winter temperature differences; • Rainfalls and snowfalls;	

After the creation of the selected pictograms, there were some comments that need to be responded to. Apart from the scale shown by the human figures, they should also serve as an indicator for the living storey, if the house contains more than one floor. The relevant figure also indicates the type of habitation - nomad, semi nomad or sedentary. This was added to the pictogram description in Table. 3. Pictograms graphics creation and description and to the test examples in **Error! Reference source not found.** as well. Additionally, in the first house pictogram (Khaima) it should have been shown ventilation or intentionally aimed air movement, which can be depicted but should be in the plan.

For the second part of this paper, it will be very important to show the pictograms in a color relevant to the climate zone.

When grouping the pictograms by the climate zones' colors, they are still observably different, but similar house types and families are able to be distinguished in a readable and informative way.
All 87 types will be depicted in this manner in part two of the paper. Apart from being an addendum, part two should be a perfect example of describing both - different house types and climate zones.

5.1 What is the new based on the results compared to the introduction?

The new results present the ability to deal with all the vernacular houses as a set and pursue the trends in their development and evolution as a whole.

5.2 What can be agreed and disagree with the similar studies?

No previous studies include a vernacular architecture map that provides a convenient pictogram description for each house. Paul Oliver's encyclopedia of vernacular architecture is considered to be the most comprehensive book created in this domain, but the aim here is to explore and compare two, three or more of the houses together, and even further, to study the entire system.

6 Conclusions

Pictograms are a quick, easy and effective method to encompass general knowledge about vernacular houses through a simple and quick approach.
It's highly plausible that this is the only way to present a worldwide overview of the knowledge accumulated around vernacular houses without requiring the explorer to probe specific details in depth before being able to obtain a general picture. In essence, this paper is a detailed study of a way of providing a general overview of vernacular houses. It delves into the specifics of the system but does not require an encyclopedic knowledge of any of its parts. The sets of pictograms are a solution to the problem of losing the enormous amount of system knowledge and correlations due to the complexity and size of the data set. The concrete techniques and architectural approaches have been demonstrated here through an extensive set of examples. The concrete approach for studying the complete vernacular houses' system through pictograms is presented here eliminating the need to undertake a deep, particular and architectural study before making substantiated overall conclusions and comparisons.

6.1 Future intents

Part 2 of the paper will present all 87 vernacular houses discussed in part 1 in pictograms on a world map. It will also propose rules for distinguishing different categories and/or ranks. On this basis, the houses could be organized in types and families, which will provide a pictogram map of the world's vernacular houses.

A *.kmz file will be created to show location of the families within the climate zones. A challenge would be to provide an opportunity for professionals to add houses in different regions or to amplify the information about the houses in a structured way. This will provide a world pictogram vernacular houses' map.

7 Acknowledgments:

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8 Literature cited;

References:

[1] Oliver, P. (Ed.). (1997). Encyclopedia of vernacular architecture. Cambridge University Press.

[2] Vellinga, M., Oliver, P., & Bridge, A. (2007). Atlas of vernacular architecture, Routledge.

[3] Olgyay, V. (2015). *Design with climate*. Princeton University Press.

[4] Tsybenov, B.D. (2012). To study the traditional daura dwellings. Bulletin of the Buryat State University,(8).

[5] Lytkin, K. A. (2007). Traditional Yakut dwelling. Architecture and Construction of Russia,(1),9-16.

[6] Sidorin, A.M. (2007). Rationality and esoteric vernacular architecture. Architecture and Construction of Russia, (1),18-30.

[7] Nogovitsyn, V.P., Solomonov, N.G., Savvinov, A., & Stepanov, A.V. (2015). Natural scientific look at the Yakut farce. Bulletin of the NEFU. MK Ammosova,12 (2).

[8] Ivanova, A. A. (2014). Features of ethnic culture and life of the Khanty people. BBK 74.58C 56.

[9] Libakova, N. M., & Serkova, E. A. (2014). Cultural studies of indigenous minorities of the North of the Krasnoyarsk Territory. Modern problems of science and education, (4), 598-598.

[10] Bourdieu, P. (1970). The Berber house or the world reversed. Information (International Social Science Council),9(2),151-170.

[11] SAADA, A., & DEKOUMI, D. (2019). Transformation of Berber Traditional Planning and Living Spaces. International Journal of Contemporary Urban Affairs, 3(2),28-34.

[12] Bebas, W. E. (1998). Rumah Bubungan Tinggi.

[13] Muchamad, B. N. (2007). Anatomi rumah bubungan tinggi (Vol. 1). Pustaka Banua.

[14] Gupta, J., & Mazumdar, S. A study of local bhunga houses in Kutch adapting to desert climates in a sustainable way, with reference to modern green building norms followed in India.

[15] Lathiya, J. B., & Design, I. (2016). Traditional Architecture of Kutch Region of Gujarat.

[16] Williams, T., & Calvert, J. (1860). Fiji and the Fijians. D. Appleton.169-175.

[17] Hayes, E. L. (1880). A natives house, Fiji, [c1880to1889].

[18] Zakharov, A.I. (1960). Folk architecture of Moldova. Stone architecture of the central regions). Kishinev.37,38 p.

[19] Shabashov, A. (2009). Gagauz relics of medieval Turkic peoples of eastern Europe based on language and culture.

[20] Kuroglo, S. Marunevich, M. Zelenchuk, V. (1983). Socialist transformations in the life and culture of the Gagauz population of the MSSR, Academy of Sciences of the Moldavian SSR.

[21] Dortlemez, A. Livanelioglu, S. Erden, A. Ozhan, M.Er, P. Cevik D. (1999). Gagauz Folk Culture. Aydınlar Matbaacılık SAN. Ve TİC. LTD. ŞTİ, Ankara.

[22] Khynku, I.G. (1974). Ethnic features in the dwellings of the population of Moldavia X-XIV centuries. Reports of the Soviet delegation III (Bucharest, September 4-10, 1974)

[23] Walton, J. (1977). Art and Magic in the southern Bantu Vernacular Architecture. Shelter, Sign and Symbol. 1977.

[24] Gall, S. (2010). The Bushmen of southern Africa. Random House.

[25] Walton, J. (1956). African village. JL Van Schaik.

[26] Martin, P. S., Rinaldo, J. B., & Bluhm, E. (1954). Caves of the Reserve area. Fieldiana. Anthropology,42,1-227.

[27] Bagwell, E. A. (2010). Domestic architectural production in Northwest Mexico.

[28] Haury, E. W. (1934). The Canyon Creek Ruin and the cliff dwellings of the Sierra Ancha (No. 14). Priv. print. for the Medallion.

[29] Smirnova, S. N. (2013). Implementation of Architectural and Planning Design Principles of Energy-Efficient Buildings in the Traditional Dwelling in the North of Russia. Internet-Vestnik VolgGASU, (28).

[30] Nilsen, A. C. (2015). The Slettnes type. Proto-Sámi dwellings in Northern Norway 0-1050 AD (Master's thesis, UiT Norges arktiske universitet).

[31] Aalen, F. H. (1964). Clochans as transhumance dwellings in the Dingle peninsula, Co. Kerry. The Journal of the Royal Society of Antiquaries of Ireland, 94(1), 39-45.

[32] Evans, E. E. (1940). The Irish peasant house. Ulster Journal of Archaeology, 165-169.

[33] Halpakhchyan, O. H. (1971). Civil architecture of Armenia. Stroiizdat.

[34] Ogly Mehdiyev, A.M. (1987). Wooden architecture of Azerbaijan. Elm.

[35] Swietochowski, T. (2004). Russian Azerbaijan, 1905-1920: The shaping of a national identity in a Muslim community (Vol. 42). Cambridge University Press.

[36] Oganesyan, A. Z., & Magomedkhanov, M. M. (2015). Caucasus' Home: History and Realms. History, Archeology and Ethnography of the Caucasus, 11(4), 69-73.

[37] Kahn, L., & Easton, B. (Eds.). (1990). Shelter. Shelter Publications, Inc. 7,103 p.

[38] Lane, P. (2006). Household assemblages, lifecycles and the remembrance of things past among the Dogon of Mali. The South African Archaeological Bulletin,40-56.

[39] Olmstead, J. (1972). The Dorze House: A Bamboo Basket. Journal of Ethiopian Studies, 10(2),27-36.

[40] Mathiszig, L. (2014). The Dorze Weavers of Ethiopia. Textile, 12(2),180-187.

[41] Svetlana, N.S. (2013). Earth Dwelling as a Component of Ecological Architecture. Architecton: Proceedings of Higher Education,(41).

[42] Nikitin, G.F. (1979). Dugout from Scythian time. Settlement of Chernivtsi region. Ow. archeology, (3),242-299.

[43] Oliver, P. (1987). Dwellings: the house across the world. Oxford: Phaidon.

Adamson, K. The Transformation of Turkana Traditional Architecture.

[44] Vagnby, B., & Jacobs, A. H. (1974). Kenya: traditional housing of the Elmolo. Ekistics,240-243.

[45] SYLVESTER, J.M.W. (1984). Traditional African Graphic Design in Kenya (Doctoral dissertation, University of Nairobi).

[46] Mincheva, E., & Georgiev, G. (2009). Ethnographic Examinations in Bessarabia (Moldova and Ukraine). Bulgarian ethnology, (4),134-144.

[47] Georgiev, G. (2014). Faith, everyday life and local culture. Functions of religion in the Bulgarians and the Gagauz of Bessarabia during the post-socialist period.

[48] Yan, H. (2015). World Heritage as discourse: knowledge, discipline and dissonance in Fujian Tulou sites. International Journal of Heritage Studies, 21(1), 65-80.

[49] Hanmin, H. (2001). Fujian 'Tulou'buildings [J]. Fujian Architecture & Construction, 1, 019.

[50] May, J., & Reid, A. (2010). Handmade houses & other buildings: the world of vernacular architecture. London: Thames & Hudson.

[51] Halpakhchyan, O.H. (1968). Medieval architecture of Armenia and its importance in the history of world architecture. Historical and philological literature, 4,51-60.

[52] Arakelyan, R. G. (2011). Determination of Traditional Values of Residential Formations on The Territory of the Armenian Highlands. Architecture and Modern Information Technologies, (3).

[53] Baeva, O. V., & Khaishbashyan, G. S. (2015). Architectural and spatial organization of settlements and residential buildings of the Armenians of the Lower Don (the end of the XVIII century., The beginning of the XX century.). Questions of theory and practice, (2-2), 32-34.

[54] Arakelyan, R. G. (2011). Improving the quality of the living environment, taking into account the values of traditional residential formations. Access mode: http://archi.com/lib/publication.html.

[55] Mackin, N. P. (2017). Future Architecture, Ancient Wisdom: Adaptable Structures from Arctic Tradition. International Journal of Computational Methods and Experimental Measurements, 5(4), 583-592.

[56] Sjølie, R. (2013). The Sami Goahti, an earthen house in the Arctic. Vernacular Architecture and Earthen Architecture: Contribution for Sustainable Architecture, 71-76.

[57] Jackson, B., & Koehler, R. (2015). Korean Architecture: Breathing with Nature (Vol. 12). Seoul Selection.

[58] Jeon, B., & Kwon, Y. (2012). Hanok and the history of the Korean house. Seoul: Dongnyok Publishers.

[59] Kang, S., & Kim, H. (2009). Korean Traditional Space Creator for Digital Contents. International Journal of Virtual Reality, 8(3).

[60] LEE, S. H. (1991). Continuity and consistency of the traditional courtyard house plan in modern Korean dwellings. Traditional Dwellings and Settlements Review, 65-76.

[61] Lee, K. H., Han, D. W., & Lim, H. J. (1996). Passive design principles and techniques for folk houses in Cheju Island and Ullūng Island of Korea. Energy and buildings, 23(3),207-216.

[62] Kim, T. J., & Park, J. S. (2010). Natural ventilation with traditional Korean opening in contemporary house. Building and Environment, 45(1), 51-57.

[63] Yun, J. (2014). Rethinking vernacular architecture: the case of Hanoks in south

[64] Johannsen, C. I. (1985). Farm buildings in Northern Germany-their historical development. Bauen fuer die Landwirtschaft (Germany, FR).

[65] Guldberg, M., & Schacke, A. 4. Description of Sub-regions.

[66] Prado, F., Vargas, M. F., D'Alençon, R., Korwan, D., & Moser, J. Traces of Construction Following Migration.

[67] Mason, R. J. (1984). Prehistoric stone structures and recent Himba settlements in northern Namibia and southern Angola. Hall et al.(eds.), Frontiers. BAR International Series, 207.

[68] Huffman, T. N. (1993). Broederstroom and the central cattle pattern. South African Journal of Science, 89, 220-220.

[69] Steen, A. S., Steen, B., & Komatsu, E. (2003). Built by hand: vernacular buildings around the world. GibbsSmith. 285,286 p.

[70] Whelan, D. (2014). Delving into the Realms of the Past: The Central Asian Yurt, the Zulu" Iqhugwane", and the Navajo Hogan. Traditional Dwellings and Settlements Review, 26(1), 44-44.

[71] Nabokov, R. E. P., Nabokov, P., & easton, R. (1989). Native American Architecture. New York: Oxford University Press. 322-348

[72] Coch, H. (1998). —Bioclimatism in vernacular architecture. Renewable and Sustainable Energy Reviews, 2(1-2), 67-87.

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

[74] Van Vuuren, C. J. (2007). Reconstructing the Ndebele grass dome house. South African Journal of Art History, 22(2), 179-194.

[75] Whelan, D. (2017). 'My culture'as a constantly changing perception, South Africa.

[76] Permilovskaya, A. B. (2013). Folk architecture of the Russian North in the space of modern culture. Person. Culture Education, (2(8)).

[77] Radulova, Y. I. (2016). Influence of Natural Climatic Factors on The Interaction of the Internal and External Space in The Architecture of the Low-Related Housing. Social, Humanitarian, Life Sciences, 18(1-2).

[78] Novinskaya, T. Y. (2015). Life and home of the peasants of the Penza region. 1945-1950s in the world of scientific discoveries, (1),297.

[79] Ilyin, V.I. (2017). Russian izba in the process of transformation from a rural dwelling to a dacha. Bulletin of St. Petersburg University. Series12. Sociology, 10(4).

[80] Ovchinnikova, E. V. (2010). Traditional Udmurt house. Structural features of buildings, Udmurt University, 337-347.

[81] Medina, D. G. (1997). El Jacalito: history and images of the jacal house type in Texas (Doctoral dissertation, University of Texas at Austin).

[82] Schroeder, A. H. (1953). The bearing of architecture on developments in the Hohokam Classic period. Southwestern Journal of Anthropology, 9(2), 174-194.

[83] Graham, J. S. (1991). The Jacal in South Texas. Hecho en Tejas: Texas-Mexican Folk Arts and Crafts, 293-308.

[84] Drew, P. (2006). Inspiration from below: Oceanian vernacular in contemporary architecture. Architectural Theory Review, 11(1), 26-40.

[85] Gangwar, G. Sustainability Lesson Learnt from the Traditional and Vernacular Architecture.

[86] Dahl, A. L. (1989). Traditional environmental knowledge and resource management in New Caledonia. IUCN, Gland and Cambridge http://islands. unep. ch/dtradknc. htm (last accessed 13 June 2007).

[87] Prizeman, O. (2016). Maintenance of shared spaces: courtyards of Tbilisi. Journal of Cultural Heritage Management and Sustainable Development, 6(3),316-329.

[88] Prussin, L. (2002). African nomadic architecture. Indian Folklife, (10).

[89] Ratti, C., Raydan, D., & Steemers, K. (2003). Building form and environmental performance: archetypes, analysis and an arid climate. *Energy and buildings*, *35*(1), 49-59.

[90] Keenan, J. (2001). Sahara man: travelling with the Tuareg. London: John Murray.

[91] Chatty, D. (Ed.). (2006). Nomadic societies in the Middle east and north Africa: entering the 21st century (Vol. 81). Brill.

[92] Al-Zubaidi, M. S. S. (2007). The sustainability potential of traditional architecture in the Arab world-with reference to domestic buildings in the UAE (Doctoral dissertation, University of Huddersfield).

[93] Che-Ani, A. I., Ramly, A., Mohd-Zain, M. F., Mohd-Tawil, N., & Hashim, A. E. (2008). Assessing the condition of traditional Khmer timber houses in Cambodia: A priority ranking approach. Journal of Building Appraisal, 4(2), 87-102.

[94] SEREYPAGNA, P. (2017). New Khmer Architecture: Docomomo Journal, (57).

[95] Özdemir, İ. M., Tavşan, C., Özgen, S., Sağsöz, A., & Kars, F. B. (2008). The elements of forming traditional Turkish cities, Building and Environment, 43(5), 963-982.

[96] İrem, D. S. Urfa-Harran Houses and Living Spatial Places.

[97] Akin, G. (1985). Meaning in the Historical House Types in Eastern and Southeastern Anatolia, Istanbul.

[98] Margiotti, M. (2011). Bodies, relatedness and density: A view from the Kuna House. In Seminar convened by I. Daniels, E. Hus, and S. Ardener, University of Oxford.

[99] Holloman, R. (1976). Cuna household types and the domestic cycle, Institute for the Study of Human Issues, 131-150.

[100] Arabaliev, G. (1982). National Traditions in Architecture. Technique.

[101] Multiple authors. (1982). Albanian Ethnography XII. Academy of Sciences of the Rps of Albania, Department of Social Culture Tirana.

[102] Riza, E., Sukaj, I., Adhami, S., Ballauri, R., Samimi, G., Papanikolla, I., Tirta, M. (1976) Monumentet. Komiteti I Kultures Dhe I Arteve, Instituti I Munumenteve Te Kultures. Tirana.

[103] Olany, G. (1988). Earth-sheltered dwellings in Tunisia. University of Delaware Press. 14-46

[104] Sebti, M., Alkama, D., & Bouchair, A. (2013). Assessment of the effect of modern transformation on the traditional settlement 'Ksar'of Ouargla in southern Algeria. Frontiers of Architectural Research, 2(3),322-337.

[105] Bouchair, A., Tebbouche, H., Hammouni, A., Lehtihet, M. C., & Blibli, M. (2013). Compact cities as a response to the challenging local environmental constraints in hot arid lands of Algeria. Energy Procedia, 42, 493-502.

[106] Informational board in the Betel Nut Park 槟榔谷 cultural village; 24.12.2017

[107] Bussmann, R. W., Gilbreath, G. G., Solio, J., Lutura, M., Lutuluo, R., Kunguru, K. & Mathenge, S. G. (2006). Plant use of the Maasai of Sekenani Valley, Journal of ethnobiology and ethnomedicine, 2(1),22.

[108] Noble, A. G. (2007). Traditional buildings: a global survey of structural forms and cultural functions (Vol. 11). IB Tauris. 72 p.

[109] Thatcher, N., Okoth, L., & Murungi, B. (2016). K'Jong. ATL, 1(1),16.

[110] Meir, I. Apology for Architecture, or the Planner's Craft.

[111] Vilà, J. C. (2007). The farmhouse: a retrospective look towards the contemporaneity. Proceedings of the International Congress on Vernacular Architecture (pp. 328-331). University Pablo de Olavide, of Seville.

[112] Vilà, J. C. (1994). The rural arquitecture of Garrotxa.

[113] Sagrera, J., Graciani, A., Chamoro, M. A., Vicente, J., Xirgu, J., Fa, J., Pareta, M. M., Ripoll, R., Barbeta, G. (2000) Evolution of the city halfway between tradition and sustainability; University of Girona.

[114] Djamila, H. (2016). Sustainable Development: Learning from Nature. Journal of Engineering and Applied Sciences, 100(4),822-827.

[115] Nelson, S. (2007). From Cameroon to Paris: Mousgoum architecture in and out of Africa. University of Chicago Press. 133 p.

[116] Black, L. (1973). The Nivkh (Gilyak) of Sakhalin and the Lower Amur. Arctic Anthropology, 10(1),1-110.

[117] Kamenju, J. Transformation of Kikuyu Traditional Architecture, Nyeri. 58-70, 80-90

[118] Rukwaro, R. W. (1996). Traditional African Architecture of the Kikuyu Masaai, Luo and Gabra Ethic groups of Kenya.

[119] Middleton, J., & Kershaw, G. (2017). The Kikuyu and Kamba of Kenya. Routledge.

[120] Beidelman, T. O. (1972). The Kaguru House. Anthropos, (H.5./6),690-707.

[121] Mosha, L. (2005). The Transformation of Rural Dwelling Compounds and the Impact of Ujamaa Villagisation and the Nyumba Bora Housing Campaign in Missungwi-Tanzania. Architecture and Policies.

[122] Van Lengen, J. (2013). Architecture of Indians of Amazonia. B4 Editores.

[123] Lengen, J. V. (1980). Manual of barefoot architects (No. 690 L566m). México, MX: Concepto, 1980.

[124] Weimer, A. G. (2014). Evolution of indigenous architecture. Ihgb-Rs: Porto Alegre.

[125] Staden, H. (1955). Trip to Brazil (Vol. 10). Livraria Progresso.

[126] Ferreira, A. R., & Brito, C. A. (2002). Trip to Brazil. Kapa Editorial.

[127] Smole, W. J. (1976). The Yanoama Indians: a cultural geography. University of Texas Press. 54-55,63-64,71

[128] Viaro, M. A. (2008). Nias Island traditional houses (pp.175-235).

[129] Dawson, B., & Gillow, J. (1994). The traditional architecture of Indonesia. London: Thames and Hudson.

[130] Schefold, R., & Nas, P. (Eds.). (2014). Indonesian Houses: Volume 2: Survey of Vernacular Architecture in Western Indonesia (Vol. 2). Brill. 175-236 p.

[131] Krinsky, C. H. (1996). Contemporary Native American architecture. Oxford University Press, USA.

[132] Gilman, P. A. (1987). Architecture as artifact. American Antiquity, 52(3),538-564.

[133] Stone, D. B. Eskimo Architecture: Dwelling and Structure in the Early Historic Period. By MOLLY.

[134] Madsen, K. (2017). The Quinzhee. Northern Review, (46),121-136.

[135] Kirtley, P. (2015). An Emergency Winter Survival Shelter for The Forest.

[136] Buhler, R. W. (1999). U.S. Patent No. 5,863,451. Washington, DC: U.S. Patent and Trademark Office.

[137] Steyn, G. (2006). The indigenous rondavel-a case for conservation. South African Journal of Art History, 21(1),21-38.

[138] Steyn, G. Appropriate South African Architecture–Concepts Derived from Vernacular Traditions and Current Practices.

[139] Naude, M. (2007). A legacy of rondavels and rondavel houses in the northern interior of south Africa. south African Journal of Art History, 22(2),216-237.

[140] Whitman, C., Armijo, G., & Turnbull, N. J. (2014). The Ruka Mapuche: clues for a sustainable architecture in southern Chile?

[141] Whitman, C., & Turnbull, N. (2014). Environmental comfort in the living heritage of the Chilean Araucania.

[142] Menapace, G. (2015). Socio-climatic morphologies. Cross-cultural analysis of four vernacular architectures in the temperate climate.

[143] Singarimbun, Masri 1975 Kinship, descent and alliance among the Karo Batak. Berkeley: University of California Press

[144] Fox J. J. (editor). 1993 Inside Austronesian Houses; Perspectives on domestic designs for living. Canberra: The Oceanian National University. 17-18 p.

[145] Schefold, R. (2003). The Southeast Asian-type house. Indonesian houses. 19-61.61-94 p.

[146] Hanan, H., Suwardhi, D., Nurhasanah, T., & Santa Bukit, E. (2015). Batak Toba cultural heritage and close-range photogrammetry. Procedia-Social and Behavioral Sciences, 184,187-195.

[145] Eyüce, A. (2007). Learning from the Vernacular: Sustainable Planning and Design. Open House International, 32(4).

[146] Grandits, D., Rieger-Jandl, A., & Stampfer, L. Architecture and Identity: Comparative Studies on Traditional Vernacular Architecture in Indonesia.

[147] Idham, N. C. (2018). Javanese vernacular architecture and environmental synchronization based on the regional diversity of Joglo and Limasan. Frontiers of Architectural Research, 7(3), 317-333.

[148] Said, S.U.Z.A.N.A., & Embi, M. R. (2007). Towards a Digital Representation of Vernacular Architecture. In CAADRIA (pp. 211-218).

[149] Said, S., & Embi, M. R. (2008). A parametric shape grammar of the traditional Malay long-roof type houses. International journal of architectural computing, 6(2),121-144.

[150] Tajudeen, I.B. (2017). Colonial-Vernacular Houses of Java, Malaya, and Singapore in the Nineteenth and Early Twentieth Centuries. Arch

[151] Beynon, D. (2013). The contemporary Iban longhouse: International journal of social sustainability in economic, social, and cultural context, 9(1),87-99.

[152] Arbi, E. (2008). Austronesian vernacular architecture and the Ise Shrine of Japan. Journal of Design and Built Environment, 4(1).

[153] Zhai, Z. J., & Previtali, J. M. (2010). Ancient vernacular architecture: characteristics categorization and energy performance evaluation. Energy and Buildings, 42(3), 357-365.

[154] Kis-Jovak, J. I. (Ed.). (1988). Banua Toraja: changing patterns in architecture and symbolism among the Sa'dan Toraja. Royal Tropical Institute Press.

[155] Julistiono, E. K., & Arifin, L. S. (2005). The sustainable traditional structural system of 'Tongkonan'in Celebes, Indonesia. In Proceedings The 2005 World Sustainable Building Conference (pp. 27-29).

[156] Blier, S. P. (1994). The anatomy of architecture: ontology and metaphor in Batammaliba architectural expression. University of Chicago Press.

[157] Dossa, L. H., & Vanvanhossou, F. U. S. (2016). The indigenous Somba cattle of the hilly Atacora region in North-West Benin: Tropical animal health and production, 48(2),349-359.

[158] Chiou, T. B. (2016). Tata. ATL,1(1),17.

[159] Elleh, N. (1997). African architecture. McGraw-Hill Professional Publishing.

[160] Glenn, D. J. (2018). Learning from Our Elders: Returning to Culturally and Climatically Responsive Design in Native American Architecture. In The Handbook of Contemporary Indigenous Architecture (pp.733-775). Springer, Singapore.

[161] Crouch, D. P., & Johnson, J. G. (2001). Traditions in Architecture: Africa, America, Asia, and Oceania. New York: Oxford University Press.

[162] Orey, D. C. (2000). The ethnomathematics of the Sioux tipi and cone. In Mathematics Across Cultures (pp. 239-252). Springer, Dordrecht.

[163] Yue, D., & Yue, C. (1984). The tipi: a center of Native American life. Knopf Books for Young Readers.

[164] Noble, A. (2013). Vernacular buildings: a global survey (Vol. 20). IB Tauris. 13-14 p.

[165] Sripan, M., Lin, X., Petchlorlean, P., & Ketcham, M. (2012, December). Research and thinking of smart home technology. In International Conference on Systems and Electronic Engineering - ICSEE'2012.

[166] Wilkinson, B. (2009). A study of turf: historic rural settlements in Scotland and Iceland. Architectural Heritage, 20(1), 15-31.

[167] Milek, K. B. (2012). Floor formation processes and the interpretation of site activity areas. Journal of Anthropological Archaeology, 31(2), 119-137.

[168] Howell, P. P. (1953). 126. Some Observations on'Earthly Spirits' Among the Nuer. Man,53,85-88.

[169] Golany, G. (1988). Earth-sheltered dwellings in Tunisia. University of Delaware Press. 20-26;48-61

[170] Boukhchim, N., Fraj, T. B., & Reynard, E. (2017). Lateral and "Vertico-Lateral" Cave Dwellings in Haddej and Guermessa. Geoheritage, 1-16.

[171] Cardinale, N., Rospi, G., & Stefanizzi, P. (2013). Energy and microclimatic performance of Mediterranean vernacular buildings. Building and Environment, 59,590-598.

[172] Leccisi, F. (2003, January). Stone buildings in Salento. In Proceedings of the First International Congress on Construction History (Vol. 20, p. 24th).

[173] Jamal, A. M. H. (2012). Chapter Eleven Traditional Shelter for Disaster Mitigation and Reconstruction. A Worldwide Study, 239.

[174] Bahamón, A. (2004). The magic of tents: transforming space. Harper Collins.

[175] Rasmussen, S. J. (1998). Within the Tent and at the Crossroads. Ethos, 26(2), 153-182.

[176] Kumie, A. (2002). Crowding in a traditional rural housing (Tukul) in Ethiopia. Ethiopian Journal of Health Development, 16(3),303-308.

[177] Doubrawa, I. (2014). Architecture in Sumba. Encyclopaedia of the History of Science, Technology, and Medicine in Non-Western Cultures, 1-8.

[178] Yusran, Y. A. (2016). Ex-Situ Conservation on Nusantara Architecture: Implementation and Challenges. International Journal of Structural and Civil Engineering Research, 5(1),5-11.

[179] Zykov, F. M., & Safronov, F. G. (1986). Settlements, dwellings and outbuildings of the Yakuts, XIX-early XX centuries: Publishing house "Science".

[180] Carson, C. (1976). Segregation in Vernacular Billldings. Vernacular Architecture, 7(1),24-29.

[181] Seymour, D. J. (2009). Nineteenth-century Apache wickiups. Antiquity, 83(319), 157-164.

[182] Simms, W. G. (1968). The Wigwam and the Cabin. University of Arkansas Press.

[183] Molodin, A. V. (2016). The contribution of multi-level heating strategies in thermal performance of vernacular architecture in Chukotka. Architectural Science Review, 59(2),71-80.

[184] Engin, N., Vural, N., Vural, S., & Sumerkan, M. R. (2007). Climatic effect in the formation of vernacular houses in the Eastern Black Sea region. Building and environment, 42(2),960-969.

[185] GAO, X. X., ZHENG, H. K., & JIN, G. (2009). Green Design Propetry of Mongolian Yurts [J]. Journal of Inner Mongolia Agricultural University (Natural Science Edition), 1,023.

[186] King, P. (2001). The complete Yurt handbook. Eco-logic books. 16p.

[187] Badarch, A. (2017). An elementary thermal analysis of a Mongolian Ger by the lattice Boltzmann method. In *Proceedings of the 13th International conference of technology and innovation "Khurel togoot-2017", Ulaanbaatar, Mongolia* (Vol. 13, pp.88-91).

[188] Gavieta, R. C. (1991). Mass housing based on traditional design and indigenous materials for passive cooling in the tropical urban climate of the Philippines. Energy and Buildings, 16(3-4),925-932.

[189] Lorente, F. L. (1982). Philippine Ancestral Houses (1810-1930).

[190] Van Lengen, J. (2008). *The barefoot architect: a handbook for green building*. Shelter Publications, Inc. 39-41, 690-691 p.

[191] Okba, E. M. (2005, May). Building envelope design as a passive cooling technique. In *Proceedings from the* (Vol. 490).

[192] Rapoport, A. (1969). *House Form and Culture*. New Delhi: Prentice-hall of India Private Ltd. 18 p.

[193] Zhai, Z. J., & Previtali, J. M. (2010). Ancient vernacular architecture: characteristics categorization and energy performance evaluation. *Energy and Buildings*, *42*(3), 357-365.

[194] Behsh, B. (2002). Building form as an option for enhancing the indoor thermal conditions. In *Build. Phys.-6th Nord.Symp*.

[195] Dixon, J. M. (2008). Heating, cooling, and lighting as form-givers in architecture.

[196] https://en.wikipedia.org/wiki/Ideogram (08.02.2019)

[197] Holden, J. (Ed.). (2005). *An introduction to physical geography and the environment*. Pearson Education.

[198] https://en.wikipedia.org/wiki/Keyhole_Markup_Language (10.03.2019)

[199] Zialcita, F. N., & Tinio, M. I. (1980). Philippine ancestral houses (1810-1930). GCF Books.

[200] Fathy, H. (1986). Natural energy and vernacular architecture.